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AI SELF-EFFICACY AND TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE (TPACK) SYNERGY OF TEACHERS IN USING ARTIFICIAL INTELLIGENCE (AI) IN TEACHING

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Abstract

This study examined the level of Artificial Intelligence (AI) self-efficacy and its relationship to Technological Pedagogical Content Knowledge (TPACK) synergy among teachers in the use of AI for instructional purposes. Employing a descriptive–correlational research design, data were collected from 133 public junior high school teachers through a structured survey questionnaire. Descriptive statistics, including frequency count, percentage, mean, and standard deviation, were used to describe teachers' profiles, levels of AI self-efficacy, and TPACK synergy. Inferential statistical tools such as independent samples t-test, one-way Analysis of Variance (ANOVA), and Pearson product–moment correlation were utilized to determine significant differences and relationships among the study variables. Findings revealed that teachers demonstrated very high levels of content knowledge, pedagogical knowledge, and pedagogical content knowledge, along with a high level of AI self-efficacy in integrating AI into instruction. However, some AI-related TPACK domains were found to be at a developing level. A significant positive relationship was established between AI self-efficacy and TPACK synergy, indicating that higher confidence in using AI supports stronger integration of technology, pedagogy, and content knowledge. Teachers also reported facing challenges such as ethical concerns, student overreliance on AI, limited training, infrastructure constraints, assessment difficulties, and increased workload. Overall, the study concludes that strong AI self-efficacy enhances TPACK synergy and promotes more effective and ethical integration of AI in teaching.

Keywords: *Artificial Intelligence in Education, TPACK Synergy, AI-Self-Efficacy, Challenges and Coping Strategies*

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INTRODUCTION

Over the past years, Artificial Intelligence (AI) has played a significant role in strengthening educational practices. It offers opportunities to enhance teaching strategies and pedagogies through personalized and adaptive instruction, as well as real-time feedback. These tools enable teachers to better understand and address individual differences among learners, leading to improved learning outcomes (Hazzan-Bishara et al., 2025). However, as the adoption of AI tools continues to expand, teachers' roles have become more complex, requiring not only content mastery but also advanced pedagogical and technological competencies.

One framework that supports effective technology integration in education is the Technological Pedagogical Content Knowledge (TPACK) framework, which emphasizes the meaningful interaction among content knowledge, pedagogy, and technology in teaching (Mishra & Koehler, 2006). TPACK highlights that effective technology use arises from the synergy of these domains. Thus, teachers must possess a strong understanding of how to integrate AI into instruction aligned with learning objectives. Teachers' confidence and ability to use AI effectively also play a critical role in successful classroom implementation.

Globally, one of the key factors influencing teachers' adoption of AI is self-efficacy, or their belief in their capability to use AI tools effectively. Studies suggest that teachers with higher AI self-efficacy are more likely to explore and utilize AI in ways that enhance teaching effectiveness and student engagement (Viberg et al., 2024). Despite this, many studies examine TPACK and AI self-efficacy as separate constructs, with limited research exploring their combined influence on instructional practices.

In the Philippine context, particularly in rural areas, AI integration is emerging but remains challenging. Teachers face constraints such as limited access to technological resources, inadequate infrastructure, and insufficient professional development opportunities (Martínez Moreno, 2024). These challenges hinder the effective use of AI and limit the application of TPACK in enhancing instruction. At the local level in Aparri, similar issues persist, compounded by geographic conditions and resource limitations. Moreover, there is a lack of local studies examining the relationship between TPACK synergy and AI self-efficacy, revealing a gap that warrants investigation.

Therefore, this study aims to examine the relationship between TPACK synergy and AI self-efficacy among teachers in Aparri, as well as identify the challenges they encounter and the coping strategies they employ in using AI. By addressing these gaps, the study seeks to provide insights into how these key factors interact within the local context and inform the development of targeted interventions and professional development programs. The findings may guide policymakers, school leaders, and educators in designing context-appropriate initiatives that promote effective and equitable AI integration, ultimately enhancing the quality of education through competent, confident, and motivated teachers.

