

Analyzing TPACK Competence among Pre-Service Indonesian Language Teachers: A Quantitative Case Study

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ABSTRACT

The integration of digital technology in education requires pre-service teachers to develop strong Technological Pedagogical Content Knowledge (TPACK). However, empirical studies examining TPACK implementation in Indonesian language teacher education—particularly in regional universities—remain limited. This study aims to examine the TPACK competencies of pre-service Indonesian language teachers and identify demographic factors influencing their technology integration capabilities. This study employed a quantitative approach using an online questionnaire distributed to 133 pre-service Indonesian language teachers at Universitas PGRI Sumatra Barat who had completed microteaching courses. The collected data were analyzed using descriptive statistics to determine TPACK competency levels and to examine variations based on demographic variables, including gender, academic level, and duration of technology use. The findings indicate that participants demonstrated a moderate level of TPACK competency (mean score = 2.69; 67.25%). Variations in competency were observed across demographic categories. The highest competency levels were found among second-year students and those with 3–4 years of technology experience, suggesting potential developmental windows for optimal TPACK acquisition. Gender differences were also evident: male participants showed higher scores in most TPACK domains, while female participants performed better in integrated TPACK. The results highlight that TPACK development may not follow a strictly linear progression. Instead, certain periods during teacher education may serve as optimal phases for strengthening technology integration skills. These findings underscore the importance of implementing structured and targeted technology integration strategies within teacher education curricula to support effective TPACK development among pre-service teachers.

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1. INTRODUCTION

The rapid transformation of education in recent decades has positioned teachers at the center of responding to global and digital-era challenges. As digital technologies increasingly shape teaching and learning, teachers are required to develop strong technological competencies supported by adequate digital infrastructure (Chai et al., 2019; Seufert et al., 2021) and to implement technology-enhanced pedagogical approaches effectively (Suarman et al., 2025). Accordingly, pre-service teachers must acquire integrated knowledge and practical skills to meaningfully embed digital tools in instruction, a need that is particularly salient within Indonesia's evolving educational context (Drajati et al., 2021).

The shift from Pedagogical Content Knowledge (PCK) to Technological Pedagogical Content Knowledge (TPACK) represents a major theoretical advancement in understanding effective digital-age teaching (Nisa & Aryni, 2023). By extending PCK to include technological dimensions, TPACK provides a comprehensive framework for preparing future teachers to integrate pedagogy, content, and technology in contextually meaningful ways (Thohir et al., 2021). Empirical studies demonstrate that effective technology integration enhances student engagement and learning outcomes, with technologically competent pre-service teachers exhibiting higher teaching effectiveness (López et al., 2025). Nevertheless, meaningful integration remains challenging, even among STEM teachers who are comfortable with technology (Sun et al., 2024).

In language education, research highlights the need for targeted professional development to strengthen pre-service teachers' TPACK capabilities (Syamdianita & Cahyono, 2021). This issue is evident at Universitas PGRI Sumatera Barat, where pre-service Indonesian language teachers are required to develop advanced technological proficiency, design thinking, and instructional expertise. This study addresses a critical research gap by examining the TPACK capabilities of pre-service Indonesian language teachers within the West Sumatran context. While prior studies have predominantly focused on TPACK development through training programs (21.05%) and specific technology integration (19.30%) (see Table 1), its application in language education—particularly Indonesian language instruction—remains underexplored (Nga et al., 2025; Tseng et al., 2022; Wijayanto et al., 2023). Although TPACK has been examined in English language education (Inpeng & Nomnian, 2020), comparable research in other language disciplines is still limited.

While (Thohir et al., 2021) have examined TPACK in science and STEM education respectively, only 3.51% (see table 1) of studies connect it to essential 21st-century digital competencies (Seufert et al., 2021). Geographic disparities exist in TPACK research, with developing countries and regional universities underrepresented, confirming (Syamdianita & Cahyono, 2021) findings on Indonesia's unique challenges. Additionally, ethical and security dimensions within TPACK remain understudied (5.26%) (see Table 1), particularly in regions with variable digital infrastructure access. These gaps necessitate more comprehensive research across diverse linguistic and cultural contexts, especially in developing nations' educational institutions.

Additionally, a systematic search was conducted using the keywords "TPACK" and "Pre-service Teacher" to identify research gaps and recent studies on these variables. Based on an analysis of the Scopus database from 2020 to 2025, a total of 57 Scopus-indexed articles were retrieved. Further details are provided in Table 1.

