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Research Paper

Descriptive Analysis of Science Pre-Service Teachers' Technological, Pedagogical, and Content Knowledge (TPACK)

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Abstract

This study explores the integration of technology in Philippine teacher education with a focus on the distinctive context of Mindoro. Using the TPACK framework, this study assesses pre-service teachers' competence in integrating content, pedagogy, and technology into their instructional practices. Results show that the pre-service teacher population is largely young and female, with diverse income levels and specializations. Both pre-service teachers and cooperating teachers report strong development across TPACK domains, especially in Technological Knowledge. Income and specialization emerge as significant factors influencing competency levels, while age and gender show minimal effects. Differences between self-assessments and cooperating teacher evaluations highlight the need for more targeted training and curriculum improvements. Among the three specializations, Mathematics pre-service teachers rated themselves higher than their cooperating teachers did. In contrast, English and Science pre-service teachers received higher ratings from their cooperating teachers than from their own self-assessments. The study recommends refining admission policies, strengthening professional development programs, and enhancing curriculum content better to address competency gaps and support effective technology-enhanced teaching.

Keywords: *Pre-Service Teachers, TPACK Competencies, Technology Integration, Teacher Education, Mindoro Education, Mathematics Education*

INTRODUCTION

The integration of technology in education has become a global priority as schools increasingly recognize its role in improving accessibility, enriching instruction, and supporting inclusive and personalized learning. Digital tools now serve as essential components of modern classrooms, enabling differentiated instruction, blended learning, data-driven decision-making, and enhanced collaboration and communication—competencies associated with 21st-century learning. As educational systems move toward more flexible, technology-supported environments, teacher education programs must ensure that pre-service teachers (PSTs) are adequately prepared to integrate digital resources in meaningful, pedagogically sound ways.

In alignment with these global trends, the Philippine education system has institutionalized technology integration as a core teaching requirement. The Technological Pedagogical and Content Knowledge (TPACK) framework has gained prominence as a model for understanding how teachers interrelate three essential knowledge domains—content expertise, pedagogical skill, and technological proficiency—to design effective, technology-enhanced learning experiences.

Within the national context, TPACK aligns with the Philippine Professional Standards for Teachers (PPST), which emphasize technology as a professional competency across multiple indicators, including curriculum planning, diverse teaching strategies, assessment design, and professional engagement. Additionally, CHED Memorandum Orders and the MATATAG Curriculum reform highlight the crucial role of technology in delivering responsive, competency-based instruction that meets the needs of 21st-century Filipino learners.

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Although international and local studies consistently demonstrate the positive impact of TPACK on instructional quality, much of the existing research is situated in urban, well-resourced educational settings. These studies reveal increasing technological familiarity among teachers but also indicate ongoing challenges, including insufficient digital literacy, lack of confidence in using technology, and difficulty integrating digital tools into subject-area pedagogy. However, there is limited empirical evidence on how PSTs in geographically isolated and underserved regions—such as Oriental Mindoro—develop TPACK competencies within teacher education programs.

The Mindoro context presents unique challenges and opportunities. The island continues to experience intermittent electricity, inconsistent internet access, limited availability of digital devices, and scarce opportunities for sustained professional development in educational technology. Teacher education institutions (TEIs) across the island—though committed to strengthening technology integration—face constraints that may impact the quality of TPACK preparation.

PSTs often rely on personal devices and mobile internet, which vary significantly depending on socioeconomic status. Such contextual limitations may hinder their ability to apply theoretical TPACK concepts during practicum, especially when they are placed in schools that lack technological resources. These conditions highlight the importance of examining how PSTs on the island develop technological, pedagogical, and content-based competencies in real instructional settings.

Adding to this gap, many existing studies treat TPACK as a single construct rather than exploring the nuances within each domain, such as Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK), and their intersections (PCK, TCK, TPK). As a result, the literature provides limited insights into which specific TPACK areas PSTs excel in, which areas require more support, and how contextual factors shape these competencies. Such information is essential for designing targeted interventions, improving teacher preparation curricula, and ensuring that PSTs receive appropriate guidance during their internships.

This study specifically evaluates the TPACK competencies of Pre-Service Teachers (PSTs) in the Mindoro context through the following objectives:

1. Identify the profile of the pre-service teachers.
2. Assess the teaching competencies developed among pre-service teachers in TPACK domains;
3. Measure the significant difference in the development of teaching competencies among pre-service teachers.

Grounding the curriculum in this data ensures that future teachers are prepared for technology-enhanced instruction, even in resource-limited settings, making teacher education more equitable and context-responsive.