More specifically, the study sought answers to the following questions:

1. What is the profile of the respondents in terms of:
   - 1.1. Personal Profile
     - 1.1.1. Sex
     - 1.1.2. Age
     - 1.1.3. Civil Status
     - 1.1.4. Highest Educational Attainment
     - 1.1.5. Field of Specialization
   - 1.2. Professional Profile
     - 1.2.1. Years of Teaching Experience
     - 1.2.2. Plantilla Position
     - 1.2.3. Grade Level Taught
     - 1.2.4. Professional Development/Training in ICT or AI
2. How do the teachers gauge their level of self-efficacy in utilizing AI tools in instruction?
3. What is the level of Technological Pedagogical and Content Knowledge (TPACK) synergy among teachers in using AI in teaching along with the following dimensions?
   - 3.1. Content Knowledge (CK)
   - 3.2. Pedagogical Knowledge (PK)
   - 3.3. AI-Technological Knowledge (AI-TK)
   - 3.4. Pedagogical Content Knowledge (PCK)
   - 3.5. AI-Technological Content Knowledge (AI-TCK)
   - 3.6. AI-Technological Pedagogical Knowledge (AI-TPK)
   - 3.7. AI-Technological Pedagogical Content Knowledge (AI-TPACK)
4. Is there a significant difference between the level of TPACK synergy and AI self-efficacy of teachers in using AI in teaching when grouped according to profile variables?
5. Is there an association between the TPACK synergy and AI Self-Efficacy among teachers in using AI in teaching with that of the following:
6. What challenges and coping strategies do teachers have along the use of AI in instruction?

METHODOLOGY

To identify the relationships and differences between teachers' TPACK synergy and AI self-efficacy in using AI in teaching, this study employed a descriptive–correlational research design. The descriptive component focused on teachers' demographic and professional profiles, their levels of TPACK across its different components, and their self-efficacy in using AI for instructional purposes. Meanwhile, the correlational component examined the degree of association between the main variables of the study, specifically determining whether higher levels of AI self-efficacy are associated with stronger AI-TPACK in teaching.

The study was conducted in four (4) public secondary schools in Aparri, namely: Bukig National Agricultural and Technical School (BNATS), Aparri West National High School (AWNHS), Aparri East National High School (AENHS), and Aparri School of Arts and Trades (ASAT). Using Lynch's formula, a total of 133 junior

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high school teachers who had completed at least one full cycle (Phase I to IV) of the Performance Management Evaluation System (PMES) were selected through stratified random sampling, ensuring equitable representation across schools.

A survey questionnaire served as the primary data collection instrument. It consisted of five (5) sections: (1) teachers' demographic and professional profiles; (2) the AI-TPACK scale adapted from Ning et al. (2024); (3) the AI self-efficacy scale adapted from Sumandal (2023); (4) researcher-developed items on challenges encountered in using AI in teaching and coping strategies employed by teachers; and (5) open-ended questions on teachers' real-life experiences regarding challenges and coping strategies in AI use. The questionnaire was pilot-tested and yielded an excellent reliability score across all sections.

The data-gathering procedure followed a systematic and organized process to ensure accuracy and reliability. It began with the development and validation of the research instrument. After finalization, ethical approval was secured to ensure adherence to research ethics. The researcher then obtained permission to conduct the study from the Schools Division Superintendent and the school heads of the participating schools.

Pilot testing was conducted at Camalaniugan National High School. The pilot data were analyzed to determine the reliability of the instrument, which resulted in an excellent reliability rating. After meeting this requirement, the final survey questionnaires were administered.

The questionnaires were distributed either personally or through Google Forms, depending on teacher availability. During the retrieval phase, completed questionnaires were collected and checked for completeness and accuracy, and any unclear responses were clarified. The data were then encoded and organized using Microsoft Excel for secure storage and preparation for statistical analysis. Finally, the analyzed data were used in writing the research report and presenting the study findings during the oral defense.

Data analysis employed various statistical tools to describe variables and examine differences and relationships. Descriptive statistics, including frequency counts, percentages, means, and standard deviations, were used to summarize teachers' profiles, levels of AI self-efficacy, levels of TPACK synergy, and the challenges and coping strategies related to AI use. To determine differences in teachers' TPACK and AI self-efficacy based on profile variables, appropriate inferential statistical tests were applied. Independent samples t-tests and one-way Analysis of Variance (ANOVA) were conducted to identify significant group differences. When significant results were found, Tukey's HSD post hoc test was used to determine specific group differences.

To examine the relationship between AI-TPACK and AI self-efficacy, the Pearson product–moment correlation coefficient was employed to measure the strength and direction of the association between the variables.

Finally, data on challenges and coping strategies were categorized into two themes: challenges and coping strategies. Both were measured using a five-point Likert scale. The challenges scale assessed the level of severity and frequency, while the coping strategies scale measured the extent to which teachers employed various strategies to address AI-related challenges.

All statistical analyses were conducted using a 0.05 level of significance to determine whether the hypotheses were accepted or rejected.

RESULTS AND DISCUSSION

The following are the results and discussion as well as the interpretations of all data collected and analyzed pertinent to this study.