Table 1. Research Gap TPACK and Pre-service Teacher 2020-2025 on data based on scopus.com

| No | Research Themes | Number of Articles | Percentage |
|----|--|--------------------|------------|
| 1 | TPACK Development through Training/Education Programs (e.g., microteaching-based training, TPACK development programs, educational technology courses, professional workshops) | 12 | 21.05% |
| 2 | Specific Technology Integration in TPACK (e.g., Facebook and social media, Augmented Reality, web-based technology, ed-tech apps, corpus technology, GeoGebra) | 11 | 19.30% |

| | | | |
|-------|---|----|--------|
| 3 | TPACK in Specific Subject Contexts (e.g., Science, Mathematics, TEFL, Chemistry, Physics) | 10 | 17.54% |
| 4 | TPACK Measurement and Evaluation (e.g., instrument development, TPACK ability assessment, self-efficacy evaluation, technology readiness measurement) | 8 | 14.04% |
| 5 | TPACK in Online/Distance Learning (e.g., virtual exchange, online learning during pandemic, blended learning, e-teaching internship) | 6 | 10.53% |
| 6 | Systematic Analysis/Literature Review (e.g., bibliometric analysis, systematic review, literature review on TPACK strategies, meta-analysis) | 5 | 8.77% |
| 7 | Ethics and Security in TPACK (e.g., ethical implications of technology use, digital security, ethical considerations in technology integration) | 3 | 5.26% |
| 8 | TPACK and 21st Century Skills (e.g., 21st century skills integration, digital competency development) | 2 | 3.51% |
| Total | | 57 | 100% |

Based on the table above, the Technological Pedagogical Content Knowledge (TPACK) framework has become increasingly essential for pre-service teachers in the digital era, particularly for Indonesian language pre-service teachers, whose TPACK development remains limited. As technological advancements demand an integrated approach beyond content and pedagogy, research shows that strong TPACK competencies enable effective digital tool integration, enhancing student engagement and learning outcomes (López et al., 2025). while supporting teachers' adaptation to evolving technologies without compromising pedagogical goals (Seufert et al., 2021). This framework is especially critical in developing countries, where balancing technology and pedagogy presents distinct challenges (Syamdianita & Cahyono, 2021), positioning TPACK as a core foundation for 21st-century teaching skills (Nisa & Aryni, 2023; Suarman et al., 2025).

Despite extensive TPACK research, substantial gaps remain in language education, particularly Indonesian language instruction, which accounts for a smaller proportion of studies compared to STEM (17.54%) and training-focused research (21.05%). Geographic disparities further indicate the underrepresentation of developing countries and regional universities, alongside limited attention to 21st-century digital competencies (3.51%) and ethical dimensions of technology use (5.26%). Pre-service Indonesian language teachers at regional universities therefore face unique challenges in developing comprehensive TPACK competencies due to limited contextualized research and empirical evidence on effective integration pathways. Addressing this gap, the present study examines TPACK capabilities of pre-service Indonesian language teachers at Universitas PGRI Sumatera Barat within Indonesia's specific educational and cultural context.

The integration of technology in 21st-century education has intensified demands on teachers' technological competencies, positioning the TPACK framework as a key model for understanding effective technology integration across disciplines, including language education. Developed by Mishra and Koehler, TPACK extends Shulman's PCK by integrating technology with pedagogical and content knowledge and emphasizing their dynamic interaction rather than isolated components (Mishra & Koehler, 2006). Unlike models examining these components separately, TPACK emphasizes their dynamic intersection (López et al., 2025; Naing & Wiedarti, 2023). Research shows TPACK-informed interventions improve teachers' instructional practices and correlate with enhanced student outcomes (Chai et al., 2019).

TPACK research in Bahasa Indonesia instruction presents unique complexities that distinguish it from other subject areas (Drajati et al., 2021; Syamdianita & Cahyono, 2021). Content Knowledge requires appropriate technological representations of linguistic structures, while Technological Knowledge is shaped by uneven digital infrastructure and institutional access (Naing & Wiedarti, 2023; Nisa & Aryni, 2023). Pedagogical Knowledge must balance diverse learning styles, cultural authenticity, and digital literacy demands (Syamdianita & Cahyono, 2021; Nga et al., 2025). These intersections complicate TCK, TPK, and PCK, particularly in representing complex linguistic

phenomena, supporting communicative learning, and assessing both language competence and digital literacy (Drajati et al., 2021; López et al., 2025).

Pre-service teacher education plays a critical role in shaping future instructional practices but faces challenges in integrating technology consistently and providing authentic learning experiences (Drajati et al., 2021; Inpeng & Nomnian, 2020; Nga et al., 2025). Studies indicate that technological self-efficacy develops progressively during teacher preparation, with identifiable stages of growth (Nisa & Aryni, 2023; Suarman et al., 2025). Meanwhile, language teaching technologies have evolved into comprehensive environments that support personalized learning, intercultural communication, and access to authentic materials, with effectiveness depending more on pedagogical alignment than on specific tools (Drajati et al., 2021; Levy & Stockwell, 2021; Naing & Wiedarti, 2023; Syamdianita & Cahyono, 2021). This literature review synthesizes key perspectives on TPACK components within the context of language education and educational technology, as summarized in Table 2.