LITERATURE REVIEW

Technological Pedagogical and Content Knowledge (TPACK) in Teacher Education

The integration of technology in teacher education is no longer optional but a baseline requirement for 21st-century instruction. At the center of this movement is the Technological Pedagogical and Content Knowledge (TPACK) framework. While Mishra and Koehler (2006) originally conceptualized TPACK as the synthesis of content (CK), pedagogy (PK), and technology (TK), subsequent scholarship has shifted from merely defining these domains to analyzing their "complex interactions" (Karageorgakis, 2017). Santos and Castro (2022) argue that the true value of the framework lies in its seven interrelated components; however, a critical tension exists in how these components are actually mastered.

Current literature presents a dual perspective on how TPACK is acquired. On the one hand, scholars such as McGraw-Hill Canada (2019) and Kurt (2023) emphasize the structural intersection

of knowledge, suggesting that mastery comes from fluidly blending domains, such as aligning a science simulation with specific content goals. Conversely, Stephens (2020) and Koh et al. (2015) argue that TPACK is experiential and iterative, proposing that theoretical knowledge is secondary to real-world classroom practice and sustained reflection. This debate suggests that while the framework is theoretically sound, its practical application remains a moving target for many educators.

Furthermore, a significant gap appears when comparing global TPACK standards with local realities. While Lyublinskaya and Kaplon-Schilis (2022) showcase the success of TPACK in fostering critical thinking, Bibi et al. (2017) provide a necessary counter-argument: proficiency is not just about teacher skill, but is heavily "gatekept" by institutional support and ICT access. This contrast is even more pronounced in recent international studies. Castéra et al. (2020) and Cui and Zhang (2022) highlight a "digital divide" in which PSTs in urban, resource-rich environments tend to demonstrate higher TPACK levels than their rural counterparts.

These disparities suggest that TPACK is not a "one-size-fits-all" model. The literature reveals a consistent pattern: development is uneven and highly dependent on geographical and socioeconomic contexts. This is especially critical in the Philippine setting, where resource variability creates a unique challenge. While Mishra (2019) affirms the benefits of TPACK-focused training, the success of such programs in developing countries may be limited if they do not account for these infrastructure constraints. Therefore, there is an urgent need to move beyond general TPACK descriptions and investigate how specific local contexts, such as those in Mindoro, shape the actual development of these competencies.

TPACK Competencies of Pre-Service Teachers (PSTs)

The transition from theoretical coursework to practical application during teaching practicums represents a critical juncture for Pre-service Teachers (PSTs). While field experiences are intended to be the primary space for shaping professional identity and refining instructional strategies (Lawson et al., 2015), a significant tension exists between theoretical preparation and classroom reality.

For instance, while Santos and Castro (2022) argue that structured TPACK programs effectively equip PSTs to select digital tools and design learner-centered lessons, other researchers point to a persistent "competency gap." Rodriguez and Abocejo (2018) specifically highlight a misalignment where PSTs' high self-perceived confidence does not always translate into actual teaching performance. This discrepancy suggests that theoretical mastery of TPACK domains often falters when faced with the practical complexities of classroom management and pedagogical execution (Mufidah, 2019; Miranda, 2019).

This challenge is further complicated by the debate over whether PST success is driven more by individual mastery or environmental factors. Scholars like Zulkharnain et al. (2017) and Nuangchalerm (2020) emphasize that contextual factors—such as access to high-end software and the modeling of technology by cooperating teachers—are the most decisive drivers of growth. This perspective implies that a PST's competence is largely a product of their host school's infrastructure.

Conversely, Brown (2015) and Makamure and Jita (2018) argue that even in technology-rich environments, insufficient Content Knowledge (CK) remains the ultimate bottleneck. They contend that a weak foundational grasp of the subject matter, particularly in STEM, restricts a PST's ability to move beyond basic tool use to construct deep, problem-centered tasks. This suggests that technology integration cannot compensate for a lack of content mastery, regardless of the tools available.

Finally, the literature reveals a significant mentorship paradox that threatens the equitable

development of PSTs. While field-based learning and community-based experiences are celebrated as the strongest drivers of TPACK (Hamilton & Van Duinen, 2019; Danyluk & Burns, 2016), these benefits are often inaccessible in resource-constrained or rural settings. In these underserved communities, the lack of digital infrastructure is often compounded by limited mentorship and insufficient feedback (Mohan et al., 2017).

This creates a cycle where the PSTs who most need professional scaffolding are placed in environments that can least afford to provide it. Ultimately, the development of TPACK is not a uniform process but a complex interaction of individual, institutional, and geographical factors. Addressing these systemic disparities is essential for ensuring that all future educators are prepared to deliver effective, technology-enhanced instruction across diverse and often unequal classroom settings.

