Developing AI-TPACK: A Framework for Mathematics Teachers' Technological, Pedagogical, and Content Knowledge in the Artificial Intelligence Era

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ABSTRACT

This study examined mathematics teachers' AI-TPACK competency, perceptions of AI-driven tools, pedagogical assessment practices, and experiences in integrating artificial intelligence in instruction within the Schools Division of Siargao. An explanatory sequential mixed-methods design was employed involving 247 mathematics teachers and 12 key informants. Data were gathered using a researcher-made questionnaire and semi-structured interviews and analyzed through descriptive and inferential statistics alongside thematic analysis.

Findings indicated that teachers are in a transitional stage of AI integration, characterized by developing AI-TPACK competency, moderate technical proficiency, frequent yet routine use of AI tools, and generally favorable perceptions of usefulness with moderate ease of use. Teachers showed strong engagement in formative AI-assisted assessment; however, the integration of AI-generated outputs into grading and instructional decision-making remained limited. Quantitative results revealed significant relationships between TPACK competency and both perceived usefulness and ease of use, with TPACK emerging as the strongest predictor of AI competency. Qualitative findings further highlighted AI as an instructional support tool while identifying challenges such as the digital divide, literacy gaps, student overdependence, and infrastructural constraints. Based on the integrated results, an AI-TPACK Capacity-Building Framework for Mathematics Teachers was developed to enhance competencies, pedagogical integration, and sustainability of AI adoption in mathematics education.

Keywords: AI-TPACK, artificial intelligence in education, mathematics education, teacher competency, Technology Acceptance Model, capacity building

INTRODUCTION

Artificial intelligence (AI) is reshaping educational practice by transforming how teaching and learning are designed and implemented. In mathematics education, its value lies in its pedagogical use, particularly in supporting differentiated instruction, providing timely feedback, and facilitating the visualization of abstract concepts. However, the effectiveness of AI depends largely on teachers' ability to integrate these tools in ways that align with sound pedagogy and deep content knowledge. Thus, this study aims to develop an AI-TPACK Capacity-Building Framework for mathematics teachers to enhance their pedagogical integration of AI in mathematics instruction.

Effective integration of AI in mathematics teaching requires teachers to develop an expanded form of Technological Pedagogical Content Knowledge (TPACK), often conceptualized as AI-TPACK, which incorporates AI literacy into the intersection of pedagogy, content, and technology (Ning et al., 2024). This integration supports teachers' instructional decision-making, creativity, and confidence in using AI tools for teaching and assessment (Lin et al., 2025; Kim et al., 2025; Xue et al., 2026). Empirical studies suggest that teachers generally perceive AI tools positively due to their usability, adaptability, and potential to enhance

instructional efficiency and engagement (Hava. & Babayiğit, 2025; Lin et al., 2025). Nonetheless, the adoption of AI in classroom practice remains uneven. Factors such as limited infrastructure, insufficient training, ethical concerns, increased workload, and risks of superficial or over-reliant use continue to constrain meaningful pedagogical integration (Wen, 2025; Li et al., 2025; Song et al., 2025). These challenges highlight that successful AI integration depends not only on access to tools but also on teachers' capacity to critically and effectively enact AI-TPACK within real classroom contexts.

In many educational systems, including the Philippine context, a persistent gap exists between the theoretical potential of AI in education and its actual classroom implementation. Empirical evidence indicates that while a high proportion of teachers report positive attitudes toward AI and demonstrate strong content knowledge, a significantly smaller percentage are able to effectively integrate AI tools into instruction, with studies noting moderate levels of technological–pedagogical competence and limited classroom application (Plantado, 2023; Siloterio et al., 2025; Ilagan et al., 2025). This disparity is further exacerbated by structural challenges, as national and regional reports reveal that a substantial number of schools—particularly in geographically isolated areas such as Siargao—continue to experience unstable internet connectivity, limited access to digital infrastructure, and insufficient professional development opportunities (PNA, 2025; PIA, 2023; Heinrich Böll Foundation, 2020). These data collectively highlight a critical need for context-responsive and capacity-building interventions that can bridge the gap between AI's pedagogical potential and its effective use in mathematics classrooms.

In response to these challenges, this study develops the AI-TPACK Capacity-Building Framework for mathematics teachers. The framework is designed to support the effective integration of AI into mathematics instruction by strengthening the interconnected domains of technological, pedagogical, and content knowledge alongside AI literacy. It provides a structured guide for teacher professional development and instructional practice, with particular attention to contextual constraints in diverse learning environments. Beyond its practical contribution, the study extends the TPACK framework by situating it within the emerging domain of AI-enhanced education and generating empirically informed insights into teachers' competencies, perceptions, and instructional practices. In doing so, it bridges the gap between theory and practice by offering a context-responsive and pedagogically grounded framework for leveraging AI to improve mathematics teaching and learning.

