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Evaluating Kindergarten Teachers' Readiness for Technology-Integrated Pedagogy: An Analysis Based on the Tpack Framework

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Abstract: Objective: This study evaluates kindergarten (TK) teachers' readiness to implement technology-integrated pedagogy using the TPACK (Technological Pedagogical Content Knowledge) framework. The TPACK framework combines three key dimensions: content knowledge (CK), pedagogical knowledge (PK), and technological knowledge (TK). These dimensions are essential for teachers to design and implement practical learning experiences that leverage technology. **Methodology:** This study uses a descriptive quantitative approach involving 50 respondents, including 40 teachers and 10 principals from kindergarten/PAUD schools in three regencies/cities in West Java: Bekasi City, Bogor Regency, and Depok City. Data were collected through a questionnaire based on TPACK aspects, namely technological knowledge (TK), pedagogical knowledge (PK), content knowledge (CK), and the integration of all three dimensions (TPACK). The data were analyzed using statistical techniques to assess teachers' readiness for integrating technology into the learning process. **Findings:** The findings reveal that many teachers demonstrate strong readiness in content and pedagogical knowledge. However, there is a notable gap in their mastery of technology and its application in teaching. Age, teaching experience, and access to technology training significantly influence teachers' readiness to implement the TPACK framework. **Conclusion:** The study concludes that while teachers possess an adequate understanding of pedagogy and content, there is a pressing need to enhance their technological skills through ongoing training and support. The implications of this study emphasize the importance of developing training programs to improve technology-related competencies for kindergarten/PAUD teachers. Such initiatives are crucial to fostering innovative teaching practices that align with the demands of modern education.

Keywords: teacher readiness, pedagogy integrated technology, TPACK, education early childhood.

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INTRODUCTION

Early childhood education (PAUD) plays a pivotal role in establishing a strong foundation for children's learning, making the role of teachers in implementing effective teaching practices crucial. With the rapid development of digital technology, new challenges have emerged for educators, particularly in integrating technology into teaching and learning processes. Assessing the readiness of kindergarten teachers to adopt technology-integrated pedagogy has become highly relevant in ensuring that education meets the demands of the digital era. Implementing technology in early childhood education (PAUD) has garnered global attention for several decades. When used effectively, technology has the potential to enhance children's learning experiences and support their academic achievement (Lee & Jen, 2015). However, the success of technology integration in education

largely depends on teachers' readiness and skills. Teachers' knowledge of technology and their ability to integrate it with pedagogy and content called Technological Pedagogical Content Knowledge (TPACK) is essential for ensuring effective and technology-based learning outcomes (Shambare & Simuja, 2024).

On the other hand, significant challenges arise in implementing technology within the PAUD environment. Low levels of technological literacy among teachers, lack of self-confidence, limited teaching guidelines, and the absence of a well-designed, relevant curriculum present significant obstacles to developing teachers' TPACK skills (Su et al., 2023); (Yang & Dong, 2024). Sustainable and structured training programs are essential to address these challenges and enhance teachers' competencies in integrating technology pedagogically (Santos & Castro, 2021). Such training should also consider individual teachers' diverse contexts, experiences, and unique needs (Chaipidech et al., 2022). In addition, adequate technical support is critical to improving teachers' readiness to integrate technology into their teaching practices. Research indicates that early childhood education professionals need sufficient time, space, and functional equipment to participate in technology-based training, such as online microlearning courses (Pölzl-Stefanec & Geißler, 2022). Without such support, the implementation of technology in classrooms may be hindered, limiting its potential to enhance the quality of learning experiences.

Research further shows that the success of technology implementation in education requires digital devices and a deep understanding of how technology can be integrated with content and teaching strategies (McDougall & Phillips, 2024). The educational environment in urban and rural areas requires a contextual approach to holistically developing TPACK (Technological Pedagogical Content Knowledge). This includes systemic changes in the educational ecosystem, such as support from school leaders, adaptive policies, and adequate facilities (Tschönhens et al., 2024). Previous studies also highlight the importance of designing technology-based learning models that are both valid and practical, such as STEM-based learning environments. This model has proven effective in enhancing the pedagogical competence of both pre-service and in-service teachers through a structured approach, ranging from training to testing implementation (Efriani et al., 2023).