Table 2. TPACK Components in the Synthesis of Indonesian Language Education

| Component | Definition | Source |
|--|--|--|
| Technological Knowledge (TK) | Knowledge of various technologies, encompassing the ability to operate specific tools, adapt to technological developments, understand their capabilities and limitations, and apply effective troubleshooting strategies beyond basic digital literacy. | (Mishra & Koehler, 2006; Suarman et al., 2025) |
| Pedagogical Knowledge (PK) | Understanding of learning theories, instructional strategies, classroom management, and assessment methods across disciplines, including second language acquisition theories, communicative language teaching, and strategies for developing language skills in language education. | (Chai et al., 2019; Mishra & Koehler, 2006) |
| Content Knowledge (CK) | Teacher's understanding of subject matter, encompassing facts, concepts theories, and procedures, including linguistics systems (phonology, morphology, syntax, semantics), pragmatics, sociolinguistic variation, and cultural contexts in language education. | (König et al., 2021) |
| Pedagogical Content Knowledge (PCK) | The transformation of subject matter knowledge into pedagogically effective forms adaptable to diverse learners, including effective presentation of language concepts, anticipation of learning challenges, and appropriate instructional sequencing. | (Chai et al., 2019; López et al., 2025) |
| Technological Content Knowledge (TCK) | Understanding the reciprocal relationship between technology and content, including how digital tools represents linguistic concepts, provide access to authentic materials, and support language analysis in language education. | (Drajati et al., 2021; Mishra & Koehler, 2006) |
| Technological Pedagogical Knowledge (TPK) | Comprehending how instructional methods and learning process evolve through technology integration, including the use of digital tools to support instructional approaches, enhance assessment, and foster engaging learning environments in language education. | (Drajati et al., 2021; Mishra & Koehler, 2006) |
| TPACK Integration | The integration of TPACK into a cohesive, holistic framework for effective technology, enhanced teaching, emphasizing the transformative and contextual interaction of technological, pedagogical, and content knowledge rather than their isolated application. | (Mishra & Koehler, 2006; Naing & Wiedarti, 2023) |

Based on the referenced table, it can be interpreted that technological, pedagogical, and content knowledge form an integrated framework that guides effective technology-enhanced instruction. This framework extends beyond simply adding technological skills to existing pedagogical content knowledge; rather, it involves a transformative understanding of how these knowledge domains interact within specific teaching contexts (Alam et al., 2024; Nisa & Aryni, 2023).

2. METHODS

2.1 Research Design

This study employs a quantitative approach to comprehensively assess the TPACK competencies of pre-service Indonesian language teachers. A survey method is utilized to collect quantitative data from the entire population, consisting of pre-service Indonesian language teacher students at Universitas PGRI Sumatera Barat. A quantitative-only approach was selected to establish baseline TPACK competency levels across 133 pre-service Indonesian language teachers and identify patterns among demographic variables. This methodology enabled standardized measurement of TPACK proficiency across groups (gender, academic levels, technology usage duration) while facilitating the identification of optimal developmental windows through systematic analysis of mean scores.

2.2 Participants

This study involved 133 prospective Indonesian language teachers who had completed microteaching courses. The participants were selected from students majoring in Indonesian language education and regional literature at Universitas PGRI Sumatera Barat. A detailed profile of the pre-service teacher participants is presented in Table 3.

Table 3. Demographic profile of Study Participants

| Variables | Category | N | Mean |
|------------------------------|-----------------------|-----|------|
| Gender | Male | 21 | 15.8 |
| | Female | 112 | 84.2 |
| Duration of using technology | 1-2 years | 10 | 7.6 |
| | 2-3 years | 17 | 12.8 |
| | 3-4 years | 28 | 21 |
| | 4-5 years | 28 | 21 |
| | >5 years | 50 | 37.6 |
| College level | Second years students | 36 | 27 |
| | Thirds years students | 40 | 30.1 |
| | Final years students | 57 | 42.9 |

Based on Table 3, it is evident that female participants constituted a greater proportion of the sample compared to male participants. Furthermore, the distribution duration of using technology was found to be relatively uniform across categories. Similarly, the distribution of college level representation demonstrated comparable uniformity, with participants being fairly evenly distributed across the various college levels.

2.3 Instrumentation

In this study, a TPACK survey instrument previously developed by Wijayanto et al. (2023) was employed, which was adapted to assess the capabilities of pre-service Indonesian Language teachers. This instrument comprises two sections: demographic indicators and TPACK indicators, with the latter consisting of content specific to the Indonesian Language field (CK, PK, PCK, and TPACK) and content specific to technology utilization (TK, TCK, TPK, TPACK). The demographic section contains 5 items, while the TPACK section encompasses 45 items. Participant responses were recorded on a 4-point Likert scale (1: I have no knowledge, 2: I have limited knowledge, 3: I am knowledgeable, 4: I am highly knowledgeable). This instrument underwent pilot testing to determine its validity and reliability. Based on the instrument trial analysis, Cronbach's alpha values ranging from 0.89 to 0.92 were obtained. These values demonstrate that the developed TPACK instrument falls within the valid and reliable category. Moreover, the instrument underwent validation by specialists in educational assessment, who confirmed its appropriateness for application. Based on participant scores across TPACK indicators, competency levels were classified using the following categorical framework.

