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Teachers' Readiness in Integrating Technology through TPACK-ICT Framework: Evidence from Papua, Indonesia

Tanta [1*], Suriyah Satar [1], Nurbaya [1], Hanida Listiani [1*]
[1] *Universitas Cenderawasih, Indonesia*

tanta@fkip.uncen.ac.id*

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ABSTRACT

This study aims to analyze the level of Technological Pedagogical Content Knowledge in Information and Communication Technology (TPACK-ICT) skills among teachers in the Papua region, specifically in Keerom Regency, Jayapura Regency, and Jayapura City. A quantitative descriptive method was employed to examine teachers' TPACK competencies. The research was conducted from May to August 2025 using an accidental sampling technique. The sample consisted of 31 elementary, junior high, and high school teachers from the three study areas who completed the questionnaire. The research instrument comprised 34 statements related to the TPACK framework, and the data were analyzed descriptively. The results reveal that teachers' overall TPACK competence falls into the good category, with an average score of 3.63. The highest component score was found in Pedagogical Content Knowledge (PCK) at 3.93, followed by Pedagogical Knowledge (PK) and Technological Pedagogical Knowledge (TPK), both at 3.88. These findings suggest that teachers are relatively proficient in designing learning strategies that align with the subject matter and effectively integrate pedagogical and technological aspects. Meanwhile, the Content Knowledge (CK) and Technological Knowledge (TK) components scored 3.79 and 3.77, respectively, indicating a satisfactory understanding of subject matter and basic technological skills. However, these aspects still require enhancement, particularly in mastering more advanced technology and deepening content understanding. The lowest scores were recorded in Technological Content Knowledge (TCK) and the overall TPACK components, both at 3.63, showing that teachers continue to face challenges in fully integrating technology into learning content and combining technology, pedagogy, and content holistically. Overall, while teachers demonstrate strong pedagogical competence, further development in technology integration is essential to achieve optimal TPACK implementation.

Keywords: TPACK-ICT, Papuan Teachers, Teachers' Readiness

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INTRODUCTION

The dynamics of technological development in the 21st century have profoundly transformed the global landscape of education (Agbo, 2015; Hsu et al., 2021). The rapid advancement of digital technology, particularly in the aftermath of the Covid-19 pandemic, has accelerated the integration of Information and Communication Technology (ICT) into classroom practices (Adetayo, 2023; Callaway-Cole & Kimble, 2021). In this new learning ecosystem, teachers are increasingly expected to reconceptualize instructional design and learning materials through the effective use of digital media (Koh, 2020; Ní Dhuinn & Ann Garland, 2022). Learning is no longer confined to teachers and textbooks as the sole sources of knowledge, as digital platforms and online resources now offer abundant learning opportunities. Consequently, teachers' ability to integrate technology into their instructional

practices is critical in optimizing students' engagement, motivation, and academic performance (Ammade et al., 2020; Durdu & Dağ, 2017).

ICT has thus emerged as a fundamental element in enhancing the overall quality of education (Fernández-Morante et al., 2023; Infante-Moro et al., 2022). In Indonesia, the implementation of the Kurikulum Merdeka (Independent Curriculum), which emphasizes digital literacy and self-directed learning, further reinforces the need for teachers to develop comprehensive technological competence. Technology-enabled learning has become a defining feature of 21st-century education, demanding that teachers design learning experiences that cultivate cognitive, metacognitive, social, and productivity skills among students (Bond et al., 2018; Salcines-Talledo et al., 2020). To achieve these goals, educators must move beyond using ICT as a mere tool for information delivery and instead adopt pedagogical models that embed technology meaningfully within student-centered learning (Chai et al., 2013). This shift underscores the importance of strengthening teachers' professional competencies in technology-based pedagogy.

To facilitate the effective integration of technology in education, a comprehensive conceptual framework is essential. The Technological Pedagogical Content Knowledge (TPACK) framework offers such a foundation, extending from Shulman's (1986) concept of Pedagogical Content Knowledge (PCK). TPACK emphasizes the interconnected integration of technology, pedagogy, and content knowledge to promote effective teaching and learning in the digital era (Ammade et al., 2020). The framework enables teachers to harmonize subject matter expertise, pedagogical strategies, and technological tools in their instructional practices an essential competency for 21st-century educators. The TPACK construct comprises seven interrelated components: Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK), Technological Content Knowledge (TCK), Pedagogical Content Knowledge (PCK), Technological Pedagogical Knowledge (TPK), and the integrated Technological Pedagogical and Content Knowledge (TPACK) (Chai et al., 2013; Hsu et al., 2021; Koehler & Mishra, 2009; Papanikolaou et al., 2017; Schmidt et al., 2009; Tømte et al., 2015).