In the kindergarten context, teachers' readiness to apply technology in learning requires technical training and structural changes in teaching paradigms. This research explores teacher readiness in implementing TPACK in technology-based learning within early childhood education environments, focusing on the challenges, opportunities, and professional development needs. Evaluating teacher readiness in applying Technological Pedagogical Content Knowledge (TPACK) to early childhood education is crucial to understanding the factors that influence the effective integration of technology. TPACK is a framework combining technological, pedagogical, and content knowledge—essential components in modern education, especially in the digital era (Koehler et al., 2013). Koehler et al. further emphasize that ongoing professional support from colleagues and peers is significant for helping teachers develop their TPACK skills. Creating a supportive environment for teachers to learn and adapt to new technologies is therefore critical to enhancing their readiness for implementing TPACK in early childhood education.

In addition, research by Liang et al. highlights the importance of teachers' understanding of integrating technology with content and pedagogy to create meaningful learning experiences for children (Liang et al., 2013). Teachers with substantial knowledge of TPACK are more effective in selecting and utilizing appropriate technologies to support children's learning, thereby improving learning outcomes. Teachers' knowledge, beliefs, and

attitudes significantly influence their teaching practices. Liu et al. emphasize the need to explore the complex relationship between TPACK and teaching practices to ensure teachers integrate technology effectively into their teaching. By understanding how teachers incorporate technology into their instruction, better support can be provided to adapt teaching materials to students' diverse needs (Liu et al., 2015).

This study offers novelty through a comprehensive analysis of the gap between age, teaching experience, and teachers' ability to adopt technology in learning. Evidence suggests that older teachers or those with extensive teaching experience often face challenges adapting to rapidly evolving technology, leading to limitations in its mastery and application in the classroom. Specifically, this research focuses on the readiness of kindergarten teachers to implement the Technological Pedagogical Content Knowledge (TPACK) framework in technology-based learning. It mainly emphasizes early childhood education, a context often overlooked in similar studies. This study evaluates teachers' knowledge and skills related to TPACK and examines critical factors such as technical support, professional training, and necessary infrastructure.

This research provides a fresh perspective on the relationship between teachers' TPACK competencies, their practical implementation of technology-based teaching, and their impact on early childhood learning outcomes. Furthermore, it contributes to the strategic development of education policies to foster relevant and sustainable technology integration in early education.

METHOD

Participants

This study involved 50 respondents, comprising 40 teachers and 10 principals from kindergarten (TK) and early childhood education institutions (PAUD) in three areas of West Java: Bekasi City, Bogor Regency, and Depok City. The sample was selected using a purposive sampling method, focusing on teachers with experience using digital technology in learning and integrating technology into their teaching practices. The selection criteria for respondents were designed to ensure the collection of relevant data aligned with the study's aim to examine the implementation of TPACK. Additionally, considerations such as geographical proximity and convenient access to the research locations were factored into the sampling process to facilitate efficient data collection.

Research Design and Procedures

This study employs a descriptive quantitative research design to objectively describe conditions or phenomena occurring in the field using measurable data. The quantitative approach enables data collection and statistical analysis to understand teachers' readiness to apply TPACK in technology-based learning within kindergarten and early childhood education contexts. Data collection was conducted through the distribution of a specially designed questionnaire to measure the three main components of TPACK: Technological Knowledge (TK), Pedagogical Knowledge (PK), and Content Knowledge (CK).

Instruments

The instruments used in this study consist of a questionnaire developed based on the Technological Pedagogical Content Knowledge (TPACK) framework, which encompasses three main components:

1. Content Knowledge (CK) This component assesses how teachers understand the material they teach in early childhood education contexts. Indicators include: (a) Understanding Basic Concepts: Evaluates teachers' comprehension of concepts relevant to the lessons, such as child development and foundational topics in mathematics, language,

or social studies. (b) Relating Material to Children's Experiences: Measures teachers' ability to connect lessons with children's daily experiences and explain concepts in simple, relevant ways. (c) Mastery of Material: Assesses the depth of teachers' understanding of the subjects and their capacity to address questions or difficulties that arise during learning.

2. Pedagogical Knowledge (PK): This component evaluates teachers' abilities to choose and implement teaching strategies appropriate for young children's characteristics and needs. Indicators include: (a) Selection of Teaching Methods: Assesses teachers' ability to select suitable methods, such as play-based learning, discussions, or simple experiments, tailored to children's developmental levels. (b) Classroom Management: Evaluates how teachers create supportive environments for active and participatory learning. (c) Differentiated Approaches: Examines teachers' ability to adapt materials and teaching strategies to meet individual learning styles and needs. (d) Learning Evaluation: Assesses how teachers evaluate children's progress and adapt teaching methods based on evaluation results.
3. Technological Knowledge (TK) This component measures teachers' understanding and use of digital technology in learning. Indicators include: (a) Use of Technological Tools: Evaluate teachers' ability to operate hardware (e.g., computers, tablets, projectors) and software (e.g., educational apps or platforms) for supporting early childhood learning. (b) Technology Integration in Learning: Assesses how effectively teachers integrate technology with lesson content, such as educational apps or interactive videos. (c) Problem-Solving in Technology: Measures teachers' ability to address technical issues that may arise and their capacity to leverage technology to enhance learning. (d) Enhancing Learning with Technology: Examines how teachers use technology to boost engagement, motivation, and learning experiences.