Table 4. Competency Category TPACK

| No | Category Point | Competency |
|----|----------------|----------------|
| 1 | 1.00 - 2.00 | Low TPACK |
| 2 | 2.01 - 3.00 | Moderate TPACK |
| 3 | 3.01 - 4.00 | High TPACK |

2.4 Data Collection Procedure

The study was carried out employing a survey approach within the period of November 2024 and January 2025. Data collection was carried out through a Google Form, which was distributed across various student WhatsApp groups and monitored by lecturers who had previously guided them in the course. Participants voluntarily responded to the questions provided in the Google Form. At the beginning of the survey, they received clear instructions on how to complete the questionnaire. To ensure the integrity of the study, participants' responses were kept confidential to prevent potential conflicts of interest.

2.5 Ethical Consideration

This research received ethical approval from the Institute for Research and Community Service (LPPM) at Universitas PGRI Sumatra Barat under approval number 092/UPGRISBA-LPPM/PN/VI/2025.

2.6 Data analysis

This study employed a systematic quantitative approach to examine the TPACK competencies and preservice Indonesia language teachers' pedagogical experiences. Exploratory descriptive statistics were used to analyse the survey and assessment data, with means and standard deviations calculated to determine proficiency levels across TPACK domains.

3. FINDINGS AND DISCUSSION

The empirical analysis of technological engagement across demographic variables reveals complex relationships among gender, duration of technology use, and academic level. Drawing on 45 measurement points, the data highlight variations in engagement patterns related to user experience, academic progression, and technological adaptation across different user groups.

3.1 Technological Knowledge (TK)

The results of the descriptive data analysis regarding technological knowledge indicators based on gender, duration of technology use, and collegiate level are presented in Figure 1. Based on the data, several notable patterns emerge across demographic categories, focusing on gender differences, technology usage duration, and college-level variations. Male respondents consistently scored higher than females (2.92 vs. 2.65), indicating a gender-based response disparity. Regarding technology usage, users with 1–2 years of experience had the lowest average score (2.30), followed by those with 2–3 years (2.40). Scores increased for users with 3–4, 4–5, and over 5 years of experience, all averaging 2.78, suggesting a plateau effect at higher proficiency levels. College-level analysis shows varied trends: second-year students scored the highest (2.82), followed by final-year students (2.69), while third-year students had the lowest (2.59). This non-linear pattern implies no direct correlation between academic level and the measured variables. For more details, see Figure 1.

3.2 Pedagogical Knowledge

The results of the descriptive data analysis regarding pedagogical knowledge indicators based on gender, duration of technology use, and collegiate level are presented in Figure 2. The data provides an overview of responses across demographic variables, including gender, technology usage duration,

and academic level. This analysis explores patterns and relationships within these categories. Male respondents show slightly higher average scores ($M = 2.84$) than females ($M = 2.75$), indicating potential gender-based differences in technological engagement or perception. A clear trend emerges in technology usage duration. Respondents with 1–2 years of experience report the lowest mean scores ($M = 2.33$), followed by those with 2–3 years ($M = 2.48$). Notably, scores increase significantly among users with 3–4 years of experience ($M = 2.98$) and remain stable for those with 4–5 years ($M = 2.97$). However, a slight decline occurs in users with over five years of experience ($M = 2.71$), suggesting a plateau effect in long-term engagement. Academic level analysis reveals distinct patterns. Second-year students score highest ($M = 2.91$), followed by final-year students ($M = 2.85$), while third-year students score lower ($M = 2.51$). This non-linear trend suggests that academic progression does not necessarily enhance technological proficiency or engagement. A visual representation is provided in Figure 2.

3.3 Content Knowledge

The results of the descriptive data analysis regarding content knowledge indicators based on gender, duration of technology use, and collegiate level are presented in Figure 3. The data reveals distinct patterns in mean scores between male and female respondents. Males consistently scored higher ($M = 2.86$) than females ($M = 2.73$). While moderate, this gender-based difference suggests potential variations in technological engagement or perception. A clear progression emerges across different durations of technology use. The lowest scores appear in users with 1–2 years of experience ($M = 2.20$), increasing significantly in the 2–3-year group ($M = 2.55$). Scores peak at 3–4 years ($M = 2.87$) before slightly declining in the 4–5-year ($M = 2.85$) and over-5-year categories ($M = 2.80$). This pattern suggests optimal engagement around the 3–4-year mark. Variations also appear across academic levels. Second-year students scored highest ($M = 2.95$), followed by final-year students ($M = 2.72$), while third-year students had the lowest scores ($M = 2.62$). This non-linear trend indicates that academic progression does not directly correlate with the measured variables. A visual representation is provided in Figure 3.

3.4 Technological Pedagogical Knowledge

The results of the descriptive data analysis regarding technological pedagogical knowledge indicators based on gender, duration of technology use, and collegiate level are presented in Figure 4. The data reveals subtle yet meaningful gender differences in response patterns. Male respondents scored slightly higher ($M = 2.83$) than females ($M = 2.79$), indicating generally balanced technological engagement despite minor variations in specific items. A distinct trend emerges in technology usage duration. Scores increase from novice (1–2 years, $M = 2.17$) to early intermediate users (2–3 years, $M = 2.54$), peaking at the advanced stage (3–4 years, $M = 3.07$). Expert users (4–5 years, $M = 2.96$) maintain high scores, while long-term users (>5 years, $M = 2.77$) show a slight decline. This suggests optimal engagement occurs around 3–4 years, followed by a plateau effect. Academic level analysis reveals notable variations: Second-year students scored the highest ($M = 2.98$), followed by final-year students ($M = 2.87$), while third-year students had the lowest scores ($M = 2.54$). This non-linear trend suggests academic progression does not directly correlate with technological engagement or proficiency. A visual representation is provided in Figure 4.