METHODOLOGY

This study employed an explanatory sequential mixed-methods design to develop an AI-TPACK Capacity-Building Framework for mathematics teachers. The quantitative phase used a descriptive-correlational approach involving complete enumeration of 247 mathematics teachers from Key Stages 2-4 from the Schools Division of Siargao, Philippines. Data were collected using a validated and reliable researcher-made questionnaire (α = 0.97) anchored on the AI-TPACK framework and Technology Acceptance Model (TAM), measuring AI-TPACK competency, perceived ease of use, perceived usefulness, and pedagogical assessment practices. Data were analyzed using descriptive statistics, Spearman's rank-order correlation, independent samples t-test, and one-way ANOVA.

The qualitative phase adopted a descriptive phenomenological approach involving 12 purposively selected mathematics teachers based on inclusion criteria related to AI integration experience and teaching exposure. Semi-structured interviews were conducted and analyzed using Reflexive Thematic Analysis (Braun et al., 2023) to explore lived experiences and contextualize quantitative findings. Data collection continued until saturation was reached.

The study was conducted in the Schools Division of Siargao, which includes schools situated in areas with limited internet connectivity and varying access to digital resources, providing a relevant context for examining AI integration in education. Quantitative and qualitative findings were integrated to generate an empirically grounded and context-responsive AI-TPACK capacity-building framework for mathematics instruction. Ethical protocols, including informed consent, confidentiality, and institutional approval, were strictly observed throughout the study.

RESULTS AND DISCUSSION

This section presents the quantitative findings of the study, focusing on mathematics teachers' profile, AI-TPACK competency, perceived ease of use, perceived usefulness, and pedagogical assessment practices. It also examines relationships and differences among variables using appropriate inferential statistics. The results are interpreted in relation to relevant literature to provide an integrated understanding of teachers' readiness and engagement with AI-driven instructional tools in mathematics education.

Profile of the Respondents

Table 1. Profile of the Respondents in terms of age, sex, highest educational attainment, available digital resources, and self-reported TPACK

Profile	Category	f	%
Age	20–29 years old	85	34.41
	30–39 years old	104	42.11
	40–49 years old	51	20.65
	50 years old and above	7	2.83
Sex	Male	142	57.49
	Female	105	42.51
Highest Educational Attainment	Bachelor's Degree	82	33.20
	With MA units	156	63.16
	Master's Degree	4	1.62
	With PhD/EdD units	5	2.02
	Doctorate Degree	0	0.00
Available Digital Resources	Khan Academy	39	15.79
	Learning Management System	23	9.31
	Gokongwei Brothers Foundation (GBF) Class Builder	46	18.62
	Magicschool	14	5.67
	Chalkie	11	4.45
	Curipod	19	7.69
	MathSpace	22	8.91
	ALEKS	12	4.86
	EduGenius	27	10.93
	Canva	34	13.77
Self-Reported TPACK Competency	Novice	56	22.67
	Basic	107	43.32
	Intermediate	73	29.55
	Advanced	11	4.46

Table 1 presents the demographic and professional profile of the respondents in terms of age, sex, highest educational attainment, availability of digital resources, and self-reported TPACK competency.

Most respondents belong to the 30–39 age group (42.11%), followed by 20–29 (34.41%), indicating a predominantly early- to mid-career teaching workforce. In terms of sex, males (57.49%) slightly outnumber females (42.51%), reflecting a relatively balanced distribution.

Regarding educational attainment, most teachers have earned master's units (63.16%), while only a small proportion have completed a master's degree or pursued doctoral studies, with no respondents holding a doctorate degree. This suggests ongoing but incomplete postgraduate professional development.

In terms of digital resources, commonly used platforms include GBF Class Builder, Khan Academy, and Canva, while AI-specific tools such as MagicSchool, ALEKS, and Curipod are less frequently used. This indicates a preference for general-purpose digital tools over advanced AI systems.

For self-reported TPACK competency, most teachers are at the basic level (43.32%), followed by intermediate (29.55%) and novice (22.67%), with only 4.46% at the advanced level. Overall, the profile suggests a workforce with foundational digital exposure but limited advanced integration capacity.

These findings reflect a transitional stage of technology adoption in education, consistent with research indicating that teachers often remain at basic to intermediate TPACK levels due to uneven training and limited sustained professional development (Lei et al., 2022; Li, 2025).

AI-Driven Tool Competency

Table 2. Level of Competency of Mathematics Teachers in using AI-driven Educational Tools

Indicators	M	SD	Adjectival Rating
Frequency of Use of Common Digital Tools	3.41	0.84	Advanced
Technical Proficiency	2.63	0.55	Proficient
Overall	3.02	0.70	Proficient

Table 2 shows that teachers demonstrate an overall proficient level of AI-driven tool competency (M = 3.02, SD = 0.70). Frequency of use is rated advanced (M = 3.41), while technical proficiency is rated proficient (M = 2.63).