All indicators were measured using a Likert scale to determine teachers' understanding and application of knowledge within each TPACK component. The instrument underwent a content validity test involving early childhood education and technology experts to ensure alignment with the TPACK framework. A preliminary trial was also conducted to refine the questionnaire. The analysis results confirmed that the instrument is valid, making it a reliable tool for assessing TPACK readiness in early childhood educators.

Data Analysis

The data were analyzed using descriptive statistics to provide a general overview of the level of teacher readiness. The analysis involved calculating the frequency and percentage of responses for each TPACK component. A reliability test was also conducted to ensure the questionnaire consistently and accurately measured the intended constructs. This analysis aimed to offer a clear understanding of the extent to which kindergarten and early childhood education teachers comprehend and apply the TPACK framework. Furthermore, the study identified supporting factors and barriers that influence the successful integration of technology into the learning process.

■ RESULT AND DISCUSSION

Findings

The level of mastery of TPACK (Technological Pedagogical Content Knowledge) among teachers and principals is crucial for successfully implementing technology-based learning in schools. TPACK mastery involves the ability of teachers and principals to effectively integrate technology, pedagogy, and content into the learning process. This study examines the readiness of kindergarten teachers to implement TPACK in technology-driven learning, focusing on three areas in West Java: Bekasi City, Bogor Regency, and Depok City.

Table 1. TPACK mastery level of teachers and principals school

TPACK Components	TPACK Mastery	
	Teachers (40 Respondents)	Principles (10 Respondents)
Mastery Technology (TK)	3.2	3.8
Knowledge Pedagogy (PK)	4.1	4.5
Knowledge Content (CK)	4.3	4.6
Knowledge Pedagogy- Content (PCK)	4.0	4.4
Knowledge Technology-Content (TCK)	3.5	3.9
Knowledge Technology-Pedagogy (TPK)	3.3	4.0
Overall TPACK	3.7	4.2

Rating scale: (Scale 1-5)
1: Very Low
2: Low
3: Medium
4: Height
5: Very High

The table describes data from 50 respondents, consisting of 40 teachers and 10 principals of Kindergarten/PAUD schools in several cities in Indonesia. The results show that teachers and principals in Schools in several cities in Indonesia have sufficient mastery of TPACK components, especially in knowledge pedagogy (PK) and knowledge content (CK), with an average value above 4. This reflects a strong understanding of aspects of education and teaching materials. However, mastery technology (TK) is still lower, especially among teachers, with an average value of 3.2, while principles reached an average of 3.8. This indicates that aspect technology still needs to improve teacher competence. Likewise, knowledge integration pedagogical technology (TPK) and content-technology (TCK) show more value , indicating that the ability to integrate technology in method teaching and teaching materials has not been fully optimized.

The table presents data from 50 respondents, consisting of 40 teachers and 10 principals from kindergarten/PAUD schools across several cities in Indonesia. The results indicate that teachers and principals have a sufficient understanding of the TPACK components, particularly in pedagogical knowledge (PK) and content knowledge (CK), with average scores above 4. This suggests a solid grasp of educational practices and teaching materials. However, technological knowledge (TK) remains relatively lower, especially among teachers, with an average score of 3.2, while principals scored an average of 3.8. This highlights the need for further development in teachers' technological competence. Additionally, the integration of pedagogical technology knowledge (TPK) and content-technology knowledge (TCK) shows moderate scores, indicating that the ability to integrate technology into teaching methods effectively and materials has yet to be fully optimized.

Regarding the level of readiness for TPACK implementation, of the 40 teachers who participated in the study, 15% (6 teachers) reported feeling fully ready to implement TPACK. A further 30% (12 teachers) felt somewhat ready, while the majority, 45% (18 teachers), were at an intermediate level of readiness. However, 7.5% (3teachers) indicated they were unprepared, and 2.5% (1 teacher) felt unprepared. This data suggests that most teachers are at an adequate level of readiness, though further strengthening of their competencies, particularly in technology and content integration, is needed.