3.5 Technological Content Knowledge

The results of the descriptive data analysis regarding technological content knowledge indicators based on gender, duration of technology use, and collegiate level are presented in Figure 5. A systematic analysis of gender-related patterns reveals consistent differences between male and female respondents. Males scored higher on average ($M = 2.86$) than females ($M = 2.73$). Though modest, this gap suggests differences in technological engagement or response patterns. The data also indicate a progression across experience levels: Initial users (1–2 years) had the lowest scores ($M = 2.18$), early-stage users (2–3 years) showed improvement ($M = 2.47$), intermediate users (3–4 years) peaked ($M =$

3.00), advanced users (4–5 years) maintained high performance ($M = 2.88$), while long-term users (>5 years) experienced a slight decline ($M = 2.74$). This trend suggests optimal engagement at 3–4 years, followed by gradual decline. Similarly, academic level influences scores: Second-year students performed highest ($M = 2.92$), final-year students remained strong ($M = 2.82$), while third-year students scored lowest ($M = 2.49$). This non-linear pattern indicates that academic progression does not directly correlate with technological engagement. A visual representation is provided in Figure 5.

3.6 Pedagogical Content Knowledge

The results of the descriptive data analysis regarding pedagogical content knowledge indicators based on gender, duration of technology use, and collegiate level are presented in Figure 6. The data reveals systematic variations between gender groups in their response patterns. Male respondents consistently demonstrated higher mean scores ($M = 2.81$) compared to female respondents ($M = 2.66$). This persistent gender differential suggests underlying variations in technological engagement or response tendencies between male and female participants. A distinct pattern emerges across different experience levels: Novice users (1-2 years) exhibited notably low scores ($M = 2.05$), Early-stage users (2-3 years) showed modest improvement ($M = 2.38$), Advanced users (3-4 years) demonstrated significant enhancement ($M = 2.88$), Expert users (4-5 years) achieved peak performance ($M = 2.89$), Long-term users (>5 years) indicated slight decline ($M = 2.68$). This progression suggests an optimal engagement period occurring between 3-5 years of technology usage, with a subsequent plateau effect. The examination across academic levels reveals intriguing patterns: Second-year students consistently achieved the highest scores ($M = 2.86$), Final-year students demonstrated moderate performance ($M = 2.68$), Third-year students showed comparatively lower scores ($M = 2.53$). To facilitate understanding of this explanation, a visual representation is shown in Figure 6.

3.7 Technological Pedagogical and Content Knowledge

The results of the descriptive data analysis regarding TPACK indicators based on gender, duration of technology use, and collegiate level are presented in Figure 7. The data present an interesting reversal of typical gender-based patterns, with female respondents demonstrating slightly higher mean scores ($M = 2.70$) compared to male respondents ($M = 2.60$). This unique gender distribution suggests potential shifts in technological engagement patterns between gender groups. The analysis reveals a clear progression across experience levels: Initial users (1-2 years) showed the lowest mean scores ($M = 2.15$), Early-stage users (2-3 years) demonstrated modest improvement ($M = 2.38$), Intermediate users (3-4 years) achieved peak scores ($M = 2.92$), Advanced users (4-5 years) maintained high performance ($M = 2.90$), Long-term users (>5 years) indicated a decline ($M = 2.63$). This pattern suggests an optimal engagement period occurring during the 3–4-year usage range, followed by a gradual decline in subsequent experience levels. Analysis across academic levels reveals distinctive patterns: Second-year students consistently achieved the highest scores ($M = 2.81$), Final-year students demonstrated strong performance ($M = 2.74$), Third-year students showed notably lower scores ($M = 2.48$). To facilitate understanding of this explanation, a visual representation is shown in Figure 7.