This disparity indicates that while teachers frequently use AI-driven tools, their mastery of advanced functionalities remains limited. Their engagement is characterized by routine, functional use rather than strategic or transformative application.

The higher variability in frequency of use suggests inconsistent integration across teachers, while the lower variability in technical proficiency reflects a relatively uniform foundational skill level.

Overall, AI use in instruction is widespread but shallow in depth, aligning with staged models of technology integration where educators progress from operational use toward pedagogically meaningful integration over time (Agyei et al., 2024; Ning et al., 2024).

Perceived Ease of Use of AI-driven Tools

Table 3. Level of Perceived Ease of Use regarding AI-driven tools

Indicators	M	SD	Adjectival Rating
User Interface Clarity	3.00	0.62	Neither Easy nor Difficult
Accessibility Features	2.53	0.55	Difficult
Learning Curve	2.35	0.74	Difficult
Integration of Daily Task	3.23	0.67	Neither Easy nor Difficult
Technical Support Requirement	2.07	0.55	Difficult
Overall	2.64	0.63	Neither Easy nor Difficult

As shown in Table 3, teachers perceive AI-driven tools as generally neither easy nor difficult to use (M = 2.64, SD = 0.63). Highest ratings are observed in interface clarity and integration into daily tasks, while accessibility features, learning curve, and technical support requirement are rated as difficult.

These results indicate partial usability: teachers can integrate AI tools into instruction but still encounter operational and structural barriers. The presence of a steep learning curve and reliance on technical support suggests moderate technological self-efficacy.

This implies that AI tools are not yet fully intuitive or seamlessly embedded in instructional workflows, requiring sustained cognitive effort and external assistance.

These findings align with literature emphasizing that system complexity, interface usability, and accessibility significantly influence perceived ease of use and sustained adoption (Lin et al., 2023; Feng et al., 2025; Tashtoush et al., 2024).

Perceived Useful of AI-driven Tools

Table 4. Level of Perceived Usefulness of AI-driven tools

Indicators	M	SD	Adjectival Rating
Enhancement of Student Engagement	4.03	0.56	Useful
Improvement of Instructional Delivery	3.70	0.73	Useful
Efficiency in Content Creation	3.61	0.69	Useful
Personalization of Learning	3.58	0.68	Useful
Accuracy of Data Analytics	3.50	0.71	Useful
Overall	3.68	0.63	Useful

Table 4 reveals that teachers perceive AI-driven tools as useful overall (M = 3.68, SD = 0.63). The highest-rated indicator is enhancement of student engagement, while accuracy of data analytics is the lowest, though still rated useful.

This indicates that AI tools are strongly valued for improving student engagement and instructional interaction. However, their use in data-driven decision-making and personalized instruction remains underdeveloped.

Thus, AI integration is currently more effective in improving immediate instructional experiences than in supporting deeper pedagogical transformation.

These findings align with studies highlighting AI's role in improving engagement and efficiency while noting that advanced pedagogical value depends on teachers' data literacy and instructional competence (Torres-Peña et al., 2024; ElSayary et al., 2025).

Pedagogical Assessment Using AI Tools

Table 5. Level of Attainment of Pedagogical Assessment when utilizing AI-driven tools

Indicators	Mean	SD	Adjectival Rating
Pedagogical Assessment (AI-driven tools)	**3.51**	**0.73**	High Level of Attainment

Table 5 indicates a generally high level of attainment in AI-supported assessment practices (M = 3.51, SD = 0.73). Teachers report strong use of AI in formative assessment, particularly in monitoring student progress and identifying learning gaps.

However, lower attainment is observed in integrating AI-generated results into grading systems and instructional decision-making. This suggests cautious use of AI in summative and high-stakes evaluation contexts.

Overall, AI is primarily used as a formative diagnostic tool rather than a decision-making system in assessment practices.

These findings are consistent with research emphasizing that AI is most effective in formative assessment contexts, while summative use requires stronger data literacy and institutional trust (Hopfenbeck et al., 2023; Gardner et al., 2021; Choiriyah et al., 2025).

Relationship Between TPACK, Perceived Ease of Use, and Usefulness

Table 6. Relationship between TPACK Competency, Perceived Ease of Use, and Perceived Usefulness of AI-Driven Tools

Independent Variable	Dependent Variable	ρ	p-value	Conclusion
TPACK Competency	**Perceived Ease of Use**	.33	.003	Significant
	User Interface Clarity	.34	.004	Significant
	Accessibility of Features	.32	.006	Significant
	Learning Curve	.30	.009	Significant
	Integration with Daily Tasks	.36	.002	Significant
	Technical Support Requirement	-.28	.011	Significant
TPACK Competency	**Perceived Usefulness**	.59	< .001	Significant
	Enhancement of Student Engagement	.58	< .001	Significant
	Improvement of Instructional Delivery	.56	< .001	Significant
	Efficiency in Content Creation	.59	< .001	Significant
	Personalization of Learning	.60	< .001	Significant
	Accuracy of Data Analytics	.61	< .001	Significant

Spearman's rho results show that TPACK competency is significantly related to both perceived ease of use and perceived usefulness of AI-driven tools.