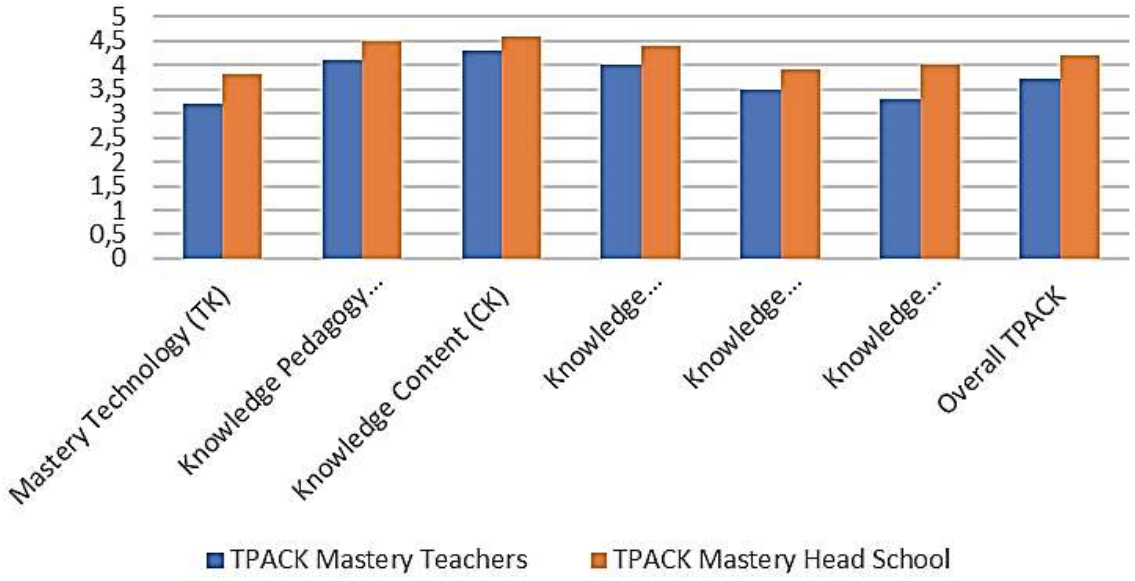

Figure 1. Mastery of teachers and heads school in TPACK

Tabel 2. Teacher and principal readiness table school in TPACK implementation

Readiness	Teacher (%)	Number of Teachers	Principles (%)	Amount Principles
Very Ready	15%	6	20%	2
Ready	30%	12	40%	4
Enough Ready	45%	18	30%	3
Not Ready	7.5%	3	10%	1
Unprepared	2.5%	1	0%	0
Total	100%	40	100%	10

Temporarily, from 10 heads of the school that became respondents, level readiness tends to be higher with the teacher. As many as 20% (2 people) of principals stated readiness and 40% (4) felt ready. On the other hand, 30% (3 people) of principals confess that enough is ready, and only 10% (1 person) felt not ready. None of the principals are in the very no category and are ready. This shows that principals, in a way, generally trust themselves more in the implementation of TPACK compared to teachers, although there is still a tiny need to support more carry-on.

Among the 10 principals who participated in the study, the level of readiness appeared to be higher than that of the teachers. Specifically, 20% (2 principals) reported feeling fully ready, and 40% (4 principals) felt ready. Meanwhile, 30% (3 principals) considered themselves sufficiently ready, and only 10% (1 principal) felt unprepared. None of the principals indicated that they were very unprepared. This suggests that principals tend to have more confidence in implementing TPACK than teachers, though there remains a small need for additional support to ensure full readiness.

A significant 85% of teachers and 70% of principals expressed the need for additional TPACK training, indicating a strong awareness of the importance of enhancing their competencies. The preferred types of training include introducing the latest educational technologies (65% of teachers and 60% of principals), strategies for integrating technology