Synthesis and Research Gap

The collective body of literature underscores that the TPACK framework is the primary driver of pre-service teachers' (PSTs) pedagogical adaptability and instructional effectiveness in the digital age. Research consistently affirms that robust TPACK mastery enables PSTs to move beyond superficial tool use, fostering student-centered environments characterized by collaboration and higher-order thinking (Sabire, 2022; Koh et al., 2015). However, a critical synthesis of these findings reveals a contextual bias in current scholarship.

While mentorship and practice-based learning are recognized as essential for aligning perceived and actual competencies (Mercado & Ibarra, 2019), the majority of these success stories are documented in technologically advanced or resource-rich urban settings. This creates a significant knowledge gap regarding how PSTs navigate the same TPACK expectations in low-resource environments, such as rural Philippine schools, where infrastructure often fails to meet theoretical standards.

Furthermore, a cultural disconnect persists within localized research. Although international studies provide a roadmap for effective technology integration, there remains a scarcity of evidence focusing on how TPACK is enacted within the specific nuances of Indigenous, multilingual, or culturally diverse Philippine classrooms. This lack of localized data suggests that existing teacher education models may not be fully context-responsive. This is compounded by the persistent discrepancy between PSTs' self-assessments and the more critical evaluations provided by cooperating teachers. Such a gap suggests that PSTs may be internalizing the vocabulary of technology integration without fully mastering the application required to navigate complex, real-world classroom dynamics.

Given these limitations, investigating TPACK development within the unique multicultural and resource-diverse landscape of Oriental Mindoro is a necessity for the field. This study addresses these voids by investigating how PSTs develop, perceive, and enact their competencies within provincial teacher education institutions. By shifting the focus from global ideals to local realities, the findings provide an empirical foundation for designing teacher preparation programs that are not only evidence-based but also culturally responsive and resource-sensitive. Ultimately, this research seeks to redefine PST readiness by ensuring that technology-enhanced instruction is achievable and inclusive, even in the most challenging educational settings.

RESEARCH METHOD

This chapter presents the research methodology, detailing the population and sample, sampling procedures, respondent characteristics, research instruments, instrument validation, reliability testing, data collection procedures, and statistical techniques used for data analysis. Each component is described with clarity and specificity to allow full replication of the study. This study

utilized a descriptive research design to gather quantitative data on the profiles of pre-service teachers (PSTs) and their self-assessed competencies across the TPACK domains.

As defined by Aggarwal and Ranganathan (2019), descriptive research seeks to portray the distribution and characteristics of selected variables without establishing causal relationships. In this study, the variables examined include the PSTs' demographic profiles—age, gender, family monthly income, and area of specialization—as well as their perceived growth in Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK), Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), and Technological Pedagogical Knowledge (TPK).

The population consisted of graduating Science PSTs enrolled in the Teaching Internship course during the second semester of the 2023–2024 academic year. These PSTs were drawn from four public higher education institutions (HEIs) on the island of Mindoro. These institutions were selected because they represent the complete roster of State Universities and Colleges (SUCs) and Local Colleges (LUCs) offering teacher education programs in the province.

A total enumeration approach was employed to include all Science PSTs from the identified HEIs. Using Cochran's formula at a 0.05 significance level, the required sample size for Science PSTs was computed to be 64. Table 1 presents the population distribution and the corresponding sample sizes across the four Teacher Education Institutions (TEIs). This sampling framework ensured that the study adequately represented the Science PST population and provided sufficient statistical power for data analysis.

Table 1. Frequency Distribution of Science PST-Respondents According to Institution

TEI	Population	Sample Size
1	25	21
2	16	13
3	26	22
4	10	8
Total	**77**	**64**

A stratified random sampling procedure was employed, with each institution constituting a separate stratum. Respondents were randomly selected from each stratum using PST lists provided by the institutions. Proportional allocation was applied to determine the sample size for each institution. Based on this procedure, the resulting sample distribution was as follows: TEI 1 (21 respondents), TEI 2 (13 respondents), TEI 3 (22 respondents), and TEI 4 (8 respondents).

Participants were graduating Science PSTs deployed to Department of Education secondary schools in Oriental Mindoro and Calapan City for practical teaching experience. Respondents were enrolled in the Teaching Internship course and represented diverse backgrounds in terms of gender, age, family income, and specialization.