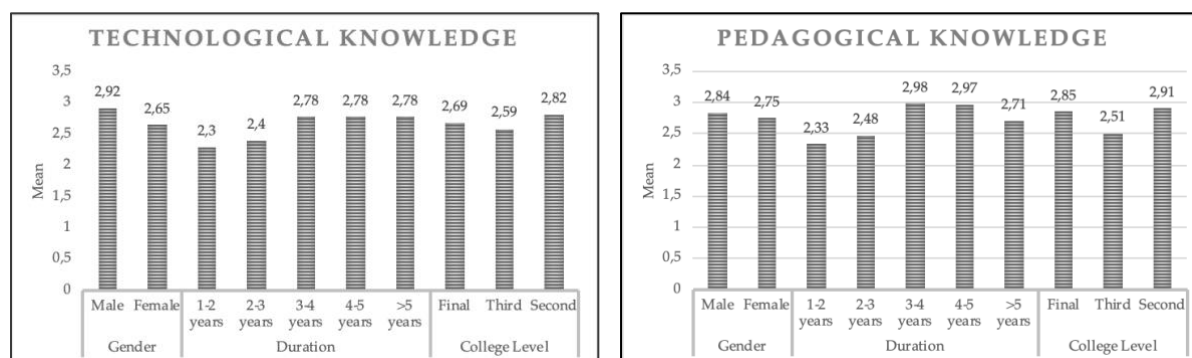


Figure 1. Mean Technological Knowledge Ability of Pre-service Teacher

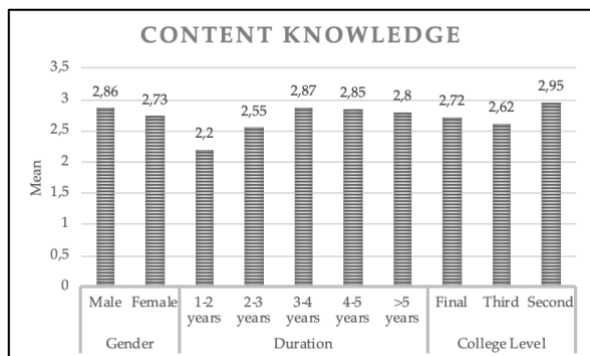


Figure 3. Mean Content Knowledge Ability of Pre-service Teacher

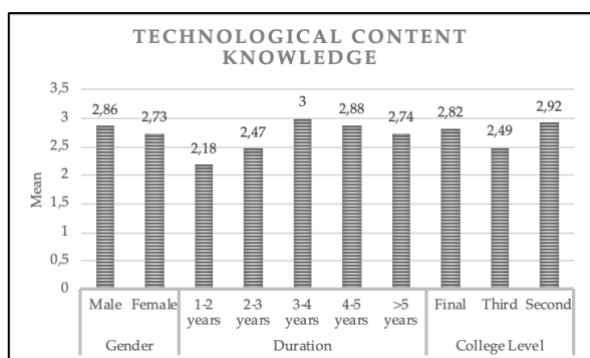


Figure 5. Mean Technological Content Knowledge Ability of Pre-service Teacher

Figure 2. Mean Pedagogical Knowledge Ability of Pre-service Teacher

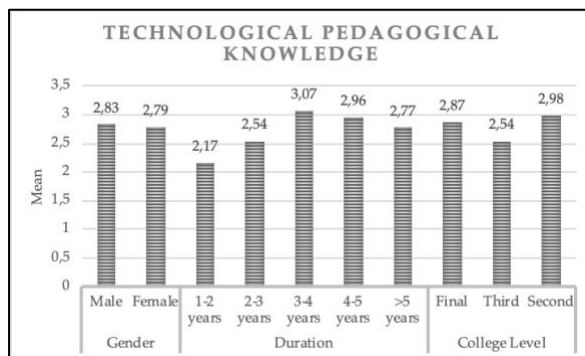


Figure 4. Mean Technological Pedagogical Knowledge Ability of Pre-service Teacher

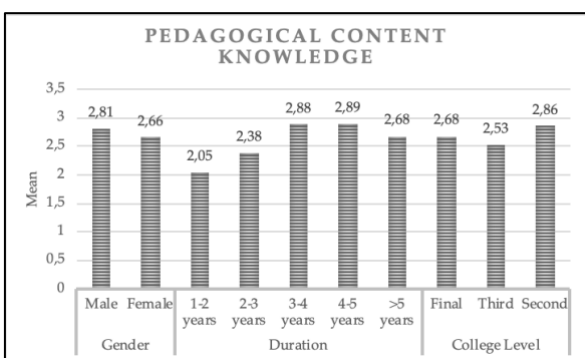


Figure 6. Mean Pedagogical Content Knowledge Ability of Pre-service Teacher

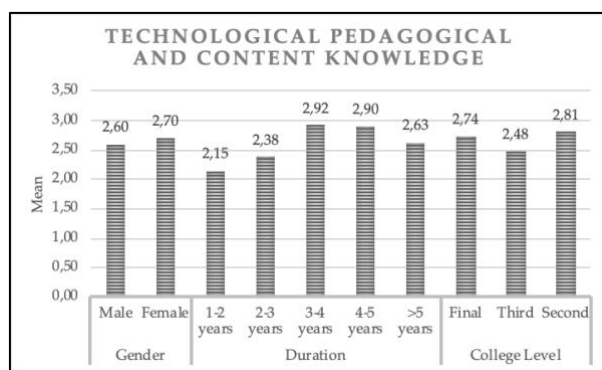


Figure 7. Mean Technological Pedagogical and Content Knowledge Ability of Pre-service Teacher

Based on the preceding analysis of TPACK indicators across demographic variables, additional analyses were conducted to establish the composite mean scores for individual TPACK components and the integrated TPACK proficiency level. For more details, see the following table 5.