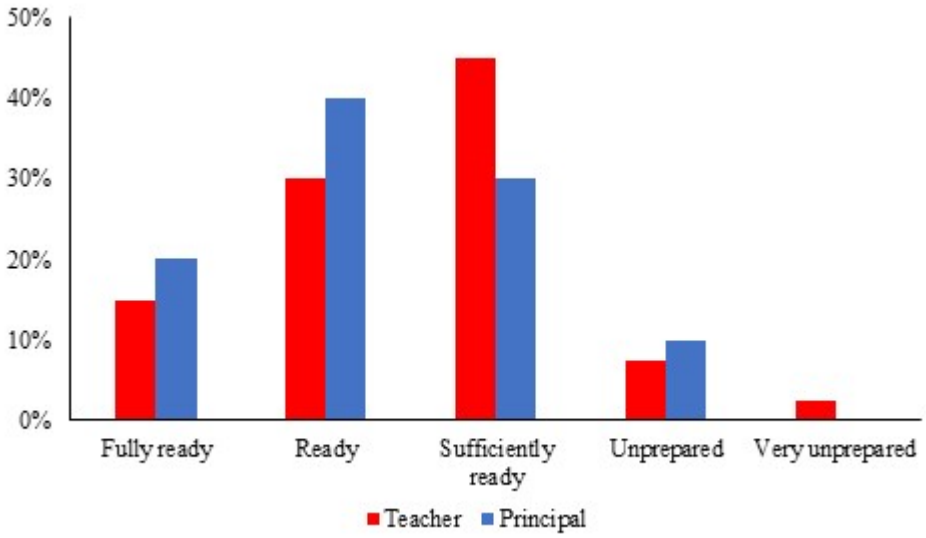

Figure 2. Level of teacher and principal readiness school

into teaching (70% of teachers and 50% of principals), and developing technology-based teaching materials (55% of teachers and 40% of principals). These results suggest that training focused on practical applications and technology integration in education will be crucial in improving the readiness and mastery of TPACK.

Implementing TPACK in early childhood education reveals significant obstacles teachers and principals face. The primary challenge

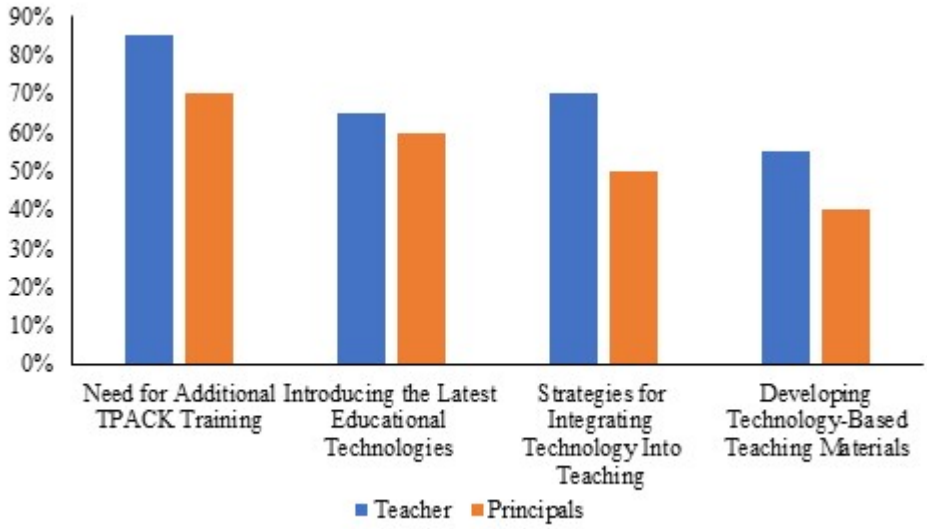

Figure 3. The need for improvement TPACK readiness and mastery

reported is the lack of ongoing training and technical support, with 60% of respondents citing insufficient opportunities for continuous professional development in technology integration for learning.

Access to technology and infrastructure limitations are also significant obstacles, with 50% of respondents reporting that facilities and access to technological devices are inadequate. Additionally, motivation and interest in adopting

Table 3. Challenges schools in implementing TPACK

The problems	Challenge Schools to implement TPACK
	Percentage Respondents (%)
Technology Access	50%
Training and Technical Support	60%
Limited Infrastructure Facilities	50%
Motivation and Interest	25%

TPACK remain relatively low, with only 25% of respondents expressing readiness and enthusiasm for integrating technology into their teaching. This suggests that providing support in training, improving infrastructure, and fostering motivation will be crucial in enhancing both teacher and principal readiness for the optimal implementation of TPACK.