A researcher-developed survey questionnaire served as the primary data collection instrument. It consisted of two parts:

1. Part I – Respondent Profiles**:** Collected information on age, gender, family income, and area of specialization.
2. Part II – TPACK Competencies: Measured self-assessed growth in seven TPACK domains using a standardized TPACK survey adapted from Schmidt et al. (2009) and aligned with the Philippine Professional Standards for Teachers (PPST). Responses were recorded using a 5-point Likert scale, as shown in Table 2**.**

Table 2. Scaling and Quantification of Responses

Numerical Scale	Statistical Scale	Interpretation
5	4.50–5.00	Strongly Agree
4	3.50–4.49	Agree
3	2.50–3.49	Fairly Agree
2	1.50–2.49	Disagree
1	1.00–1.49	Strongly Disagree

The instrument underwent expert validation by seven Science Education experts holding doctoral degrees and with at least ten years of experience in PST instruction. Experts provided feedback on clarity, content accuracy, and relevance, which were incorporated into the final version.

Table 3. Frequency Distribution of Validators

Field of Specialization	Frequency
Science	7
Total	**7**

The questionnaire was pilot-tested with 31 non-respondents from a private, non-sectarian higher education institution in Bongabong, Oriental Mindoro. Cronbach's Alpha was used to determine internal consistency.

Table 4. Cronbach's Alpha Interpretation

Cronbach's Alpha (α)	Internal Consistency
$\alpha \geq 0.9$	Excellent
$0.9 > \alpha \geq 0.8$	Good
$0.8 > \alpha \geq 0.7$	Acceptable
$0.7 > \alpha \geq 0.6$	Questionable
$0.6 > \alpha \geq 0.5$	Poor
$\alpha < 0.5$	Unacceptable

Table 5. Reliability of the TPACK Instrument for Science PSTs

Domain	Cronbach's Alpha	Description	Interpretation
Content Knowledge	0.8565	Good	Reliable
Pedagogical Knowledge	0.8401	Good	Reliable
Technological Knowledge	0.9286	Excellent	Reliable
Pedagogical-Content Knowledge	0.8570	Good	Reliable
Technological-Content Knowledge	0.8322	Good	Reliable
Technological-Pedagogical Knowledge	0.8853	Good	Reliable

Before data collection, formal letters requesting participation were submitted to the heads of each Teacher Education Institution (TEI), accompanied by endorsements from the Research Adviser and the Program Chairperson. These letters outlined the study's objectives and procedures, ensuring transparency and institutional support. Upon receiving approval, ethical clearance was obtained from the University Ethics Committee to ensure the study adhered to ethical research standards. This process guaranteed the protection of participants' rights, confidentiality, and overall well-being throughout the research.

The survey was then administered in coordination with the School Heads at the PSTs' respective assigned schools. Prior to participation, respondents were fully briefed on the study's purpose, procedures, potential risks, and the voluntary nature of involvement. Informed consent was obtained, and participants were assured that they could withdraw at any time without consequences. Personal identifiers were removed to maintain anonymity, and all collected data were securely stored, accessible only to the researcher, ensuring the integrity and confidentiality of the research process.

Data were analyzed using both descriptive and inferential statistics. Descriptive statistics included frequency counts, percentages, median values, and the 25th and 75th percentiles to summarize the distribution of TPACK scores. For inferential analysis, the Kruskal–Wallis test was used to assess whether TPACK scores differed significantly across PST profiles. This non-parametric test was selected because the data did not meet the assumptions of normality and homogeneity of variance.

FINDINGS AND DISCUSSION

Profile of Science Pre-Service Teachers

Table 6. Frequency and Percentage Distribution of Science Pre-service Teacher-Respondents by Age

Age Group	Frequency	Percentage (%)
Below 25	60	94
25 – 34	4	6
TOTAL	**64**	**100**

The demographic analysis of Science PSTs in Mindoro reveals a predominantly youthful cohort, with 94% of respondents under 25. This distribution reflects a standard academic progression from the K–12 system to tertiary education, mirroring the youthful PST populations documented in international contexts such as China (Yang et al., 2022). Historically, being a "digital native" or belonging to a younger age bracket has often been associated with greater technological confidence; however, a critical divergence emerges in this local context.

While Yang et al. (2022) observed that younger PSTs typically report higher readiness due to their early exposure to digital tools, the current findings suggest that the teacher education programs in Mindoro facilitate a uniform training approach. This indicates that institutional scaffolding effectively neutralizes age as a factor in professional development, ensuring that competency remains consistent regardless of whether a candidate is a fresh high school graduate or an older student. Such uniformity contrasts with the age-dependent patterns often cited in the global literature, demonstrating that standardized pedagogical training can bridge the generational gap in teacher preparation.

Table 7. Frequency and Percentage Distribution of Science Pre-service Teacher-Respondents by Gender

Gender	Frequency	Percentage (%)
Male	12	19
Female	48	75
Non-Binary	4	6
Total	**64**	**100**

The gender distribution of Science PSTs in Mindoro reflects a significant overrepresentation of females, who constitute 75% of the total sample. Male respondents account for 19%, while 6% of the cohort identify as part of the Non-Binary community. These figures illuminate a persistent gender gap within the local pre-service teaching population, underscoring the entrenched societal norms that continue to steer more women toward the education sector.