Profile of the respondents

Personal Profile

Table 1a. Frequency and Percentage Distribution of Teachers in terms of Personal Profile Variables

Personal Profile Variables	Frequency (n=133)	Percentage
Sex		
Female	87	65.41
Male	46	34.59
Age		
25-30	24	18.05
31-40	54	40.60
41-50	40	30.08
51-60	15	11.28
Mean	***39.07***	
S.D.	***8.55***	
Civil Status		
Single	44	33.08
Married	88	66.17
Widowed	0	0
Separated	1	0.75
Highest Educational Attainment		
Bachelor's Degree Graduate	17	12.78
With Units in Masters Degree	65	48.87
Masters Degree Graduate	35	26.32
With units in doctorate degree	8	6.02
Doctorate Degree Graduate	8	6.02
Field of Specialization		
Math	20	15.04
Science	25	18.80
English	27	20.30
Filipino	15	11.28

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MAPEH	15	11.28
TLE	12	9.02
Social Science	16	12.03
Values Education	3	2.26

The distribution of respondents by sex, as shown in Table 1a, indicates that out of 133 respondents, the majority are female (87 or 65.41%), while 34.59% (46) are male. This shows that females predominantly constitute the teaching profession.

The table also shows that the largest group of respondents is aged 31–40, comprising 40.60% (54), while the smallest group falls within the 51–60 age range at 11.28% (15). The respondents have a mean age of 39.07 years with a standard deviation of 8.55. These results indicate that most respondents belong to the mid-age range, where the majority are considered digital natives, while a few are digital immigrants.

With regard to civil status, the majority of respondents are married, with 88 individuals or 66.17%. Single respondents account for 44 individuals or 33.08%, while only one respondent (0.75%) is separated.

In terms of highest educational attainment, most respondents (48.9% or 65) have earned units toward a master's degree, making this the largest group. This is followed by those who have completed a master's degree (26.3% or 35). A smaller proportion (12.8% or 17) hold only a bachelor's degree. Meanwhile, 6.0% (8) have units toward a doctorate degree, and another 6.0% (8) have completed a doctorate. The data indicate that the majority of respondents are engaged in postgraduate education, particularly at the master's level.

Lastly, most respondents specialize in English, accounting for 20.30% (27) of the total. This is followed by Science at 18.80% (25) and Mathematics at 15.04% (20). Respondents specializing in Social Science make up 12.03% (16), while Filipino and MAPEH each comprise 11.28% (15). TLE represents 9.02% (12) of the group, whereas Values Education has the smallest proportion at 2.26% (3). Overall, the data show that respondents come from diverse fields of specialization, with English, Science, and Mathematics having the highest representation.

Professional Profile

Table 1b. Frequency and Percentage Distribution of the Teachers in terms of Professional Profile Variables

Professional Profile Variables	**Frequency (n=133)**	**Percentage**
Years of Teaching Experience		
1-5	24	18.05
6-10	43	32.33
11-15	36	27.07
16-20	17	12.78
21 and above	13	9.77
Mean	***11.56***	
S.D.	***7.15***	
Plantilla Position		
Teacher I	39	29.32
Teacher II	5	3.76
Teacher III	76	57.14
Master Teacher I	10	7.52
Master Teacher II	3	2.26
Grade level taught		
Grade 7	36	27.07
Grade 8	33	24.81
Grade 9	28	21.05
Grade 10	36	27.07
Professional Development/Training in ICT or AI 2		
0	121	90.98
1	9	6.77
1-2	2	1.50
3- above	1	0.75

As shown in the grouped data in Table 1b, the lowest proportion of respondents falls under the 21 years and above teaching experience bracket, accounting for only 9.77% (13). In contrast, the highest proportion belongs to the 6–10 years bracket, comprising 32.33% (43) of the respondents. The respondents have a mean teaching experience of 11.56 years and a standard deviation of 7.15, indicating that most respondents are clustered within the mid-range of teaching experience.

The table also reveals that the majority of respondents hold the position of Teacher III, representing 57.14% (76) of the total. This is followed by Teacher I at 29.32% (39). Smaller groups include Master Teacher I at 7.52% (10) and Teacher II at 3.76% (5), while Master Teacher II has the fewest respondents at 2.26% (3).

With regard to grade levels taught, the data show that respondents are fairly evenly distributed across the four grade levels. Grade 7 and Grade 10 have the highest proportion of respondents, each with 27.07% (36) teachers, while Grade 9 has the lowest number at 21.05% (28). This indicates that teachers from all grade levels are adequately represented in the study.

Finally, the data show that most teachers have not attended any ICT or AI-related training. A large majority, 90.98% (121), reported that they had not participated in any training. Only a small number of teachers, 6.77% (9), reported attending one training session. This indicates that very few teachers have engaged in ICT or AI professional development.