The relationship with perceived ease of use is weak but positive, while the relationship with perceived usefulness is moderate and positive. This indicates that TPACK more strongly influences perceived instructional value than usability perception.

At the indicator level, all ease of use dimensions show weak positive correlations, while usefulness indicators show moderate correlations, with data-driven decision-making showing the strongest association.

These findings suggest that higher TPACK enhances teachers' ability to recognize and utilize the pedagogical benefits of AI tools rather than merely improving usability perceptions.

This supports the AI-TPACK framework, which emphasizes integrated knowledge for meaningful AI use (Ning et al., 2024), and TAM literature showing perceived usefulness as a stronger determinant of adoption than ease of use in AI contexts (Xue et al., 2026).

Differences in AI Competency by Profile Variables

Table 7. Differences in the Level of Competency in using AI-driven Tools when Respondents are Grouped According to their Profile

AI-TPACK Competency	Profile Variables	Test Statistic	p-value	Conclusion
Frequency of Use of Common Digital Tools	Sex	t = 1.08	.281	Not Significant
	Age	F = 2.11	.122	Not Significant
	Educational Attainment	F = 5.94	< .001	Significant
	Digital Resource Availability	F = 12.91	< .001	Significant
	Self-Reported TPACK	F = 18.92	< .001	Significant
Technical Proficiency	Sex	t = 0.94	.347	Not Significant
	Age	F = 2.56	.079	Not Significant
	Educational Attainment	F = 6.48	< .001	Significant
	Digital Resource Availability	F = 11.73	< .001	Significant
	Self-Reported TPACK	F = 19.44	< .001	Significant

Table 7 shows no significant differences in AI competency in terms of sex and age, indicating that demographic factors do not influence AI-related competencies.

However, significant differences are observed in educational attainment, digital resource availability, and self-reported TPACK competency.

Higher educational attainment is associated with stronger AI competency, likely due to increased exposure to pedagogical and research-based practices. Likewise, access to digital resources significantly enhances competence, highlighting the importance of infrastructure and availability.

Most importantly, self-reported TPACK emerges as the strongest differentiating factor, underscoring that AI competency is primarily driven by integrated technological, pedagogical, and content knowledge rather than demographic characteristics.

These findings align with the AI-TPACK framework (Ning et al., 2024) and prior studies emphasizing that TPACK is a stronger predictor of technology integration than age or sex (Wijaya et al., 2024; Sadaf et al., 2025).

Qualitative Findings: Lived Experiences of Mathematics Teachers in AI Platforms to Support Learning

This section presents the qualitative findings derived from Braun and Clarke's (2022) Reflexive Thematic Analysis, which explored mathematics teachers' lived experiences in using AI-driven instructional platforms. The analysis generated seven interrelated themes organized into two broad categories: (1) experiences in AI-enhanced instruction and (2) coping mechanisms for optimizing AI integration. Collectively, the findings illustrate how AI reshapes instructional practice while simultaneously introducing pedagogical, cognitive, and infrastructural tensions in mathematics teaching.

Table 8. Themes and Sub-themes emerged on the Experiences of Mathematics Teachers in Implementing AI-driven Instruction

Themes	Sub-themes
AI as an Instructional Support Tool in Mathematics Teaching	Lesson Generation and Instructional Efficiency
	Instructional Support and Classroom Management Efficiency
	Differentiated and Structured Instruction for Learner Engagement
	Supplementary and Reinforcement Instruction
	Adaptive and Personalized Learning Support
Student Overdependence and Surface-Level Learning	Surface-Level Learning and Guessing Behavior
	Passive Learning Engagement
	Overdependence on AI-Generated Answers
	Reduced Conceptual Understanding in Mathematics
Digital Divide and Technological Instability in AI-Enhanced Instruction	Limited Access and Digital Exclusion
	Connectivity Inequality and Network Instability
	Instructional Disruption and Workflow Interruption
	Participation and Engagement Barriers in AI-Dependent Learning Environments

Theme 1: AI as an Instructional Support System

Teachers consistently described AI tools as integrated instructional systems that streamline lesson planning, material generation, classroom management, and differentiated instruction. AI reduced preparation time through automated lesson sequencing, problem generation, and assessment design, while also centralizing instructional resources and learner tracking systems. This is evident in P_1's observation that AI

"greatly supports lesson planning… it generates lesson structure, activities, and assessments aligned with competencies."