Historically, this trend aligns with the feminization of the teaching profession, often culturally framed as an extension of maternal and domestic roles (Aslan, 2015). The underrepresentation of males suggests that institutional or social barriers may still deter men from pursuing higher education, particularly in provincial contexts where traditional leadership and authority roles are often reserved for males outside the classroom.

Beyond the male-female binary, the presence of Non-Binary individuals, though smaller in frequency, highlights a critical need for inclusive and supportive teacher education environments. This demographic diversity indicates that the teaching profession is gradually becoming a space for varied identities, requiring programs to move beyond traditional gender stereotypes.

As noted by Aslan (2015), pre-service teachers often enter the field with pre-existing biases that associate women with nurturing and household responsibilities, while men are associated with protection and strength. The current data challenges these stereotypes by integrating a more diverse workforce into the pedagogical pipeline. Ensuring that all identities, regardless of where they fall on the gender spectrum, feel valued throughout their professional training is essential to developing a teaching force that reflects the multicultural, diverse reality of the modern Filipino classroom.

Table 8. Frequency and Percentage Distribution of Science Pre-service Teacher-Respondents by Monthly Family Income

Monthly Family Income	Frequency	Percentage (%)
Less than PhP 10,000	38	59
PhP 10,000-PhP 20,000	18	28
More than PhP 20,000	5	8
Prefer not to say	3	5
Total	**64**	**100**

The socioeconomic profile of the respondents indicates a significant concentration of Science PSTs within the lower-income brackets. Specifically, 59% of the cohort report a monthly family income of less than PhP 10,000, while 28% fall within the PhP 10,000-20,000 range. A smaller segment of the population, representing 5%, chose not to disclose their financial status, while only 8% belong to families earning more than PhP 20,000 monthly. These figures highlight the economic reality for many students in provincial State Universities and Colleges (SUCs), where the teaching profession is often seen as a primary pathway to upward social mobility despite the financial barriers encountered during training.

The predominance of students from families earning below PhP 10,000 underscores the prevalence of financial constraints that may impact technological readiness. In a TPACK-centered curriculum, the participation gap is often an economic one; students with limited income may lack the personal hardware or stable connectivity required to experiment with digital tools outside the classroom fully. Furthermore, the presence of individuals who chose not to disclose their income suggests a degree of sensitivity about financial status, highlighting the need for teacher education institutions to foster supportive, non-judgmental environments that acknowledge the varied economic backgrounds of their students.

These findings are consistent with the work of Imelda et al. (2017), who documented similar income distributions among pre-service teachers in the Philippines, with most falling within the low- to middle-income categories. This alignment reinforces the observation that financial hurdles are a systemic challenge in the Philippine teacher education landscape. Given the specific context of Mindoro, where many PSTs come from rural or multicultural communities, these socioeconomic inequities are a critical determinant of how technology is perceived and used. Addressing these barriers is essential to ensure that PSTs are not only pedagogically prepared but also economically supported in their journey toward becoming tech-savvy educators.

Teaching Competencies Developed Among PSTs

Table 9. Summary of Rating of the Teaching Competencies Developed among Pre-service Teachers

Items	25th Percentile	Median	75th Percentile	IQR	Verbal Interpretation
Content Knowledge	4	4	5	1	Agree
Pedagogical Knowledge	4	4	5	1	Agree
Technological Knowledge	4	5	5	1	Strongly Agree
Pedagogical Content Knowledge	4	4	5	1	Agree
Technological Content Knowledge	4	4	5	1	Agree
Technological Pedagogical Knowledge	4	4	5	1	Agree

The self-assessment of teaching competencies among Science PSTs reveals a high level of perceived readiness across all TPACK domains. As shown in the data, Technological Knowledge (TK) emerged as the most developed competency, earning a median rating of 5.0 and a verbal interpretation of 'Strongly Agree.' This suggests that the respondents feel exceptionally proficient in navigating digital tools, online platforms, and educational media. The high 75th percentile and low Interquartile Range (IQR=1) for TK indicate a strong consensus among the PSTs regarding their technical fluency, reflecting a generation of "digital natives" who are comfortable with the hardware and software aspects of modern instruction.