Level of self-efficacy in utilizing AI tools in instruction

Table 2. Teacher's level of self-efficacy in utilizing AI tools in instruction

Statement	**Weighted Mean**	**Descriptive Value**
I can craft good questions for students with the help of AI.	4.17	High Level
I can provide an alternative explanation/example when students	4.14	High Level

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need clarification with the help of AI.		
I can develop lesson plans that are fitted to the needs of each student using AI.	4.08	High Level
I can explain difficult lessons in simple instructions with the help of AI.	4.08	High Level
I can use various assessment strategies with the help of AI.	4.08	High Level
I can adjust lessons to the proper level of each student with the help of AI	4.14	High Level
I can present the lesson more engagingly through the help of AI.	4.16	High Level
I can instantly respond to students' difficult questions with the help of AI.	4.04	High Level
I can create relevant content, supplementary materials, and other resources beyond traditional textbooks with the help of AI.	4.10	High Level
I can accurately provide knowledge to students through AI-generated information.	4.05	High Level
I can quickly provide feedback on students' output through the help of AI.	4.05	High Level
I can help students increase their memory of the lessons taught through AI.	3.94	High Level
I can keep students on task on difficult assignments using AI.	3.96	High Level
I can maintain students' discipline with the aid of AI.	3.84	High Level
I can assist parents in using AI for them to monitor their children's school tasks.	3.77	High Level
I can help students think critically using AI.	3.89	High Level
Category Mean	***4.03***	***High Level***

Table 2 presents the teachers' level of self-efficacy in utilizing AI tools in instruction. The weighted mean scores range from 3.77 to 4.17, all of which are interpreted as High Level. The computed category mean of 4.03 indicates that teachers generally possess a strong sense of confidence in using AI to support instructional tasks, including lesson planning, questioning, assessment, feedback provision, and student engagement.

The key findings reveal that teachers demonstrate a high level of confidence in using AI tools in their teaching. This finding is consistent with previous studies, which indicate that teachers tend to feel more confident when digital tools enhance flexibility and efficiency in teaching (Bandura, 2018; Holmes et al., 2019).

Among the indicators, the use of AI to create effective questions for students obtained the highest mean score (4.17). This suggests that teachers are most comfortable using AI to support lesson planning and questioning, as AI tools facilitate idea generation and content development. In contrast, assisting parents in using AI to monitor their children's schoolwork received the lowest mean score (3.77). This may be attributed to limited teacher–parent collaboration and variations in parents' digital competence. Studies likewise indicate that extending AI use beyond the classroom presents challenges related to access, training, and communication (Zawacki-Richter et al., 2019).

Overall, the results on teachers' AI self-efficacy suggest a strong level of confidence in using AI for teaching-related tasks, particularly those directly connected to classroom instruction. However, additional support—such as targeted training focused on parent engagement and classroom management using AI—may further enhance teachers' confidence. Research supports that focused professional development enables teachers to integrate new technologies more effectively into their instructional practices (Darling-Hammond et al., 2017).

Level of Technological Pedagogical and Content Knowledge (TPACK) synergy among teachers in using AI in teaching

Content Knowledge (CK)

Table 3a. Level of Technological Pedagogical Content Knowledge (TPACK) synergy among teachers in using AI in teaching in terms of Content Knowledge (CK)

Statement	**Weighted Mean**	**Descriptive Value**
I possess a strong understanding of the concepts and principles within my discipline.	4.55	Very High
I completely understand the historical evolution of concepts and principles in the subject I teach.	4.41	Very High
I am knowledgeable about how the subject matter I teach can be applied in everyday life.	4.61	Very High
I have a deep understanding of the knowledge structure (organization) of the content I teach.	4.54	Very High
I possess substantial depth of subject-specific knowledge and am highly familiar with the instructional materials and curriculum standards	4.43	Very High
Category Mean	***4.55***	***Very High Level***

Table 3a reveals the level of Technological Pedagogical Content Knowledge (TPACK) synergy among teachers in using AI in teaching in terms of Content Knowledge (CK). The results show that respondents have a very high level of confidence in their subject matter knowledge, as indicated by the category mean of 4.55. All indicators obtained high weighted mean scores, suggesting that respondents believe they have a strong understanding of the concepts, structure, and applications of the subjects they teach.

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The highest weighted mean (4.61) was recorded for the indicator related to applying subject matter knowledge to everyday life. This indicates that respondents are most confident in relating lessons to real-world situations, which may be attributed to the emphasis on practical and contextualized teaching approaches in classrooms. In contrast, the lowest weighted mean (4.41) was observed for understanding the historical development of subject concepts. Nonetheless, this still reflects a high level of confidence. This suggests that teachers tend to feel more confident applying practical skills than explaining the historical or theoretical foundations of their subjects. This observation aligns with previous studies, which indicate that teachers often focus more on practical application than on historical content during instruction (Jeschke et al., 2021; Bjerke & Solomon, 2019).