Professional teachers are therefore expected to possess sufficient TPACK competence as a core professional attribute, complementing pedagogical, personal, and social competencies (Joko et al., 2020). Assessing teachers' TPACK proficiency is consequently a crucial step in determining their readiness to implement technology-enhanced instruction effectively. Globally, the acceleration of ICT integration following the Covid-19 pandemic has reshaped both classroom practices and teachers' professional roles (Adetayo, 2023; Callaway-Cole & Kimble, 2021), redefining the meaning of teaching and learning in the digital age (Agbo, 2015; Hsu et al., 2021). Learning has evolved beyond textbooks and conventional classrooms, enriched instead by diverse online platforms that support flexible and personalized instruction (Koh, 2020; Ní Dhuinn & Garland, 2022). Accordingly, ICT competence is indispensable for facilitating equitable and adaptive learning experiences (Durdu & Dağ, 2017; Fernández-Morante et al., 2023).

Within the Indonesian context, the Kurikulum Merdeka highlights the importance of digital literacy and independent learning, reinforcing the urgency for teachers to develop holistic mastery of technological tools (Infante-Moro et al., 2022). Technology-enabled instruction functions not merely as a pedagogical supplement but as a transformative driver for cultivating critical thinking, creativity, and metacognitive capacities among students (Bond et al., 2018; Salcines-Talledo et al., 2020). However, successful integration of technology requires more than technical proficiency it necessitates a sophisticated balance of pedagogical and content understanding (Akyüz & Samsa, 2018; Scherer et al., 2017).

The TPACK framework (Koehler & Mishra, 2009), as an evolution of Shulman's (1986) PCK theory, conceptualizes this balance through three interrelated knowledge domains: technology, pedagogy, and content. A growing body of empirical research confirms TPACK's validity as an effective model for assessing teachers' readiness to implement technology-rich instruction (Olofson et al., 2016; Yeh et al., 2017; Schmid et al., 2021; Backfisch et al., 2024). In recent years, the TPACK model has been further refined to encompass new dimensions, including contextual knowledge (Petko, 2025), ethical awareness (Deng et al., 2023), and

artificial intelligence literacy (Çelik et al., 2023; Tan et al., 2025), reflecting its adaptability to evolving digital ecosystems.

In developing contexts such as Papua, Indonesia, limitations in digital infrastructure and accessibility continue to pose significant challenges to equitable technology integration. Previous studies indicate that although teachers in these regions demonstrate satisfactory pedagogical and content mastery, their technological integration remains largely instrumental rather than transformative (Tanta et al., 2023; Satar et al., 2024; Doukakis et al., 2021). Hence, it is essential to examine teachers' TPACK-ICT competence to identify both their strengths and areas needing improvement in fostering 21st-century learning. Empirical investigations among science teachers in eastern Indonesia (Satar, Mawara, et al., 2025) consistently reveal that while teachers exhibit good technological and content knowledge, their pedagogical application of technology remains limited. Satar, Nurbaya, et al., (2025a, 2025b) findings highlight the need for a deeper understanding of teachers' readiness, particularly in regions where disparities in digital infrastructure persist. Therefore, this study aims to analyze the level of Technological Pedagogical Content Knowledge in Information and Communication Technology (TPACK-ICT) among teachers in Papua specifically in Keerom Regency, Jayapura Regency, and Jayapura City and to provide a comprehensive overview of their readiness to meet the demands of 21st-century learning.

METHOD

This study employed a quantitative research method with a descriptive approach to describe the TPACK competencies of teachers in Papua, specifically in Keerom Regency, Jayapura Regency, and Jayapura City. The research was conducted from May to August 2025 across the three regencies.

The sampling technique used in this study was accidental sampling, which involved selecting respondents based on their availability and willingness to participate at the time of data collection. This technique was chosen due to the geographical challenges and wide distribution of schools across the Papua region, as well as time and access limitations faced by the researchers. However, this non-probability sampling limits the generalization of results beyond the sample population, as it may not fully represent all teachers in Papua.

The research sample consisted of 31 teachers from elementary, junior high, and high schools in the three regencies who completed the research questionnaire. The instrument used in this study was a questionnaire consisting of 34 statements related to TPACK competence. The questionnaire items were developed and adapted from Karamina (2021) and Sa'adah & Kariadinata (2018), covering the seven TPACK components: Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK), Technological Content Knowledge (TCK), Pedagogical Content Knowledge (PCK), Technological Pedagogical Knowledge (TPK), and Technological Pedagogical and Content Knowledge (TPACK). The instrument validity was ensured through expert judgment by specialists in educational technology and pedagogy, while the reliability test was conducted previously by Karamina (2021) using Cronbach's Alpha, which obtained a reliability coefficient of 0.935, indicating excellent internal consistency.