Table 5. Average Total TPACK

| TPACK Components | Average Score | Category | Level Distribution |
|---|---------------|----------|------------------------|
| Technological Knowledge (TK) | 2.67 | Moderate | 100% Moderate |
| Pedagogical Knowledge (PK) | 2.73 | Moderate | 100% Moderate |
| Content Knowledge (CK) | 2.72 | Moderate | 100% Moderate |
| Technological Pedagogical Knowledge (TPK) | 2.75 | Moderate | 90% Moderate, 10% High |
| Technological Content Knowledge (TCK) | 2.71 | Moderate | 100% Moderate |
| Pedagogical Content Knowledge (PCK) | 2.64 | Moderate | 100% Moderate |
| TPACK Integration | 2.63 | Moderate | 100% Moderate |
| Average Total TPACK | 2.69 | Moderate | 67.25% |

(Source: Authors Analysis, 2025)

Discussion

Technological Knowledge (TK)

The aggregated data show moderate scores across demographic categories (2.30–2.92), indicating generally balanced response patterns with variations among subgroups. These findings align with digital native theory while challenging assumptions of uniform technological proficiency (Smith et al., 2020), and support socio-cultural perspectives that emphasize the influence of social context and individual preferences on technology engagement (Hennessy et al., 2022). The results also resonate with Rogers' diffusion of innovations theory by highlighting the role of demographic factors in adoption patterns (Alam et al., 2024), and contribute to discussions on digital divide 2.0, underscoring disparities in the quality of technological engagement despite widespread access (Li et al., 2024). This is consistent with digital literacy frameworks that view technological competence as a multifaceted construct shaped by exposure, experience, and educational context (Chai et al., 2019; Seufert et al., 2021).

Pedagogical Knowledge (PK)

The overall means indicate higher engagement among intermediate-duration technology users (3–4 years) and second-year students, suggesting optimal points in both technology use and academic progression. The stronger performance of second-year students is linked to curriculum structures in Indonesian teacher education, where foundational pedagogical coursework is completed and educational technology is formally introduced, enabling effective TPACK development before the increased cognitive demands of advanced practicum and thesis work (Drajati et al., 2021; Nga et al., 2025; Nisa & Aryni, 2023; López et al., 2025). At this stage, students possess sufficient theoretical grounding and cognitive flexibility, aligning with Vygotsky's Zone of Proximal Development, while later-year students may experience cognitive overload due to heightened academic pressures (Drajati et al., 2021).

These patterns reveal complex interactions between demographic variables and technology engagement, supporting digital natives theory while challenging assumptions of linear proficiency gains with prolonged exposure (Smith et al., 2020). The engagement peak among intermediate users corresponds with Kolb's Experiential Learning Theory, indicating that optimal technology adoption emerges through experience and reflection rather than at initial exposure (Nga et al., 2025). This finding further reinforces developmental perspectives, suggesting technology integration is most effective at specific learning stages rather than increasing uniformly over time (Drajati et al., 2021; Hennessy et al., 2022; Nga et al., 2025; Syamdianita & Cahyono, 2021). The strong association between second-year students and higher technology engagement also aligns with Situated Learning Theory and Social Cognitive Theory, highlighting the roles of legitimate participation, self-efficacy, and environmental mastery (Yan et al., 2024; Täschner et al., 2025). However, these results diverge from Moore's Technology Adoption Lifecycle by suggesting that technology integration follows a context- and stage-dependent trajectory rather than a simple adoption curve (López et al., 2025; Tseng et al., 2022).

Content Knowledge (CK)

The results show that second-year students consistently achieved higher scores, with 3–4 years of technology use representing an optimal duration, indicating a “sweet spot” in academic progression and technology exposure. These patterns highlight the complex, non-linear interactions between demographic variables, academic level, and technology engagement. The superior performance of second-year students aligns with Vygotsky’s Zone of Proximal Development, suggesting optimal achievement at specific developmental stages (Bamalan, 2024), and is further explained by Anderson’s Adaptive Control of Thought theory, which describes the transition from declarative to procedural knowledge in skill acquisition (Wessel & Anderson, 2024). However, this trend challenges digital natives’ theory, which assumes more uniform technological competence across academic levels (Smith et al., 2020). The optimal 3–4-year duration of technology use corresponds with Kolb’s Experiential Learning Theory, emphasizing learning through cycles of experience and reflection rather than linear accumulation (Nga et al., 2025). This finding contrasts with Rogers’ Diffusion of Innovation theory, which predicts continuous improvement with increased exposure (Alam et al., 2024), and instead supports Lave and Wenger’s concept of legitimate peripheral participation, where technological proficiency develops through structured engagement within specific temporal contexts (Yan et al., 2024).

Technological Pedagogical Knowledge (TPK)

The results indicate optimal performance among users with 3–4 years of technology use and second-year students, suggesting convergence between experience duration and academic level in shaping technology engagement. These patterns reflect complex, non-linear interactions between demographic variables and engagement, with implications for educational technology implementation and targeted student support. The peak performance of users with 3–4 years of exposure aligns with Bandura’s Self-Efficacy Theory, which emphasizes mastery experiences as drivers of performance (Täschner et al., 2025), and with Dreyfus and Dreyfus’s Skills Acquisition Model, where peak performance often occurs at the proficient stage rather than through continuous accumulation of experience. However, this challenges the Technology Acceptance Model’s assumption of a linear relationship between experience and performance. Similarly, the higher performance of second-year students corresponds with Vygotsky’s Zone of Proximal Development, indicating an optimal balance between foundational knowledge and emerging expertise (Bamalan, 2024), and is supported by Situated Learning Theory, which highlights meaningful participation in learning communities (Yan et al., 2024). These findings diverge from Digital Natives theory, suggesting that technological proficiency depends more on developmental stages and exposure periods than on generational factors alone (Smith et al., 2020).