Overall, the findings indicate that teachers are well prepared to deliver effective and meaningful instruction to students. Their strong confidence in subject matter knowledge supports instructional quality and enhances student learning. However, strengthening teachers' understanding of the historical foundations of their disciplines through targeted professional development may further improve content mastery. Previous research supports the view that strong content knowledge positively contributes to teacher confidence and instructional effectiveness (Shukla, 2024).

Pedagogical Knowledge (PK)

Table 3b. Level of Technological Pedagogical Content Knowledge (TPACK) synergy among teachers in using AI in teaching in terms of Pedagogical Knowledge (PK)

Statement	Weighted Mean	Descriptive Value
I am capable of using variety of divers teaching methods in the classroom	4.42	Very High
I can select appropriate teaching methods based on the instructional content.	4.53	Very High
I can adjust my teaching methods based on the performance or feedback of the students.	4.57	Very High
I possess knowledge of effective classroom organization and management.	4.53	Very High
I take into consideration students backgrounds, interests, motivations, and other needs during teaching.	4.55	Very High
I am proficient in using multiple assessment methods to evaluate students learning outcomes.	4.39	Very High
Category Mean	***4.50***	***Very High Level***

Table 3b presents the level of Technological Pedagogical Content Knowledge (TPACK) synergy among teachers in terms of Pedagogical Knowledge (PK) when using AI tools in teaching. The weighted mean scores range from 4.39 to 4.57, all of which are interpreted as Very High. The category mean of 4.50 indicates a Very High Level overall, suggesting that teachers possess strong pedagogical competence, particularly in selecting teaching strategies, managing classrooms, considering learner diversity, adjusting instruction, and applying assessment methods in AI-supported teaching.

The findings indicate that teachers demonstrate a very high level of pedagogical knowledge, reflecting strong confidence in lesson planning and the use of effective teaching strategies. This aligns with previous studies emphasizing the importance of solid pedagogical knowledge in effective teaching, especially when integrating technology and AI into classroom instruction (Darling-Hammond et al., 2017).

Among the indicators, adjusting teaching methods based on students' performance or feedback recorded the highest weighted mean (4.57). This suggests that teachers are most confident in modifying instruction to address learners' needs, a capability supported by digital tools and AI that facilitate learning monitoring and feedback. Research highlights instructional adaptability as a critical component of effective teaching and successful technology integration (Koehler et al., 2019). Meanwhile, the indicator on using multiple assessment methods obtained the lowest weighted mean (4.39), although it still falls within the Very High category. This result suggests that assessment—particularly in AI-supported learning environments—may require additional training and support. Studies note that assessment in digital contexts is often more challenging than lesson planning (Redecker & Punie, 2017).

Overall, the results suggest that teachers are pedagogically prepared to integrate AI into their teaching practices. They demonstrate strong skills in adjusting instruction to meet diverse learner needs. However, continued professional development—particularly in AI-supported assessment strategies—may further enhance instructional effectiveness. Previous research underscores the importance of sustained professional learning in supporting effective and ongoing technology integration in education (Trust et al., 2020; Darling-Hammond et al., 2017).

AI-Technological Knowledge (AI-TK)

Table 3c. Level of Technological Pedagogical Content Knowledge (TPACK) synergy among teachers in using AI in teaching in terms of AI-Technological Knowledge (AI-TK)

Statement	Weighted Mean	Descriptive Value
I am familiar with commonly encountered AI technologies in the educational environment.	4.04	High
I possess the capability to easily acquire AI technologies necessary for teaching.	3.97	High
I frequently incorporate AI technologies in the pedagogical context.	3.80	High
I am proficient in using AI technologies to enhance the instructional process.	3.75	High
I am knowledgeable about using AI technologies for interactive teaching purposes.	3.75	High
Category Mean	***3.86***	***High Level***

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The level of Technological Pedagogical Content Knowledge (TPACK) synergy among teachers in terms of AI–Technological Knowledge (AI-TK) is presented in Table 3c. The indicators obtained weighted mean scores ranging from 3.75 to 4.04, all of which are interpreted as High. The category mean of 3.86, likewise described as High Level, indicates that teachers possess adequate foundational knowledge of AI technologies and are capable of learning and applying them in teaching, although they are still in the process of further developing their skills.

Teachers' familiarity with common AI technologies earned the highest weighted mean score (4.04). This may be attributed to the increasing use of AI-supported platforms and tools in schools. Conversely, the lowest mean score (3.75) was associated with using AI to enhance instruction and support interactive teaching. This finding suggests that while teachers are generally aware of AI tools, they are less confident in applying them to more advanced and interactive instructional activities. According to Zawacki-Richter et al. (2019), effective AI integration in teaching requires not only technical competence but also pedagogical adjustments, which many teachers are still developing.