Beyond efficiency, AI enabled differentiated instruction by allowing teachers to adjust task difficulty based on learner performance and extend learning through supplementary activities. As P_1 noted,

"I can choose the level of difficulty of activities depending on my class performance".

Teachers also reported using AI for reinforcement tasks and personalized learning support, with P_9 explaining,

"I use AI to provide additional practice activities for students after class".

These findings suggest that AI functions not merely as a productivity tool but as an instructional infrastructure that reshapes pedagogical workflow. Consistent with Walkington (2025) and Gligorea et al. (2023), AI reduces cognitive load in planning while enabling more responsive and adaptive instruction; however, teachers remain central in ensuring pedagogical alignment, contextual appropriateness, and instructional quality.

Theme 2: Student Overdependence and Surface-Level Learning

The findings reveal that student overdependence and surface-level learning in AI-supported mathematics instruction is characterized by four interrelated dimensions: surface-level engagement, passive interaction with learning materials, reliance on AI-generated scaffolds, and limited conceptual understanding. Across narratives, teachers consistently observed that students prioritize task completion over mathematical reasoning, often engaging in guessing behaviors and bypassing instructional processes. This is reflected in P_7's account:

"Some students just click through the activities or guess answers just to finish quickly."

This was further emphasized by P_6, who noted that students may complete tasks without demonstrating actual understanding of the lesson content.

Similarly, participants highlighted passive learning behaviors, where students skip videos, explanations, and structured activities intended to support conceptual development. As P_3 explained, students

"skip through the tasks or guess answers without really understanding,"

while P_4 observed that learners often bypass instructional videos and procedural explanations.

In addition, teachers reported strong reliance on AI-generated scaffolds such as hints and guided solutions. P_1 noted that students

"rely too much on guided solutions instead of thinking through the process," a pattern further supported by P_{11}, who observed that learners depend heavily on hints rather than attempting independent problem-solving.

Most critically, this pattern results in reduced conceptual understanding, where students are able to produce correct answers but cannot explain their reasoning. As P_{12} stated:

"They get correct answers but cannot explain their reasoning."

This indicates a disconnect between procedural completion and conceptual understanding, where AI tools support task efficiency but may also encourage superficial engagement when used without cognitive effort. This suggests that the educational value of AI in mathematics is highly dependent on instructional design and teacher mediation, particularly in ensuring that learning tasks require explanation and reasoning rather than mere completion.

These results align with Liu et al. (2025), who describe AI-supported learning as "high-volume yet low-yield" engagement, and Sahin and Kırmızıgül (2023), who found that students often rely on procedural execution rather than conceptual understanding, limiting their ability to explain and transfer mathematical knowledge.

Theme 3: Digital Divide and Technological Instability

The findings reveal that digital divide and technological instability in AI-enhanced instruction are characterized by unequal access to devices, unstable internet connectivity, and system disruptions that limit both learner participation and instructional continuity. Participants consistently noted that many students experience difficulty accessing AI platforms due to connectivity issues, resulting in fragmented engagement and delayed learning activities. As P_{12} explained:

"Some students lacked consistent access to devices or internet connectivity, which affected their participation."

Connectivity-related barriers were further emphasized, as some learners were unable to log in or could only engage with lessons when physically present in school due to the absence of stable internet at home. These constraints created unequal learning opportunities, where participation depended heavily on digital access rather than academic readiness.

Teachers also highlighted instructional consequences of these limitations. Delays in submissions and uneven participation were commonly observed, not due to lack of understanding, but due to connectivity problems. As P_8 noted:

"Some can submit on time, others cannot—not because they don't understand, but because of connectivity issues."

On the instructional side, teachers experienced workflow interruptions caused by unstable systems during lesson preparation and delivery. In some instances, AI platforms became slow or disconnected, disrupting instructional momentum and limiting access to teaching materials. Teachers also observed a decline in student engagement when interactive AI-based activities failed mid-session, as system freezes led to confusion and loss of interest.

Collectively, these findings indicate that AI integration is highly dependent on stable digital infrastructure. When connectivity is unreliable, both teaching efficiency and student engagement are significantly compromised, reinforcing existing educational inequities.

In relation to existing literature, these findings align with Vesna et al. (2025) and Mesuwini and Mokoena (2024), who emphasize that digital access gaps and connectivity instability remain major barriers in technology-enhanced education, particularly in rural and resource-limited contexts.