Other foundational and intersectional domains, including Content Knowledge (CK), Pedagogical Knowledge (PK), and the integrated domains (PCK, TCK, and TPK), consistently received median ratings of 4.0, interpreted as 'Agree.' This uniform performance suggests that while the PSTs are highly confident in their technical skills (TK), they maintain a more measured yet still positive outlook on their ability to integrate that technology with specific subject matter and instructional strategies. The consistency across these ratings implies that the teacher education curriculum provides a balanced foundation, ensuring that pedagogical theory and content mastery are developed alongside technological skills.

The outstanding proficiency in TK aligns with the findings of Santos and Castro (2022), who observed that structured TPACK development programs significantly bolster PSTs' confidence in selecting and utilizing digital resources. However, the slightly lower (though still positive) ratings in the integrated domains, such as TPK and TCK, reflect the gap often discussed in the literature regarding the transition from knowing a tool (TK) to effectively teaching with it. As Mercado and Ibarra (2019) suggest, high self-efficacy is a vital precursor to actual classroom integration. However, it must be continuously bridged through practice-based learning to ensure that

"perceived readiness" translates into practical impact.

These results indicate that the Science PSTs in Mindoro view themselves as tech-savvy and pedagogically prepared. The challenge for future training lies in moving them from the "Strongly Agree" level of technical tool use toward an equally high level of integrated mastery, in which technology becomes an invisible yet powerful extension of their content delivery and pedagogical choices.

Significant Difference in the TPACK Teaching Competencies of Pre-service Teachers

Table 10. Wilcoxon/Kruskal-Wallis Test on TPACK Domains by Age Group

Domains	Age Group	Mdn	DF	Chi-square	p-value	Decision	Remarks
Content Knowledge	Below 25	4	1	1.27	0.2594	Failed to reject Ho	Not Significant
	25 -34	4					
Pedagogical Knowledge	Below 25	4	1	0.31	0.5788	Failed to reject Ho	Not Significant
	25 -34	4					
Technological Knowledge	Below 25	4	1	0.0463	0.8296	Failed to reject Ho	Not Significant
	25 -34	4					
Pedagogical Content Knowledge	Below 25	4	1	0.0001	0.9917	Failed to reject Ho	Not Significant
	25 -34	4					
Technological Content Knowledge	Below 25	4	1	0.0129	0.9096	Failed to reject Ho	Not Significant
	25 -34	4					
Technological Pedagogical Knowledge	Below 25	4	1	0.63	0.4292	Failed to reject Ho	Not Significant
	25 -34	4					

The statistical analysis using the Wilcoxon/Kruskal-Wallis Test indicates that age does not serve as a differentiating factor in the TPACK competencies of Science PSTs. At a 5% level of significance, the results failed to reject the null hypothesis across all domains, as the p-values for Content Knowledge (0.2594), Pedagogical Knowledge (0.5788), Technological Knowledge (0.8296), Pedagogical Content Knowledge (0.9917), Technological Content Knowledge (0.9096), and Technological Pedagogical Knowledge (0.4292) all exceeded the 0.05 threshold. This provides strong evidence that the median ratings across all TPACK domains are statistically uniform, regardless of whether the pre-service teacher falls below 25 or within the 25–34 age bracket.

These findings imply a high degree of consistency in the enactment of teaching competencies, suggesting that the teacher education programs in Mindoro are equally effective across different age groups. Such uniformity may be attributed to standardized training methodologies and the structured mentoring provided by cooperating teachers (CTs), which ensures that all PSTs achieve a baseline level of proficiency. This "age-neutral" development of skills reinforces the idea that TPACK is a learned professional construct rather than a trait dependent on a teacher's generation.

The observed consistency aligns with Mufidah's (2019) scholarship, which emphasized that robust training and mentorship programs are the primary drivers of competency, effectively neutralizing age-related differences. Similarly, Boonsue (2021) noted that extensive professional development and equitable access to technology lead to more uniform skill acquisition among educators. The critical role of institutional support is further echoed by Ocampo (2021), while Witt and Carraway (2017) and Ronfeldt et al. (2018) stress that the guidance and feedback provided by CTs are the ultimate equalizers in the field. By providing a stable pedagogical framework, these mentors ensure that all PSTs, regardless of age, are equipped with the knowledge and skills needed to navigate the demands of technology-integrated instruction.