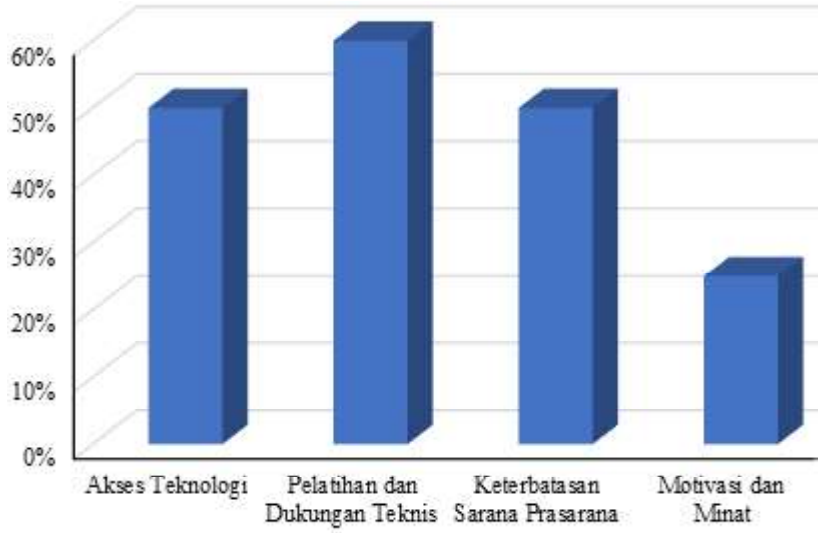

Figure 4. Challenges in implementation

Analysis Readiness Implementation

The data indicates that TPACK (Technological Pedagogical Content Knowledge) mastery among teachers and principals in Kindergarten/PAUD schools shows positive progress, though several aspects still require further attention. Mastery of TPACK components, particularly in pedagogical knowledge (PK) and content knowledge (CK), has yielded promising results. The average mastery of PK and CK for teachers ranges between 4.1 and 4.3, while principals achieved averages of 4.5 and 4.6. This indicates a strong understanding of teaching principles and learning materials relevant to early childhood education.

However, while mastery of PK and CK is relatively high, technological knowledge (TK) remains challenging. Teachers' average mastery of technology is 3.2, while principals' average is slightly higher at 3.8. These figures suggest that the ability to use technology in learning effectively is still considered low and requires improvement. Additionally, the integration of technology in pedagogy (TPK) and content (TCK) shows slightly higher scores, at 3.3 and 3.5 for teachers. This indicates that while there is some understanding of technology, the capability to integrate it into teaching methods effectively and content is still not optimal. This highlights the need to strengthen teacher and principal skills in

merging technology with pedagogy and content.

Regarding readiness for implementing TPACK, most teachers (45%) rate their readiness as "moderately ready," while 30% feel ready, and only 15% feel fully prepared. This shows that many teachers still need further support, particularly in technology and the integration of knowledge fields. Additionally, 10% of teachers feel unprepared or very unprepared, indicating concerns or a lack of confidence in implementing TPACK. In contrast, the readiness level among principals is higher, with 60% feeling either "ready" or "very ready" and only 10% feeling unprepared. This suggests that principals generally have more confidence in implementing TPACK than teachers, although additional support is needed to enhance implementation further.

Analysis Need Training and Challenges

Regarding additional training, 85% of teachers and 70% of school principals stated the need for further training to improve their mastery of TPACK. The expected training includes the introduction of the latest educational technologies (65% of teachers, 60% of school principals), strategies for integrating technology into learning (70% of teachers, 50% of school principals), and the development of technology-based materials (55% of teachers, 40% of school principals). This indicates that teachers and principals recognize the importance of training that can help them master relevant technology and integrate it into the learning process.

The biggest challenge faced in implementing TPACK is the lack of continuous training and technical support, with 60% of respondents identifying this issue as the main barrier. Additionally, 50% of respondents feel limited by access to technology and inadequate facilities (Budiarti, 2023). These limitations can hinder the effective implementation of technology in learning. Meanwhile, 25% of respondents stated that motivation and interest in adopting TPACK are still low, indicating a need to inspire and encourage teachers and principals to be more enthusiastic about integrating technology into their teaching.

However, the study also identifies several significant challenges. The biggest obstacle is the lack of sustainability and technical support for training, with 60% of respondents citing this issue as the primary challenge. This lack of continued training and technical support hinders the ability to maintain and expand the effective use of technology in the classroom. Additionally, 50% of respondents reported that inadequate access to technology and infrastructure presents another key challenge, restricting the ability to implement technology-based learning optimally. Furthermore, 25% of respondents noted low levels of motivation and interest in adopting TPACK, signaling a need for additional efforts to inspire and engage teachers and principals in integrating technology into their pedagogical practices. Educators may hesitate to experiment with or fully embrace TPACK approaches without the necessary motivation.

The research also reveals a disparity between teachers and principals regarding their readiness and ability to implement TPACK. While principals tend to feel more prepared, they still face technological limitations that hinder their support for TPACK implementation. Teachers who directly interact with students report feeling more impacted by limited access to digital tools and infrastructure, making it more difficult for them to adopt technology effectively in their teaching practices.