Table 9. Themes and Sub-themes emerged on the Coping Mechanisms of Mathematics Teachers in AI-Enhanced Instruction

Themes	**Sub-themes**
Critical Pedagogical Judgement as Core Competency	Content Evaluation and Output Validation
	Instructional Alignment and Curriculum Consistency
	Contextualization and Localization of AI-Generated Content
	Content Refinement for Pedagogical Suitability
Prompting Literacy as an Emerging Competency	Prompt Specificity in AI Interaction
	Prompt Refinement and Iterative Improvement
	Digital Literacy as a Foundation for Effective Prompting
Teacher Adaptability and Instructional Flexibility	Instructional Contingency and Access-Responsive Planning
	Differentiated and Context-Based Instructional Adjustment

	Instructional Pacing and Real-Time Teaching Adjustment
	Cognitive Engagement and Pedagogical Enrichment Strategies
Instructional Triangulation and Validation of Student Learning	Multi-Source Assessment for Learning Validation
	Formative and Summative Verification Strategies
	AI Output Verification and Accuracy Checking
	Ensuring Authentic Learning Beyond AI Assistance
	Learning Evidence Monitoring and Progress Tracking

Theme 4: Critical Pedagogical Judgment as Core Competency

The findings reveal that critical pedagogical judgment is a core competency in AI-assisted instruction, manifested through content evaluation, instructional alignment, contextualization, and refinement of AI-generated materials. Across narratives, teachers consistently emphasized that AI outputs are not directly usable and must be carefully validated to ensure accuracy, appropriateness, and alignment with curriculum standards.

This is evident in P_7's account:

"There are times when I still need to adjust the difficulty level, rephrase instructions, or correct some solutions before using them in class."

Similarly, P_{10} highlighted the need for validation before instructional use:

"Some solutions needed correction before I could confidently use them."

Participants also noted that AI-generated materials often lack developmental appropriateness and contextual relevance. As P_1 explained, some instructional texts are too advanced for learners and require simplification and rephrasing to match students' cognitive level. Likewise, P_5 emphasized that certain word problems are not fully contextualized to Filipino learners, requiring teacher adaptation.

Beyond technical adjustments, teachers stressed the centrality of professional judgment in ensuring instructional quality. As P_7 stated:

"I still need to use my own judgment as a teacher… I cannot just copy and use the outputs directly."

These accounts indicate that AI-generated outputs function as semi-processed instructional materials that require human refinement. Teachers act as critical mediators who ensure mathematical accuracy, pedagogical appropriateness, and curriculum alignment. This demonstrates that AI shifts teaching toward evaluative and adaptive work, where instructional quality depends on continuous validation and contextualization of generated content.

In relation to existing literature, Jia et al. (2024) note that AI-generated instructional materials in mathematics often lack consistency in accuracy and pedagogical coherence. Similarly, Karatas (2025) emphasizes that effective use of AI in education depends on teachers' ability to critically evaluate and adapt outputs to learner needs, reinforcing the centrality of pedagogical judgment in AI-enhanced instruction.

Theme 5: Prompting Literacy as an Emerging Competency

The findings reveal that prompting literacy is an emerging pedagogical competency in AI-assisted instruction, manifested through prompt specificity, iterative refinement, and digital literacy as its foundational enabler.

Teachers consistently emphasized that the quality of AI-generated outputs depends on how clearly and strategically prompts are structured, particularly when key instructional parameters such as grade level, competency, difficulty, and context are explicitly defined.

This is reflected in P_7's account:

"When I structure the prompt with grade level, competency, difficulty level, and context, the outputs become more useful and classroom-ready."

Participants further noted that poorly structured prompts often result in generic or misaligned outputs, highlighting prompting as a deliberate instructional act rather than a simple input process. As P_6 explained, AI is not a "click and generate" tool but requires intentional and strategic input from teachers to produce appropriate materials.

In addition, teachers emphasized that prompting involves iterative refinement, where AI outputs are treated as drafts that must be evaluated and improved rather than used directly. As P_7 further noted, generated materials are consistently refined before classroom use, underscoring the cyclical nature of AI interaction in instruction.

Digital literacy also emerged as a foundational requirement, enabling teachers to effectively navigate platforms and translate instructional intent into structured prompts. Participants highlighted that familiarity with tools such as MagicSchool and Chalkie enhances the ability to produce more accurate and relevant outputs.

These findings indicate that prompting literacy shifts teaching practice toward instructional design within AI systems, where teachers actively shape output quality through structured input and iterative evaluation. This reflects a move from content delivery to AI-mediated instructional engineering.

In relation to existing literature, Park and Choo (2025) emphasize that structured prompts significantly improve the relevance and accuracy of AI-generated educational materials. Similarly, Chiu (2024) identifies prompt engineering as a core dimension of AI literacy, highlighting its iterative and evaluative nature. Ng et al. (2023) further stress that digital literacy extends to the strategic design of AI inputs, while Kehoe (2023) underscores prompting as a continuous refinement process aligned with instructional goals.