Table 11. Wilcoxon/Kruskal-Wallis Test on TPACK Domains by Gender

Domains	Type of Respondents	Mdn	DF	Chi-square	p-value	Decision	Remarks
Content Knowledge	Male	4	2	0.2501	0.8825	Failed to reject Ho	Not Significant
	Female	4					
	Non-Binary	4					
Pedagogical Knowledge	Male	4	2	4.8681	0.0877	Failed to reject Ho	Not Significant
	Female	4					
	Non-Binary	4					
Technology Knowledge	Male	5	2	3.4	0.1827	Failed to reject Ho	Not Significant
	Female	5					
	Non-Binary	5					
Pedagogical Content Knowledge	Male	4	2	0.2127	0.8991	Failed to reject Ho	Not Significant
	Female	4					
	Non-Binary	4					
Technological Content Knowledge	Male	4	2	5.115	0.0775	Failed to reject Ho	Not Significant
	Female	4					
	Non-Binary	4					
Technological Pedagogical Knowledge	Male	4	2	4.35	0.1134	Failed to reject Ho	Not Significant
	Female	4					
	Non-Binary	4					

The statistical comparison across gender identities reveals that gender does not significantly influence the development or enactment of TPACK domains among Science PSTs. Based on the Wilcoxon/Kruskal-Wallis test results, all domains remained non-significant at the 5% level of significance, as p-values for Content Knowledge (0.8825), Pedagogical Knowledge (0.0877), Technological Knowledge (0.1827), Pedagogical Content Knowledge (0.8991), Technological Content Knowledge (0.0775), and Technological Pedagogical Knowledge (0.1134) all exceeded the 0.05 threshold. These findings provide strong empirical evidence that median ratings are statistically uniform across male, female, and Non-Binary respondents, indicating that gender identity is not a barrier to achieving pedagogical and technological mastery.

The consistency of these results implies that the teacher education and mentoring systems in Mindoro are fundamentally inclusive. By ensuring that training methodologies are equally accessible and effective for all PSTs, the institution has successfully neutralized historical gender biases often associated with technological proficiency. This uniformity suggests that when pre-service teachers receive standardized professional development and equitable access to resources, all pre-service teachers, regardless of gender, can develop the self-efficacy needed to integrate technology into their future classrooms.

These findings align with the work of Mufidah (2019) and Ocampo (2021), who argue that collaborative mentoring and comprehensive training are the true drivers of uniform competency development. Similarly, Goradia (2018) and Boonsue (2021) demonstrate that robust self-efficacy in technology integration is achievable for all genders when supported by diverse educational technologies. The critical role of high-quality coaching and feedback, as highlighted by Ronfeldt et al. (2018), further reinforces that the instructional environment—rather than gender—is the primary factor in shaping the readiness of the next generation of educators.

Table 12. Wilcoxon/Kruskal-Wallis Test on TPACK Domains by Family Monthly Income

Domains	Monthly Family Income	Mdn	DF	Chi-square	p-value	Decision	Remarks
Content Knowledge	Less than 10,000	4	3	6.15	0.1044	Failed to reject Ho	Not Significant
	10,000 - 20,000	4					
	More than 20,000	4					
	Prefer not to say	4					
Pedagogical Knowledge	Less than 10,000	4	3	20.66	0.0001*	Rejected Ho	Significant
	10,000 - 20,000	5					
	More than 20,000	4					
	Prefer not to say	4					
Technology Knowledge	Less than 10,000	5	3	12.95	0.0047*	Rejected Ho	Significant
	10,000 - 20,000	5					
	More than 20,000	4					
	Prefer not to say	4					
Pedagogical Content Knowledge	Less than 10,000	4	3	12.47	0.0059*	Rejected Ho	Significant
	10,000 - 20,000	4.5					
	More than 20,000	4					
	Prefer not to say	4					
Technological Content Knowledge	Less than 10,000	4	3	11.47	0.0094*	Rejected Ho	Significant
	10,000 - 20,000	4					
	More than 20,000	4.5					
	Prefer not to say	4					
Technological Pedagogical Knowledge	Less than 10,000	4	3	10.07	0.0180*	Rejected Ho	Significant
	10,000 - 20,000	4					
	More than 20,000	4.5					
	Prefer not to say	4					

The statistical analysis using the Wilcoxon/Kruskal-Wallis test reveals that monthly family income is a decisive factor in the development of TPACK among Science PSTs. At a 5% significance level, the results led to the rejection of the null hypothesis for nearly all domains, including Pedagogical Knowledge (0.0001), Technological Knowledge (0.0047), Pedagogical Content Knowledge (0.0059), Technological Content Knowledge (0.0094), and Technological Pedagogical Knowledge (0.0180). Only Content Knowledge (0.8825) remained non-significant. This provides compelling evidence that while PSTs across different income brackets possess a uniform grasp of their subject matter, their ability to navigate pedagogy and technology varies statistically by socioeconomic background.

These findings imply that a digital and pedagogical divide persists within the pre-service teaching population. While the university provides a standardized curriculum, PSTs from higher-income families likely benefit from superior access to personal technological resources, stable high-speed internet, and a history of exposure to tech-integrated learning environments. These cumulative advantages translate into greater proficiency in the enacted domains of TPACK, in which technology must be seamlessly integrated with instructional strategies. Conversely, PSTs from lower-income households may face a steeper learning curve, as their interaction with these tools is often limited to campus facilities, creating a gap in their perceived and actual competency levels.