Training and technical support must be prioritized to address these challenges. Teachers require training that covers the theoretical and practical aspects of integrating technology into their teaching methods. Technical support is also crucial to assist in troubleshooting issues that arise during the use of technology in classrooms. While principals generally feel somewhat prepared, they still require ongoing development in technology

use to provide appropriate guidance and create a supportive environment for the implementation of TPACK.

Lastly, motivation and interest emerge as critical factors in successfully adopting TPACK. More motivated teachers tend to be more creative in exploring ways to integrate technology into their teaching. However, some teachers may feel uncomfortable with technology or reluctant to experiment with new methods. Therefore, school leaders and stakeholders should focus on providing incentives, showcasing success stories, and offering relevant support to increase teacher motivation and foster a more positive, technology-ready educational environment. These efforts will ensure that schools are better prepared to transition toward technology-based learning.

Interpretation and Discussion

Technology integration in education has become increasingly necessary in globalization and rapid technological advancement. Technology is a learning aid and a medium capable of transforming how children learn, and teachers teach. In early childhood education, particularly in kindergartens (Budiarti & Yasmin Adar, 2023), technology in learning must be well-managed so that it becomes more than just entertainment but supports children's cognitive, social, and emotional development. Therefore, teachers' readiness to integrate technology into the learning process is crucial. The Technological Pedagogical Content Knowledge (TPACK) framework becomes the primary reference to ensure effective integration. This framework emphasizes teachers' skills in holistically combining content knowledge, pedagogy, and technology to make learning more meaningful. Young children need an interactive learning environment to actively participate, ask questions, and understand concepts through engaging and immersive activities (Siti Alipiyani et al., 2024).

The benefits of technology in educational practice are evident within the TPACK framework. It demonstrates the interaction of three essential elements (TK, PK, CK) and highlights the intersections that result in Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK), and Pedagogical Content Knowledge (PCK). It concludes that TPACK is the best integration of these three components. The relationship among these elements substantially enhances the incorporation of technology in education. Each framework provides a unique perspective on the integration of technology. Their experiences can also influence teachers' readiness to deal with atypical learning situations, such as online learning during the COVID-19 pandemic. Ayuni et al. reported that kindergarten teachers in Pariaman City showed varying readiness levels to face online learning, indicating that prior experiences can affect their ability to adapt to new technology (Ayuni et al., 2020). This research indicates that teachers who better understand TPACK tend to be more prepared to tackle challenges arising from technology-based learning. Teachers must also understand digital literacy, emphasizing the effective use of devices and digital resources to face the ever-evolving digital landscape (Hartanti et al., 2025).

In the context of kindergartens, it is crucial to consider the developmental characteristics of young children. Research by Qori'ah et al. shows that teachers must understand how technology can support children's social and emotional development and cognitive skills (Qori'ah et al., 2021). Therefore, teachers' readiness to apply TPACK relates to technical ability, understanding of child development, and how technology can support their learning process (Budiarti et al., 2022).

Applying TPACK (Technological Pedagogical Content Knowledge) in kindergartens and early childhood education can significantly impact children's development. TPACK integrates three key aspects: technology knowledge (TK), pedagogical knowledge (PK),

and content knowledge (CK), all of which are essential in creating effective and enjoyable learning experiences for children (Rihlah et al., 2021).

Using TPACK, teachers can use technology to create more interactive and engaging learning. For example, educational apps and interactive games can increase children's learning motivation (Ria Fajrin Rizqy Ana Ria & Nourma Oktaviarini, 2022). Studies have shown that children who engage in technology-based learning tend to be more active and enthusiastic in learning activities (Nugraheni & Pamungkas, 2022).

Integrating technology in learning can also support children's social and emotional development. Through group activities involving technology, children can learn to collaborate, communicate, and interact with their peers, which are essential skills in early childhood (Hanifah et al., 2021). Research shows that guided and controlled gadgets can stimulate children's language and social development (Z et al., 2022).

TPACK allows teachers to design learning experiences focusing on content and how children interact with that content. Thus, children can develop critical and creative thinking skills through the appropriate use of technology (Dheasari & Fajriyah, 2022). For example, educational videos and digital props can help children understand complex concepts more simply and enjoyably.

Using technology, teachers can provide various learning resources suitable for each child's developmental level and interests, allowing each child to learn most effectively (Afandi & Astuti, 2023). Implementing the TPACK framework in education allows teachers to tailor teaching materials to meet students' individual needs more effectively. Using technology, teachers can access and provide various learning resources suited to each student's developmental levels and interests. Implementing TPACK in education helps teachers effectively integrate technology into their teaching, which in turn supports the customization of teaching materials to meet the diverse needs of students (Najjari et al., 2021).