Theme 6: Teacher Adaptability and Instructional Flexibility

The findings reveal that teacher adaptability and instructional flexibility in AI-enhanced instruction are manifested through contingency planning, differentiated instructional adjustments, real-time pacing decisions, and pedagogical enrichment strategies. Across narratives, teachers consistently emphasized the need to continuously modify instruction in response to unstable connectivity, learner variability, and limitations of AI-generated materials.

This is evident in P_1's emphasis on contingency planning:

"I really need to prepare a complete backup plan. I cannot rely fully on technology because connectivity is not always reliable in our context."

Teachers also highlighted the need to adapt AI-generated materials to learner needs and classroom realities. As P_4 noted, instructional design requires continuous refinement of AI outputs to ensure meaningful and engaging mathematics lessons, while P_{10} emphasized the use of alternative tasks to ensure no learner is left behind despite limited access.

In addition, participants reported adjusting instructional pacing and revisiting concepts when learners demonstrated gaps between task completion and conceptual understanding. Some teachers slowed lessons, added offline activities, and re-explained topics to reinforce understanding. Blended strategies such as discussions, group work, and reflection activities were also commonly used to deepen conceptual processing.

Collectively, these accounts indicate that teacher adaptability operates as a multidimensional competence that includes proactive planning, real-time instructional decision-making, and the restructuring of AI-generated content. Rather than simplifying teaching, AI integration increases instructional demands by requiring constant calibration between technological outputs and classroom realities.

In relation to existing literature, UNESCO (2024) emphasizes that teachers remain central in ensuring inclusive and context-responsive implementation of AI in education, highlighting adaptability as essential in technology-mediated environments. Similarly, Afzal et al. (2023) and Mesuwini and Mokoena (2024) note that infrastructural limitations and connectivity issues necessitate flexible and contingency-based instructional strategies to sustain learning continuity.

Theme 7: Instructional Triangulation and Validation of Learning

The findings reveal that instructional triangulation and validation of learning in AI-supported instruction involve the integration of multiple evidence sources, including AI-generated analytics, classroom assessments, oral questioning, and reflective tasks. Across narratives, teachers consistently emphasized that student performance in digital platforms does not always reflect actual conceptual understanding, necessitating the use of complementary assessment strategies.

This is evident in P_3's practice of using follow-up tasks:

"I add follow-up tasks to ensure students are really thinking—not just answering for completion."

Similarly, P_8 emphasized linking digital activities with classroom discourse by requiring students to explain their reasoning, reinforcing understanding beyond online task completion.

Participants also noted mismatches between digital scores and actual understanding. As P_3 observed, online performance does not always align with classroom performance, while P_2 highlighted that interpreting AI-generated results is often complex due to possible influences such as effort level or technical issues.

These findings indicate that teachers actively engage in instructional triangulation by validating learning through multiple sources of evidence rather than relying solely on AI-generated data. This practice ensures that assessment captures not only task completion but also conceptual understanding and reasoning.

The findings further suggest that AI-generated analytics are insufficient as standalone indicators of learning, as they may reflect procedural success rather than cognitive depth. Consequently, teachers emphasize explanation-based assessment and reflective tasks as safeguards to ensure authenticity in student learning.

In relation to existing literature, Lichtenberger et al. (2025) emphasize that effective formative assessment requires eliciting evidence of student thinking rather than relying on correctness alone, while Chen et al. (2025) argue that AI-generated data must be interpreted and validated through teacher judgment and additional classroom evidence. Collectively, these studies support the present findings that instructional triangulation is essential in AI-enhanced education to ensure accurate, authentic, and meaningful assessment of learning.

Developed AI-TPACK Capacity-Building Framework

The AI-TPACK Capacity-Building Framework is a structured intervention model designed to strengthen mathematics teachers' competencies in integrating artificial intelligence into instruction. It is composed of four interrelated pillars that collectively address the key dimensions of AI integration. The AI-TPACK Competency Development Pillar focuses on enhancing teachers' AI literacy, prompting skills, instructional design capacity, and ability to evaluate AI-generated outputs critically. The Pedagogical Integration and Instructional Design Pillar emphasizes the use of AI in lesson planning, differentiated instruction, formative and summative assessment, and instructional triangulation to ensure pedagogical alignment.