Overall, the findings suggest that teachers are ready to use AI but remain in the process of achieving deeper integration. Therefore, professional development initiatives should focus on hands-on training to help teachers better understand how to use AI for instruction, interaction, and teaching strategies. Enhancing teachers' AI technological knowledge may support the transition from basic awareness to meaningful and effective AI use in teaching. Research highlights that sustained training and continuous support are essential in strengthening teachers' confidence and skills in AI integration within educational contexts (Bond et al., 2023; UNESCO, 2021).

Pedagogical Content Knowledge (PCK)

Table 3d. Level of Technological Pedagogical Content Knowledge (TPACK) synergy among teachers in using AI in teaching in terms of Pedagogical Content Knowledge (PCK)

Statement	Weighted Mean	Descriptive Value
I am proficient at formulating curriculum plans with ease.	3.97	High
I am well-acquainted with the focal points and challenging aspects of teaching.	4.20	Very High
I prioritize analyzing students learning situations and am capable of altering instructions to suit their individual needs.	4.23	Very High
I am capable of creating engaging group activities for students.	4.42	Very High
I am aware of the common mistakes students frequently make during their learning process.	4.44	Very High
I can assist students in correcting the learning errors they often commit.	4.44	Very High
Category Mean	***4.28***	***Very High Level***

The level of Technological Pedagogical Content Knowledge (TPACK) synergy among teachers in terms of Pedagogical Content Knowledge (PCK) in using AI in teaching is presented in Table 3d. The recorded weighted mean scores range from 3.97 to 4.44, with descriptive ratings from High to Very High. The category mean of 4.28, described as Very High Level, indicates that teachers demonstrate strong competence in integrating content knowledge with appropriate pedagogical strategies to support student learning.

The findings reveal that teachers possess a very high level of pedagogical content knowledge. They are skilled in identifying students' common misconceptions, creating engaging learning activities, and adjusting instruction to meet learners' needs. This demonstrates teachers' ability to transform subject matter knowledge into effective teaching strategies, which is essential in AI-supported learning environments. These results support previous studies emphasizing the importance of pedagogical content knowledge for effective teaching and technology integration (Darling-Hammond et al., 2017).

Teachers' awareness of common student errors and their ability to address them obtained the highest weighted mean score (4.44). This indicates strong competence in diagnosing learning difficulties and guiding students toward improvement. AI tools that provide real-time feedback and learning analytics further enhance these instructional capabilities. In contrast, the lowest weighted mean score (3.97) was related to creating curriculum plans with ease. Although this score still reflects a high level of confidence, it suggests that curriculum planning in AI-enhanced environments may pose challenges, as teachers must effectively balance content, pedagogy, and technology.

Overall, the results suggest that teachers are well prepared to implement instructional strategies that address student needs, misconceptions, and engagement when using AI in the classroom. However, additional professional development focused on curriculum planning and instructional design in AI-supported environments may further strengthen teachers' pedagogical content knowledge. Research indicates that enhancing PCK contributes to improved teaching quality and more effective integration of emerging technologies such as AI (Ning et al., 2024).

AI Technological Content Knowledge (AI-TCK)

Table 3e. Level of Technological Pedagogical Content Knowledge (TPACK) synergy among teachers in using AI in teaching in terms of AI Technological Content Knowledge (AI-TCK)

Statement	Weighted Mean	Descriptive Value
I am familiar with AI in specific academic domains, such as mathematical intelligent tutoring systems.	3.86	High
I am capable of effortlessly using AI in specific academic domains.	3.83	High
I am proficient in using AI to update my knowledge base within the academic discipline.	3.89	High
I can select appropriate AI tools based on the subject matter I am teaching.	3.84	High

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I am adept at using AI to effectively enhance students' comprehension of the material.	3.83	High
I can use AI to broaden the knowledge horizons of students.	3.95	High
Category Mean	***3.87***	***High Level***

As shown in Table 3e, the level of Technological Pedagogical Content Knowledge (TPACK) synergy among teachers in terms of AI–Technological Content Knowledge (AI-TCK) is presented. The recorded weighted mean scores range from 3.83 to 3.95, all of which are described as High Level. The computed category mean of 3.87, likewise interpreted as High Level, indicates that teachers possess a sufficient level of competence in using AI tools aligned with specific subject areas to support teaching and learning.

The results indicate that teachers demonstrate a high level of AI technological content knowledge. They are capable of selecting and using AI tools appropriate to their subject areas. Teachers utilize AI to enhance their own content knowledge, support students' understanding of lessons, and introduce learners to new ideas and concepts.