The data obtained were analyzed using descriptive statistical analysis, specifically by calculating the mean (average) of each TPACK component to describe teachers' competence levels. The data were processed and tabulated using Microsoft Excel, which enabled clear visualization and interpretation of the findings. All participants were informed about the purpose of the research and voluntarily agreed to participate, ensuring that the study adhered to ethical research standards. This method enables the researchers to describe the current level of teachers' TPACK-ICT competence in the Papua region and to identify areas that require further improvement to enhance teachers' readiness for 21st-century learning.

Table 1. Technological Pedagogical and Content Knowledge Competency Indicators

No.	Indicators
1.	Technology Knowledge
2.	Content Knowlegde
3.	Pedagogical Knowledge
4.	Pedagogical Content Knowledge
5.	Technological Content Knowledge
6.	Technological Pedagogical Knowledge
7.	Technological Pedagocical Content Knowledge

The data obtained from the questionnaire results were calculated using the formula from Karamina (2021), namely as follows:

$$\bar{X} = \frac{\sum Xi}{N}$$

$\bar{X}$: mean score

$\sum Xi$: total score obtained from all respondents

N : number of respondents

Each respondent's score for the 34 questionnaire items was first summed, and then the mean was calculated for each of the seven TPACK components. The results were interpreted using the following classification criteria (Karamina, 2021):

Table 2. Questionnaire Value Interval Criteria

Interval	Category
4.21-5.00	Excellent
3.41-4.20	Good
2.61-3.40	Fair
1.81-2.6	Poor
1.00-1.80	Very Poor

This classification helps identify which aspects of teachers' TPACK-ICT competencies are strong and which require further development.

RESULT AND DISCUSSION

1. Technological Knowledge (TK)

Technological Knowledge (TK) is the knowledge of how to use various technologies, including hardware, software, and digital applications, to support the learning process. The average proficiency for each TK indicator among 31 teachers in Papua (Keerom Regency, Jayapura Regency, and Jayapura City) can be seen in Table 3 below:

Table 3. Average Values of TK Component Indicators

No.	Component TK	Average	Category
1.	Knowledge of computer technical troubleshooting	3.45	Good
2.	Skills in using technology	3.81	Good
3.	Knowledge of the latest technological developments	3.81	Good
4.	Understanding of basic computer components	3.65	Good
5.	Skills in using word processing, spreadsheet, and presentation programs	3.48	Good
6.	Skills in using printers, scanners, projectors, and digital cameras	3.81	Good
7.	Knowledge of storing data on digital media	3.81	Good
8.	Knowledge of using the internet as a	4.32	Very Good

	communication medium		
Average		3.77	Good

The analysis revealed that teachers in Papua demonstrated a moderate-to-high level of Technological Knowledge (M = 3.77), categorized as Good. Among the indicators, the highest mean (4.32) was observed in the ability to use the Internet as a communication and learning medium. This suggests that most teachers are familiar with basic online platforms—such as email, WhatsApp groups, or Google Classroom—for facilitating communication and resource sharing with students. However, relatively lower scores were observed in computer troubleshooting (3.45) and using word processing and presentation software (3.48), indicating that teachers' operational technical skills remain somewhat limited.

This pattern is consistent with Muhaimin et al. (2019), who found that Indonesian science teachers' TK averaged 3.12 (SD = 0.77) the lowest among all TPACK components. The higher mean in this study suggests that digital infrastructure and post-pandemic exposure have improved teachers' familiarity with technology, even in remote regions such as Papua. Yet, limited access to ICT training and maintenance facilities may still constrain deeper mastery of technical operations. Therefore, while teachers have reached functional digital literacy, the transition toward creative and productive technology use still requires systematic capacity building.