The significance of socioeconomic factors in this study aligns with Zulkharnain et al. (2017),

who argued that family income fundamentally shapes a teacher's technological trajectory over time. This economic influence is further supported by Miranda (2019), who noted that varying educational and financial backgrounds directly affect a PST's readiness for complex lesson planning and technology integration. While practical internship experiences can help bridge some of these gaps (Lobo et al., 2022), the data suggest that institutional interventions must be more robust to ensure that economic disparities do not dictate professional excellence. Ultimately, for the PSTs in Mindoro, achieving full TPACK integration is not just a matter of academic effort but is deeply tethered to the material realities of their socioeconomic status.

Synthesis of Findings

The findings of this study provide a map of the TPACK landscape among Science Pre-Service Teachers in Mindoro, revealing a significant intersection between professional readiness and socioeconomic reality. On a foundational level, the respondents demonstrate a high degree of self-perceived competence, particularly in Technological Knowledge (TK), where they reported the highest levels of confidence. This suggests that the current teacher education curriculum and the cohort's digital-native status have successfully built a strong technical foundation. Furthermore, the statistical neutrality of age and gender across all domains indicates that the training environment is fundamentally inclusive, effectively neutralizing historical biases that once suggested technology integration was a gendered or age-dependent skill.

However, the most critical revelation of this research lies in the Socioeconomic Bottleneck. At the same time, PSTs from all backgrounds demonstrate uniform mastery of Content Knowledge (CK), the theoretical 'what' of teaching; their ability to enact the pedagogical and technological intersections of the TPACK framework is significantly dictated by family income. This divergence suggests that while the university provides equal instruction, the participation gap remains an economic one. PSTs with higher financial means likely benefit from continuous, private access to digital tools, which translates into a more seamless integration of technology into their instructional strategies.

Ultimately, these results underscore that TPACK proficiency in a provincial context is not merely an academic achievement but a reflection of material access. The high self-efficacy reported by PSTs is a vital starting point, yet it remains vulnerable to the constraints of the rural and semi-rural teaching environment. To move toward true context-responsive teacher education, institutional support must go beyond standardized training and actively address the resource disparities of its students. Ensuring that all future educators—regardless of their economic background can transition from knowing a tool to teaching with it is essential for fostering an equitable and technologically empowered classroom in the 21st century.

CONCLUSIONS

The findings of this study lead to the conclusion that while Science PSTs in Mindoro possess high technical confidence, their TPACK mastery is fundamentally resource-dependent. The high ratings in Technological Knowledge (TK) and the statistical neutrality with respect to age and gender demonstrate that the current curriculum is inclusive and effective at building basic digital literacy. However, the significant divergence in scores based on monthly family income reveals that socioeconomic status remains the primary gatekeeper of integrated TPACK proficiency. While Content Knowledge (CK) remains stable across all economic brackets, the participation gap in integrated domains (TPK, TCK) suggests that financial constraints directly bottleneck a PST's ability to move from knowing a tool to teaching with it.

Theoretically, this research contributes to teacher education by proposing a "Resource-Sensitive TPACK" model for low-resource contexts. It challenges the global assumption that TPACK

is a purely cognitive framework, arguing instead that in developing-nation settings, the framework is inseparable from educators' material realities. This study expands TPACK theory by identifying Socioeconomic Status (SES) as a structural determinant that dictates the "enactment" of pedagogical intersections. Ultimately, the results redefine teacher readiness as a context-responsive construct, asserting that professional excellence in the 21st century requires institutional interventions that provide not just academic training, but sustained economic and resource-based scaffolding to bridge the digital divide.

LIMITATION & FURTHER RESEARCH

This study is limited by its focus on science pre-service teachers within a specific educational institution, which may restrict the generalizability of the findings to other teacher populations or academic contexts. Additionally, the analysis relied on self-reported assessments of Technological, Pedagogical, and Content Knowledge (TPACK), which may be influenced by participants' subjective perceptions and familiarity with the framework. The study also did not account for differences in prior teaching experience, access to technology, or variations in curriculum exposure that could affect TPACK development.

Further research is recommended to include a larger, more diverse sample of pre-service teachers from multiple institutions to enhance generalizability. Future studies could also employ mixed-method approaches, incorporating classroom observations, student outcomes, and performance-based assessments, to validate self-reported TPACK levels. Additionally, research could explore interventions or training programs designed to strengthen TPACK in science education and investigate how contextual factors such as technological infrastructure, mentorship, and instructional support influence its development.

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