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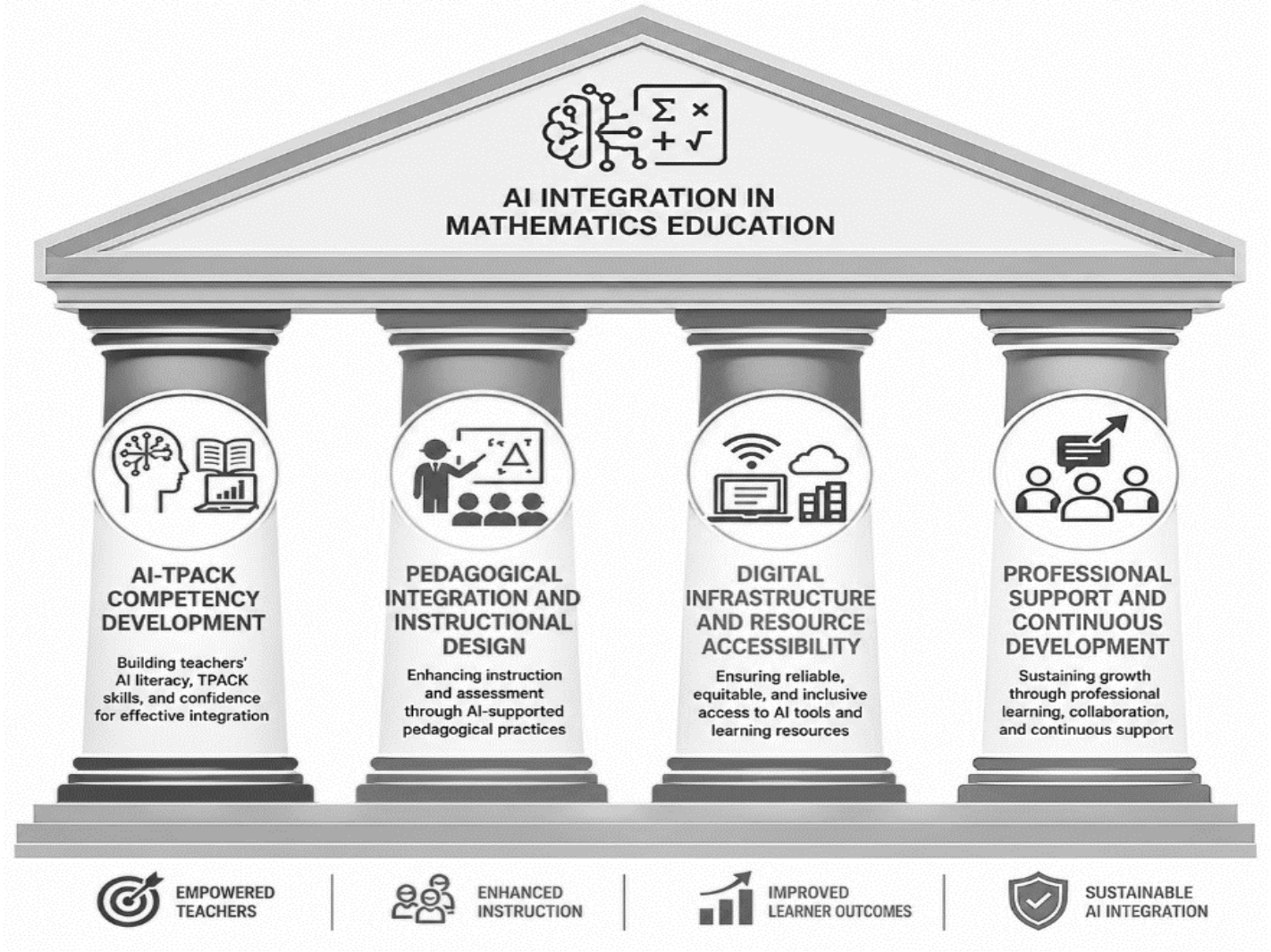


Figure 1. AI-TPACK Capacity-Building Framework for Teachers

The Digital Infrastructure and Resource Accessibility Pillar addresses systemic barriers by improving access to reliable internet connectivity, providing appropriate digital devices, standardizing approved AI platforms, and strengthening ICT support systems within schools. The Professional Support and Continuous Development Pillar ensures sustainability through ongoing professional development, mentoring programs, professional learning communities, and continuous feedback mechanisms that support teacher growth and adaptation to emerging AI technologies.

CONCLUSION

Mathematics teachers in the Schools Division of Siargao are in a transitional stage of readiness for AI-integrated instruction, with foundational to intermediate TPACK competency, moderate access to digital resources, and generally positive but cautious perceptions of AI-driven tools. AI is already used in routine instructional tasks such as lesson preparation, content generation, and formative assessment, yet its integration remains largely functional rather than transformative, with limited use of advanced features and uneven application in pedagogy and assessment. Teachers view AI as moderately easy to use and useful, particularly for improving student engagement and instructional efficiency, but its use is constrained by accessibility issues, technical dependence, and learning complexity. Findings further show that AI competency is primarily shaped by TPACK, educational attainment, and resource availability rather than demographic factors, with TPACK emerging as the strongest predictor of effective integration. Despite its benefits, AI adoption is challenged by infrastructural instability, student overdependence, and the need for continuous validation of outputs, underscoring the central role of teacher judgment. Overall, AI integration reflects both promise and limitation, informing an AI-TPACK Capacity-Building Framework to strengthen teacher competence, pedagogical alignment, and institutional support for sustainable implementation.

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