Technological Content Knowledge (TCK)

The aggregate means indicate that users with 3–4 years of technology use achieved consistently higher scores, second-year students maintained higher averages across most items, and male respondents showed more consistent scores than female respondents. These patterns reveal complex, non-linear relationships between demographic variables and technology engagement, suggesting that experience duration and academic level significantly shape response patterns. The identified optimal engagement points offer important implications for educational technology implementation and student support strategies. The optimal performance among intermediate-duration users aligns with Benner’s Novice to Expert Theory, which posits peak competence at the proficient stage rather than through continuous experience accumulation (Ozdemir, 2019; Seufert et al., 2021), and is reinforced by Growth Mindset Theory, emphasizing adaptive learning through sustained engagement (Dweck, 2006). However, these findings challenge the Technology Acceptance Model, which predicts a more linear relationship between experience and performance (Legramante et al., 2023). The observed gender-based consistency and higher performance of second-year students correspond with Social

Cognitive Career Theory, highlighting interactions between personal and environmental factors in shaping performance (Hennessy et al., 2022; Täschner et al., 2025). While male respondents' consistency may reflect socially shaped confidence in technology use (Nisa & Aryni, 2023), this pattern contrasts with Feminist Technology Theory, suggesting the need for further investigation into the socio-cultural factors underlying gender differences in technology engagement (König et al., 2021; Sun et al., 2024).

Pedagogical Content Knowledge (PCK)

The aggregate means show optimal performance among users with 4–5 years of technology use and second-year students, indicating a complex interaction between experience duration and academic progression. The peak performance at 4–5 years aligns with Bandura's Social Cognitive Theory, emphasizing mastery experiences and self-efficacy (Täschner et al., 2025), and is supported by Anderson's ACT-R theory, which explains skill development through progressive proceduralization (Wessel & Anderson, 2024). However, this pattern challenges Digital Natives theory, which assumes more uniform performance across experience levels (Smith et al., 2020). Similarly, the strong performance of second-year students corresponds with Vygotsky's Zone of Proximal Development, reflecting an optimal balance between foundational knowledge and emerging expertise (Bamalan, 2024), and is reinforced by Situated Learning Theory, which highlights legitimate participation in learning communities (Yan et al., 2024). These findings diverge from Rogers' Diffusion of Innovation theory by suggesting that technological proficiency is shaped by specific developmental stages rather than a continuous adoption curve (Alam et al., 2024).

Integrated Technological Pedagogical and Content Knowledge (TPACK)

The results indicate optimal technological engagement among participants with 3–4 years of technology use and second-year students, reflecting complex interactions between experience duration and academic progression. The peak performance of intermediate-duration users aligns with Kolb's Experiential Learning Theory, which emphasizes learning through cycles of experience and reflection (Nga et al., 2025), and with Dreyfus and Dreyfus's Model of Skill Acquisition, where peak efficiency often occurs at the proficient stage rather than through linear accumulation of experience (Dreyfus & Dreyfus, 1986). These findings challenge the Technology Acceptance Model, which assumes a linear relationship between experience and performance (Legramante et al., 2023).

Similarly, the superior performance of second-year students corresponds with Vygotsky's Zone of Proximal Development, indicating an optimal balance between foundational knowledge and emerging expertise at this academic stage (Bamalan, 2024), and is reinforced by Lave and Wenger's Communities of Practice framework (Yan et al., 2024). Collectively, these patterns contradict digital natives' theory and aspects of Rogers' Diffusion of Innovation theory by demonstrating that technological proficiency is shaped more by developmental stages and structured engagement than by generational factors or cumulative exposure (Smith et al., 2020). The observed demographic variations further highlight the multifaceted nature of TPACK development, where non-linear engagement patterns and gender-based consistency differences suggest socially mediated influences, aligning with Social Cognitive Career Theory while challenging linear assumptions of the Technology Acceptance Model.

4. CONCLUSION

In conclusion, this study found that the TPACK competence of pre-service Indonesian language teachers at Universitas PGRI Sumatera Barat is at a moderate level, with variations influenced by gender, duration of technology use, and academic level, and with evidence suggesting that TPACK development follows a non-linear trajectory, particularly showing optimal growth among second-year students and those with 3–4 years of technology experience. These findings highlight the need for teacher education programs to design structured and developmentally appropriate TPACK interventions to support more effective and sustainable technology integration in language teaching. However, this study is limited by its focus on a single institution and a relatively short data collection period, which may restrict the generalizability of the results. Therefore, future research is

recommended to involve a broader sample of pre-service teachers across multiple higher education institutions in Indonesia, employ longitudinal and mixed-methods approaches, and examine contextual factors such as curriculum design, institutional support, and academic culture to provide a more comprehensive understanding of TPACK development.

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