2. *Content* Knowledge (CK)

Content Knowledge (CK) refers to a teacher's in-depth mastery of subject content, including core concepts, facts, disciplinary structures, and relationships between ideas, which form the foundation for effective teaching. The average CK performance for each indicator among 31 teachers can be seen in Table 4 below:

Table 4. Average Values of CK Component Indicators

No.	Component TK	Average	Category
1.	Understanding the concepts, laws, and theories being taught	3.65	Good
2.	Knowledge related to the historical development of the material being taught	3.77	Good
3.	Knowledge in designing and implementing learning	4.03	Good
4.	Knowledge in using the latest sources such as books and journals	3.90	Good
5.	Attending seminars or activities related to the field of study being taught	3.61	Good
	Average	3.79	Good

Teachers' Content Knowledge (M = 3.79, Good) demonstrates their ability to master the disciplinary foundations of their teaching subjects. The highest indicator was designing and implementing lessons aligned with learning objectives (4.03), implying strong command of curriculum design and subject relevance. Teachers also exhibited good ability in using up-to-date sources such as textbooks and online journals (3.90). However, participation in seminars or professional learning communities scored the lowest (3.61), suggesting that continuous academic engagement remains a challenge.

Compared to Muhaimin et al. (2019), who reported CK = 3.92 (SD = 0.51) as the highest domain among Indonesian science teachers, the CK level in Papua remains comparable though slightly lower. The difference may reflect disparities in access to professional learning opportunities and scholarly resources between urban and rural regions. The findings underline the need for sustainable teacher professional development programs that enhance both mastery of disciplinary content and engagement with current educational research.

3. Pedagogical Knowledge (PK)

Pedagogical Knowledge (PK) refers to a teacher's comprehensive understanding of various important aspects of the learning process. The average ability for each PK indicator for 31 teachers can be seen in Table 5 below:

Table 5. Average Values of PK Component Indicators

No.	PK Components	Average	Category
1.	Implementing varied learning	3.87	Good
2.	Able to manage and control the class well	3.97	Good
3.	Using a variety of assessment methods and techniques	3.90	Good
4.	Conducting reflective actions to improve the quality of learning	3.77	Good
Average		3.87	Good

Teachers' Pedagogical Knowledge (M = 3.87, Good) reflects their understanding of instructional strategies, classroom management, and assessment practices. The highest score appeared in classroom management and control (3.97), showing that teachers can maintain order and foster conducive learning environments. Similarly, diverse assessment methods (3.90) received high ratings, indicating awareness of using various tools to measure student learning outcomes. However, reflective practices to improve instruction received a relatively lower score (3.77), revealing that continuous self-evaluation and pedagogical reflection are not yet fully embedded in teachers' routines.

These results echo findings from Fernández-Morante et al. (2023), who emphasized that even though teachers can manage instruction effectively, reflection-based practices remain underdeveloped across many educational contexts. The data suggest that while Papuan teachers are pedagogically competent in organizing and delivering instruction, deeper professional reflection—an essential component of 21st-century teaching—is an area requiring institutional support, such as mentoring or professional learning communities.

4. Pedagogical Content Knowledge (PCK)

PCK is a form of professional knowledge that combines content (teaching materials) and pedagogy (teaching methods) into an inseparable whole. The average ability for each PCK indicator for 31 teachers can be seen in Table 6 below:

Table 6. Average Values of PCK Components

No.	PCK Components	Average	Category
1.	Selecting learning approaches and strategies appropriate to the existing learning material	3.87	Good
2.	Preparing your own lesson plans	4.03	Good
3.	Measuring students' understanding of the material being taught	3.94	Good
4.	Knowing the appropriate flow of material presentation that is likely to be easier for students to understand	3.90	Good
Average		3.93	Good

The Pedagogical Content Knowledge (PCK) dimension yielded the highest average (M = 3.93, Good) across all TPACK components. Teachers demonstrated particular strength in preparing lesson plans independently (4.03) and assessing students' understanding (3.94). These findings reflect a strong capacity to align instructional methods with subject matter content. Teachers appear to understand how to sequence material logically and how to use appropriate teaching strategies that fit the nature of their subjects.

Compared with Muhaimin et al. (2019), who reported an average PCK score of 3.76 (SD = 0.55), Papuan teachers in this study scored slightly higher. This outcome supports Tanta et al. (2023), who noted that teachers in eastern Indonesia demonstrate notable competence in lesson planning and implementation but still require reinforcement in varying teaching strategies. The results imply that while PCK development in Papua is progressing well, teachers need exposure to more adaptive and inquiry-based pedagogical models to enhance their capacity for differentiated instruction.