Among the indicators, using AI to broaden students' knowledge obtained the highest weighted mean score (3.95). This indicates that teachers feel most confident in using AI to enrich lessons and expose students to broader perspectives. In contrast, the lowest weighted mean score (3.83) was associated with using AI seamlessly within specific subject areas to improve student understanding. This suggests that subject-focused AI integration is more challenging and requires additional technical and pedagogical skills, which teachers are still developing.

Overall, in the domain of AI-TCK, teachers appear prepared but are still progressing toward deeper integration of AI into subject content. Professional development initiatives should therefore focus on helping teachers align AI tools more effectively with subject concepts and learning objectives. Strengthening AI technological content knowledge may support teachers' transition from basic AI use to more meaningful and subject-focused instructional practices. Research emphasizes that continuous training is essential for enhancing teachers' competencies in applying AI to specific subject areas (Holmes et al., 2019; UNESCO, 2021).

AI Technological Pedagogical Knowledge (AI-TPK)

Table 3f. Level of Technological Pedagogical Content Knowledge (TPACK) synergy among teachers in using AI in teaching in terms of AI Technological Pedagogical Knowledge (AI-TPK)

Statement	Weighted Mean	Descriptive Value
I am capable of using AI to enhance my pedagogical perspectives.	3.92	High
I am able to apply appropriate AI in various teaching activities.	3.85	High
I have the capacity to select AI to sustain students' motivation and interest.	3.87	High
I can apply AI to assess the learning outcomes of students.	3.82	High
I am proficient in using AI to optimize classroom instructional management.	3.78	High
I possess the ability to explain information derived from AI to provide real-time feedback.	3.83	High
Category Mean	***3.84***	***High Level***

Table 3f presents the level of Technological Pedagogical Content Knowledge (TPACK) synergy among teachers in terms of AI–Technological Pedagogical Knowledge (AI-TPK). The recorded weighted mean scores in this domain range from 3.78 to 3.92, all of which are described as High. The computed category mean of 3.84, likewise interpreted as High Level, suggests that teachers possess adequate skills in using AI to support instructional activities such as lesson delivery, assessment, classroom management, and feedback provision.

The results indicate that teachers demonstrate a high level of AI technological pedagogical knowledge, reflecting their readiness to integrate AI tools into their teaching practices. Teachers are able to use AI to enhance lesson delivery, increase student motivation, and provide feedback, indicating a growing level of experience in applying AI for instructional purposes. This finding supports previous studies emphasizing that AI should be integrated into pedagogical strategies and instructional planning rather than being treated merely as a technical tool (Ning et al., 2024; Mishra & Koehler, 2006).

As shown in the table, using AI to improve teaching approaches obtained the highest weighted mean score (3.92), suggesting that teachers are most confident in applying AI to lesson planning and content delivery. In contrast, using AI for classroom management yielded the lowest weighted mean score (3.78). This suggests that many teachers still find it challenging to efficiently integrate AI into classroom management during instruction.

In general, the findings in the AI-TPK domain suggest that teachers are generally prepared to use AI but still need to further develop their ability to integrate AI more deeply into teaching practices. Additional professional development focused on classroom management, assessment, and feedback strategies using AI may help strengthen these areas. Research highlights that continuous training and sustained support are essential for the effective and meaningful integration of AI in educational settings (Ning et al., 2024; Mishra & Koehler, 2006).

AI Technological Pedagogical Content Knowledge (AI-TPACK)

Table 3g. Level of Technological Pedagogical Content Knowledge (TPACK) synergy among teachers in using AI in teaching in terms of AI Technological Pedagogical Content Knowledge (AI-TPACK)

Statement	Weighted Mean	Descriptive Value
I am knowledgeable in integrating AI with educational content and teaching methods to improve classroom teaching efficiency and effectiveness.	3.83	High

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I am capable of selecting appropriate teaching methods and AI based on the educational content for instruction.	3.85	High
I can use AI to create, simulate, and adapt scenarios that are in line with the educational content.	3.81	High
I can use personalized AI to select suitable teaching methods as well as guide students in practical learning.	3.74	High
I will use AI for self-directed learning, further deepening my subject knowledge and understanding of educational pedagogical theories.	3.93	High
Category Mean	***3.83***	***High Level***

The level of Technological Pedagogical Content Knowledge (TPACK) synergy among teachers in terms of AI–Technological Pedagogical Content Knowledge (AI-TPACK) is presented in Table 3g. The weighted mean scores across the indicators range from 3.74 to 3.93, all of which are interpreted as High. The category mean for this domain is 3.83, also described as High Level, indicating that teachers possess adequate skills to integrate AI with subject content and pedagogical strategies to support effective teaching and learning.