In this context, it is essential to understand that TPACK encompasses not only knowledge of technology but also pedagogical and content knowledge. Kirikçilar and Yýldýz Kirikçilar & Yýldýz emphasize that a good understanding of pedagogy and content is crucial for designing practical learning activities, such as the use of GeoGebra in mathematics education. They show that although teachers may know about technology, a lack of pedagogical understanding can hinder their ability to address students' conceptual errors. Therefore, a balanced mastery of TPACK is essential for creating a learning environment responsive to students' needs (Kirikçilar & Yýldýz, 2018).

Furthermore, Saputro highlights that teachers' understanding of TPACK competencies is crucial to education programs in Indonesia. By preparing teachers to utilize technology in teaching, TPACK serves as a framework supporting integrating technology into classroom instruction, which can be tailored to meet the needs of individual students. This indicates that TPACK is relevant for technology-based teaching and creating more personalized and adaptive learning experiences (Saputro et al., 2023). Tondeur et al. (2019) also emphasize the importance of developing TPACK among teachers. They note that a more integrated approach to developing teachers' knowledge, skills, and dispositions in line with the TPACK framework can enhance their ability to incorporate technology into their teaching. Teaching and modeling that intentionally integrate technology can support the development of TPACK in pre-service teachers (Ozden et al., 2024).

Thus, training focused on TPACK can help teachers better understand how to effectively tailor teaching materials to students' needs (Tondeur et al., 2019). In the increasingly digital educational context, TPACK is becoming more relevant. Chakim (2023) notes that pre-service

teachers exposed to various digital applications in Edu-Tech classrooms show readiness to apply more innovative teaching practices. However, despite their pedagogical knowledge, they often still use traditional teaching methods. This highlights the need for further development in applying TPACK to encourage teachers to adjust teaching materials creatively to meet students' needs (Chakim et al., 2023).

Additionally, it is important to pay more attention to improving practical skills through experiential learning and problem-solving activities (Chua & Jamil, 2012). Although implementing TPACK has many benefits, there are several challenges to address. One of the main challenges is the lack of training and support for teachers in effectively using technology in teaching. Research shows that many teachers feel less confident using technology, which can hinder the integration of TPACK into learning (Iswantiningtyas et al., 2022). Furthermore, inadequate infrastructure, such as limited internet access and a lack of technological devices, can also become obstacles to implementing TPACK in kindergartens and early childhood education (Rustiana, 2023).

Infrastructure challenges, such as limited access to devices or internet connectivity, are significant obstacles to implementing TPACK in many schools, especially in certain regions. Adequate access to devices is crucial for optimizing the use of technology in learning, yet many schools still lack the necessary equipment, such as computers, tablets, or projectors. A stable and fast internet connection is also essential for accessing various digital learning resources. These challenges are often more pronounced in remote areas or those with inadequate infrastructure, such as rural regions or economically disadvantaged areas. This issue is less significant in more developed areas like Bekasi City or Depok. It is also important to note that teachers need to be supported in effectively integrating technology into their teaching methods through training that focuses more on using technology suited to existing conditions. This training could cover using technology effectively even with limited devices or unstable connections. Teachers should also be encouraged to innovate using lightweight applications and technology resources that can be accessed offline, ensuring that technology can still support the learning process without infrastructure issues.

■ CONCLUSION

This study demonstrates that TPACK (Technological Pedagogical Content Knowledge) mastery among kindergarten/early childhood education (TK/PAUD) teachers and principals shows positive progress, although several aspects still need more attention, particularly in technology mastery. In general, pedagogical knowledge (PK) and content knowledge (CK) are pretty strong, but integrating technology into pedagogy and content remains a significant challenge. Most teachers need further training to improve their technological proficiency and skills in integrating technology into teaching. The readiness of school principals to support the implementation of TPACK is higher than that of teachers, although they also face similar challenges, such as limited access to technology and the need for ongoing training.

The impact of this study on education is the importance of increasing training and technical support for teachers and principals in integrating technology into teaching. The study highlights the need for better access to technology, appropriate training, and stronger motivation for educators to adopt TPACK. However, this study has limitations, such as the limited sample scope, which only covers a few cities in Indonesia, meaning the results may not fully represent the entire region. Additionally, the study has not explored external factors that may influence TPACK implementation, such as government policies or community support. Further research is needed to delve deeper into the challenges and

solutions in the widespread application of TPACK.

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