5. Technological Content Knowledge (TCK)

TCK refers to knowledge of how technology can be used to deliver content effectively, namely how digital tools can enhance the delivery of material and student interaction with it. TCK can be defined as a teacher's understanding of how certain technologies can facilitate,

transform, or even limit the representation of subject matter concepts. The average ability for each TCK indicator for 31 teachers can be seen in Table 7 below:

Table 7. Average Values of TCK Component Indicators

No.	TCK Components	Average	Category
1.	Using technology to help understand concepts, laws, and theories of learning materials	3.68	Good
2.	Knowing computer applications related to the material being taught	3.58	Good
3.	Having knowledge in developing student activities and assignments that involve the use of technology	3.65	Good
Average		3.63	Good

The TCK component (M = 3.63, Good) reflects teachers' ability to use technology to represent and deliver content effectively. Teachers performed best in using technology to clarify concepts, laws, and theories (3.68), suggesting confidence in employing visuals, simulations, or multimedia resources to facilitate understanding. However, they were less proficient in recognizing subject-specific software and applications (3.58), indicating that technology use is still largely generic rather than tailored to discipline-specific needs.

This finding aligns with Doukakis et al. (2021), who reported TCK = 3.51 among in-service computer science teachers, showing that content–technology integration is a global challenge, even in technologically advanced contexts. The relatively low TCK implies that teachers in Papua may still depend on general-purpose tools (e.g., PowerPoint, YouTube) rather than leveraging specialized digital resources that align closely with their subjects. Hence, future professional training should introduce teachers to discipline-oriented technologies—such as virtual labs, educational simulations, or data analysis tools—to enhance conceptual delivery.

6. Technological Pedagogical Knowledge (TPK)

Technological Pedagogical Knowledge refers to knowledge of how technology can be leveraged to support pedagogical strategies, namely how digital tools can enhance teaching and learning processes, regardless of the subject matter being taught. The average ability for each TPK indicator for 31 teachers can be seen in Table 8 below:

Table 8. Average Value of TPK Components

No.	TPK Components	Average	Category
1.	Using computer applications such as Microsoft Word and PowerPoint in learning or teaching practice	3.87	Good
2.	Choosing technology that aligns with the learning approach and strategies implemented by the teacher in the teaching practice	3.84	Good
3.	Using internet facilities such as social media and blogs as learning resources	3.94	Good
Average		3.88	Good

The Technological Pedagogical Knowledge (M = 3.88, Good) reveals that teachers are capable of integrating technology into pedagogical processes. The strongest item was using internet-based platforms such as social media and blogs for learning activities (3.94), showing that teachers are increasingly comfortable with interactive digital environments. However, selecting appropriate technology aligned with pedagogical strategies received a lower mean (3.84), suggesting that technology use tends to be operational rather than strategically pedagogical.

In Muhaimin et al. (2019), the average TPK score was 3.02 (SD = 1.08), much lower than in this study, indicating that Papuan teachers exhibit stronger pedagogical–technological alignment. Nonetheless, Koh (2020) highlighted that teachers often remain at a "substitution level" of technology integration, where technology merely replaces traditional tools without transforming pedagogy. Thus, while the TPK level here is encouraging, continued training is

needed to elevate technology use toward transformative teaching—incorporating blended learning, flipped classrooms, and collaborative online pedagogies.

7. Technological *Pedagogical Content Knowledge* (TPACK)

TPACK is a comprehensive integration of technology, pedagogy, and content knowledge that enables teachers to design, implement, and evaluate learning effectively. The average ability for each TPK indicator for 31 teachers can be seen in Table 9 below:

Table 9. Average Values of TPACK Components

No.	TPACK Components	Average	Category
1.	Selecting learning strategies and technology appropriate to the material to be presented in practical learning activities	3.77	Good
2.	Integrating existing technological knowledge to achieve effective learning	3.74	Good
3.	Applying different learning strategies and using a variety of computer applications in practical learning activities	3.39	Good
Average		3.63	Good

The integrated TPACK score (M = 3.63, Good) reflects the teachers' ability to harmonize technology, pedagogy, and content simultaneously. The highest indicator was selecting suitable strategies and technology according to the material (3.77), while applying diverse technology-based strategies received the lowest (3.39). This suggests that while teachers conceptually understand how to combine the three domains, practical application and variation in technology-mediated instruction remain limited.

Doukakis et al. (2021) reported similar integration challenges, where computer science teachers scored highly on TK (4.16) and CK (4.38) but much lower on integrative domains (3.51–3.68). Similarly, Ningtyas et al. (2024) found that Indonesian pre-service EFL teachers achieved a higher TPACK mean (3.97, SD = 0.73) than in-service teachers, likely due to more recent formal exposure to digital pedagogy. The current findings confirm that in-service teachers in Papua possess a solid foundation in TPACK but still need practical reinforcement through structured professional learning, particularly in designing and executing technology-integrated lesson plans.

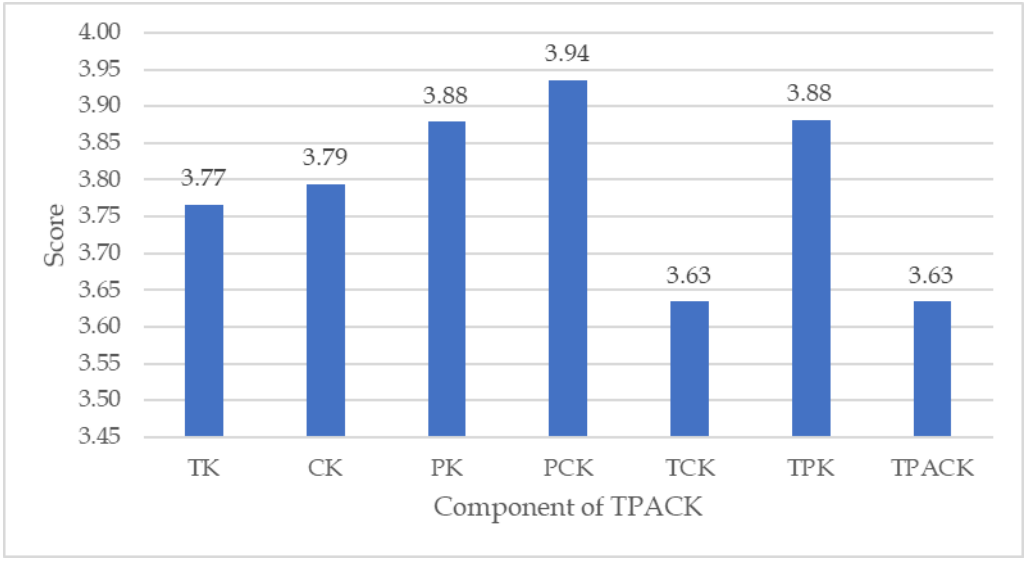

Figure 1. Average score of TPACK components based on teachers' responses (n = 31).

As illustrated in Figure 1, all TPACK dimensions fall within the Good category, with mean values ranging from 3.63 to 3.93. The most established competencies are in pedagogical and content domains (PCK, PK, CK), while technological integration components (TCK, TPACK) remain relatively weaker. This pattern aligns with international literature (Chai et al., 2013; Doukakis et al., 2021), which consistently reports that teachers tend to master content and pedagogy earlier than technology integration.

These findings indicate that while Papua's teachers are well-prepared in traditional teaching domains, there is an emerging need for systematic professional development in digital pedagogy. Strengthening integrative domains (TCK, TPK, TPACK) can bridge the gap between knowing how to teach and knowing how to teach with technology. Overall, this study provides a nuanced understanding of the current landscape of TPACK-ICT competence among teachers in Papua, revealing not only their readiness for 21st-century learning but also the areas requiring strategic intervention to ensure equitable, technology-enhanced education.

DISSCUSSION

The research findings indicate that teachers in Papua already possess good competencies across all TPACK components. The main strengths lie in Pedagogical Content Knowledge (PCK), Pedagogical Knowledge (PK), and Technological Pedagogical Knowledge (TPK), while the greatest challenges are evident in Technological Content Knowledge (TCK) and TPACK, which require further development in terms of innovative use of technology applications relevant to the teaching materials and the full integration of technology into instructional strategies. The highest performance in PCK demonstrates teachers' ability to effectively integrate pedagogy and content. Teachers are capable of designing lesson plans, sequencing material logically, and evaluating student understanding comprehensively. However, there remains room for improvement in employing more contextual and varied teaching strategies to enhance the quality of learning. As Boedeker et al. (2025) emphasize, PCK goes beyond knowing what to teach and how to teach; it involves understanding why particular approaches work best for certain topics or learners (Nuangchalerm, 2020; Padmavathi, 2017). This deep pedagogical reasoning enables teachers to make adaptive instructional decisions that align with students' needs and learning contexts, fostering meaningful and student-centered learning experiences. Following PCK, both Pedagogical Knowledge (PK) and Technological Pedagogical Knowledge (TPK) obtained relatively high mean scores, reflecting teachers' capability to manage classrooms, design varied learning methods, and integrate technology to promote interactivity. These findings suggest that teachers are not only grounded in core pedagogical theories but also able to apply technology to enhance instruction. However, improvement is still needed in reflective teaching and in aligning technological tools with pedagogical strategies. Research by Liu, Su, and Li (2022) supports this, noting that teachers are better able to apply pedagogical approaches involving technology when supported by structured training. Similarly, Schmid, Brianza, and Petko (2021) found that teachers' self-assessed TPACK levels are positively associated with the frequency and sophistication of technology use in lesson design.

The findings for Content Knowledge (CK) indicate a good mastery of subject matter, particularly in lesson design and utilization of updated academic resources. However, teachers' participation in scholarly or professional learning activities remains limited, and their conceptual understanding of theories and principles could be deepened. Content mastery plays a crucial role in ensuring that knowledge is not only accurate but also pedagogically accessible to students (Ammade et al., 2020; Hardisky, 2018). Similarly, the results for Technological Knowledge (TK) demonstrate teachers' adequate ability to use the Internet and digital devices, confirming their readiness to adopt technology in teaching (Armiyati & Facrurozi, 2022). Nonetheless, weaknesses in troubleshooting and productivity software skills (e.g., spreadsheet or presentation tools) show that foundational technical proficiency still needs to be reinforced. As Huang and Lajoie (2021) argue, TK serves as the base for higher-order integration in TPK and TCK; without solid technical fluency, complex digital pedagogies are harder to achieve. The lowest components—TCK and TPACK—highlight teachers' difficulty in merging technological knowledge with subject-specific content and in achieving seamless integration among technology, pedagogy, and content. These findings align with Doukakis et al. (2021), who reported that secondary computer teachers exhibited high confidence in CK and TK but lower confidence in TCK (M = 3.68) and TPACK as an integrated construct. Such results indicate that although teachers are familiar with digital tools, their application remains generic and lacks contextual adaptation to specific learning materials. This underscores the need for

integrative and contextual professional development programs focusing on authentic digital pedagogy and technology-enhanced content representation.

This research offers several practical and theoretical implications. First, the findings provide a diagnostic overview of teachers' readiness for technology-integrated teaching in Papua, a region often underrepresented in national ICT education studies. The good overall TPACK profile demonstrates that teachers possess the foundational competence to support Indonesia's Merdeka Curriculum, which emphasizes digital literacy and student-centered learning. Second, the results highlight that professional development programs should prioritize the integrative domains (TCK and TPACK) rather than focusing solely on technical training. Training modules should involve discipline-specific technology use such as simulations, data visualization, and digital experimentation—to strengthen teachers' capacity to embed technology meaningfully into learning content. Third, these findings have policy-level implications, suggesting that educational stakeholders in Papua—especially local education authorities and teacher education institutions—should adopt targeted mentoring models to bridge technological and pedagogical divides across schools. By leveraging these insights, policymakers can design capacity-building initiatives that foster sustainable digital pedagogy in geographically and infrastructurally diverse contexts.

Despite its contributions, this study has several limitations. First, the sample size (n = 31) was relatively small and limited to three regions (Keerom, Jayapura Regency, and Jayapura City), which restricts the generalizability of the findings. Future studies should include larger and more diverse samples to represent the broader teacher population in Papua and eastern Indonesia. Second, the use of self-reported questionnaires may introduce bias, as teachers might overestimate their actual competence. Subsequent research could adopt a mixed-methods design incorporating classroom observations or performance-based assessments to obtain more objective data. Third, the study's cross-sectional design limits its ability to capture developmental changes over time. Longitudinal studies could better reveal how teachers' TPACK evolves following specific interventions or training programs. Finally, while the descriptive approach provided valuable baseline data, it does not identify causal relationships among TPACK components. Future research could apply correlational or structural equation modeling (SEM) to examine the interdependencies between domains more precisely.

In summary, this study confirms that teachers in Papua exhibit strong pedagogical and content competencies, with emerging but uneven technological integration. Strengthening the interconnection between technology and content (TCK) and achieving a holistic synthesis of TPACK remain essential priorities. Addressing these challenges through targeted training, policy alignment, and contextualized digital learning resources can significantly enhance teachers' capacity to deliver meaningful 21st-century education. PCK obtained the highest mean (3.93), indicating that teachers can align instructional strategies with content. This supports the notion that pedagogical reasoning is foundational for adaptive instruction (Boedeker et al., 2025; Nuangchalerm, 2020). Similar findings were reported by Muhaimin et al. (2019), where Indonesian science teachers scored 3.76 in PCK. The results affirm that PCK functions as the cognitive bridge between content structure and learner understanding (Padmavathi, 2017; Auerbach & Andrews, 2018). Teachers also performed well in PK (3.87) and TPK (3.88), showing competence in classroom management and use of interactive digital media. These findings correspond with Schmid et al. (2021), who found a positive correlation between self-assessed TPACK and the actual use of digital tools. Liu, Su, and Li (2022) and Shambare et al. (2024) further emphasized that sustained professional development enhances teachers' capacity to select technology that aligns with instructional goals. However, reflective practice remains underdeveloped (Fernández-Morante et al., 2023).

CK (3.79) and TK (3.77) were also in the "Good" category, suggesting that teachers possess adequate mastery of content and technology use. However, participation in academic activities was limited—mirroring global findings that professional isolation often reduces innovation (Nelson et al., 2019; Nguyen et al., 2024). In terms of TK, teachers' high familiarity with internet tools aligns with Armiyati and Facrurozi (2022) but contrasts with Olofson et al. (2016), who noted that technical fluency does not always translate into pedagogical innovation.

The weakest domains were TCK (3.63) and integrated TPACK (3.63). Teachers struggled to apply technology in subject-specific contexts, echoing Doukakis et al. (2021) and Kosiol et al. (2024), who found similar integration gaps. This indicates the need for contextualized training that demonstrates how technology mediates conceptual understanding in different subjects (Ammade et al., 2020; Li et al., 2025).

The empirical pattern observed here aligns with global evidence (Fabian et al., 2024; Tondeur et al., 2025), suggesting that teachers often master pedagogy and content earlier than complex digital integration. Petko (2025) and Hang (2025) recently expanded TPACK with a contextual knowledge (XK) dimension, underscoring that school culture, resources, and leadership strongly moderate teachers' integration capacity. This study implies that teachers in Papua have the foundational knowledge necessary to support the Merdeka Curriculum's emphasis on digital literacy but require support for deeper integration. Consistent with Tan et al. (2025) and Willermark (2025), professional development should focus on AI-assisted teaching and contextual TPACK application. Institutional support—including mentoring, peer learning, and access to discipline-specific digital tools—can help bridge the TCK and TPACK gaps (Tschönhens et al., 2024; Mustafa, 2024). The study's limitations include the small sample size (n = 31) and reliance on self-reported data, which may not reflect actual classroom practice. Future research should incorporate performance-based assessments and longitudinal designs (Backfisch et al., 2024; Fontyn et al., 2025). Moreover, including contextual factors such as leadership and infrastructure could provide a more comprehensive understanding of teachers' digital readiness (Schmitz et al., 2025; Antonietti et al., 2025).

In summary, teachers in Papua exhibit strong pedagogical and content knowledge but moderate technological integration. The study reinforces the global finding that TPACK development is an iterative process shaped by context, access, and professional support (Tondeur et al., 2025; Backfisch et al., 2024). Therefore, localized capacity-building programs that integrate contextual knowledge, ethics, and AI literacy are vital to prepare teachers for 21st-century learning. Despite methodological constraints, this research contributes empirical evidence to the growing literature on TPACK in underrepresented regions. Future inquiries should employ mixed-methods and comparative approaches to evaluate the long-term effects of digital pedagogy interventions on teaching quality and student outcomes (Song, 2025; Ding et al., 2024).

CONCLUSION

This study investigated the level of teachers' Technological Pedagogical Content Knowledge (TPACK) in Papua, encompassing Keerom Regency, Jayapura Regency, and Jayapura City. The findings reveal that teachers generally possess good competence across all TPACK domains, with the highest performance in Pedagogical Content Knowledge (PCK), Pedagogical Knowledge (PK), and Technological Pedagogical Knowledge (TPK). These results reflect teachers' strong foundation in pedagogy and content integration, supported by moderate technological capability. However, the lower scores in Technological Content Knowledge (TCK) and TPACK suggest that technology integration remains largely instrumental rather than transformative. The study implies that while teachers in Papua have reached functional digital literacy, there is an urgent need to strengthen their ability to apply contextual, discipline-specific technology in teaching. Professional development programs should thus move beyond basic ICT training toward integrative pedagogical design, emphasizing how digital tools can enhance conceptual understanding, student engagement, and higher-order thinking. Furthermore, policymakers and educational institutions in Papua should establish structured mentoring systems and continuous professional learning communities to support teachers' technological growth within local constraints.

Although limited by its small sample size and reliance on self-reported data, this research provides an essential diagnostic baseline for future studies on teacher competence in eastern Indonesia. Continued exploration using longitudinal and mixed-method approaches is recommended to measure the long-term impact of digital pedagogy interventions on teachers' TPACK development and student learning outcomes.

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AUTHOR CONTRIBUTION STATEMENT

TT and SS designed and developed the research design, developed the instruments, and performed data analysis. NN assisted in data collection, instrument validation, and documentation of implementation results. HL contributed to the literature review, questionnaire data processing, and editing of the final manuscript. All authors (TT, SS, NN, HL) actively participated in the discussion of the results and in revising the article for publication.

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