The findings further reveal that teachers demonstrate a high level of AI-TPACK, suggesting that they are generally prepared to combine AI tools with instructional methods and content knowledge. Teachers are able to select AI tools aligned with their instructional goals, design flexible learning activities, and utilize AI to support their own professional development.

As shown in the table, the use of AI for self-paced learning to enhance subject knowledge and teaching skills obtained the highest weighted mean score (3.93). This indicates that teachers feel most confident using AI for their own learning, as these tools are generally accessible, user-friendly, and support independent study. In contrast, the lowest weighted mean score (3.74) was recorded for the use of personalized AI to support hands-on learning among students. This may be attributed to the increased instructional planning and technical requirements associated with personalized AI applications, which can make classroom implementation more challenging (Holmes et al., 2019).

Overall, the AI-TPACK findings suggest that while teachers are generally prepared to use AI, they are still developing more advanced AI-supported teaching practices. Although teachers show confidence in basic AI use and self-directed learning, additional professional development is necessary to strengthen their capacity to implement personalized and adaptive AI tools for student-centered instruction. Research emphasizes that continuous professional development is essential for enhancing teachers' AI-TPACK and ensuring the effective and meaningful integration of AI in classroom instruction (Darling-Hammond et al., 2017).

Summary

Table 3h. Level of Technological Pedagogical Content Knowledge (TPACK) synergy among teachers in using AI in teaching

Level of Technological Pedagogical and Content Knowledge (TPACK)	**Weighted Mean**	**Descriptive Value**
synergy among teachers		
Content Knowledge (CK)	4.51	Very High Level
Pedagogical Knowledge (PK)	4.50	Very High Level
AI-Technological Knowledge (AI-TK)	3.86	High Level
Pedagogical Content Knowledge (PCK)	4.28	Very High Level
AI Technological Content Knowledge (AI-TCK)	3.87	High Level
AI Technological Pedagogical Knowledge (AI-TPK)	3.84	High Level
AI Technological Pedagogical Content Knowledge (AI-TPACK)	3.83	High Level
Composite Mean	***4.10***	***High Level***

The summary of teachers' TPACK synergy in using AI for teaching across seven domains is presented in Table 3h. The results show that Content Knowledge (CK), Pedagogical Knowledge (PK), and Pedagogical Content Knowledge (PCK) were rated at a Very High Level, while the AI related domains (AI-TK, AI-TCK, AI-TPK, and AI-TPACK) were rated at a High Level. And these seven domains have a composite mean of 4.10, interpreted as High Level, this indicates that teachers demonstrate strong TPACK synergy with solid strengths in content and pedagogy and developing skills in AI integration.

With all the domains, Content Knowledge has the highest mean score (4.51). This shows that teachers are confident in their understanding of the subjects they teach. Also, it is expected on the teacher to have a content mastery which is the key component of lesson preparation and classroom practice. On the other hand, AI TPACK had the lowest mean score (3.83). This indicates that combining AI, teaching strategies, and subject content remains the most challenging process for teachers. Study suggests that, TPACK integration involving technologies like AI requires continuous experience, training, and strong institutional support (Holmes et al., 2019; Mishra & Koehler, 2006).

In general, teachers are strong in instruction yet, ongoing professional development is still needed to strengthen AI integrated teaching skills. Training programs must be the priority to help teachers align AI tools with their pedagogical approaches and subject content. Strengthening AI TPACK can help teachers deliver more effective, efficient, and student centered instruction using AI. Research consistently shows that continuous and focused professional development is essential for successful technology and AI integration in education (Darling Hammond et al., 2017; UNESCO, 2021).

Comparison between the level of TPACK synergy and AI self-efficacy of teachers in using AI in teaching when grouped according to profile variables

Table 4a. Comparison between the level of TPACK synergy when grouped according to profile variables

Profile Variables	**F/t-value**	**p-value**	**Statistical Inference**

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Sex	**2.898**	**0.0044***	**Significant**
Age	**2.893**	**0.0379***	**Significant**
Civil Status	1.134	0.2589	Not Significant
Highest Educational Attainment	**2.549**	**0.0424***	**Significant**
Field of Specialization	1.299	0.2560	Not Significant
Years of Teaching Experience	**2.774**	**0.0299***	**Significant**
Plantilla Position	1.310	0.2696	Not Significant
Grade level taught	0.870	0.4587	Not Significant
No. of Professional Development/Training in ICT or AI 2	0.504	0.6153	Not Significant

Tested at 0.05 level of significance: See appendix C for the post hoc analysis

Table 4a presents the comparison of teachers' TPACK synergy in using AI in teaching when grouped according to personal and professional variables. The results indicate statistically significant differences in TPACK synergy when teachers are grouped by sex ($t = 2.898$, $p = 0.0044$), age ($F = 2.893$, $p = 0.0379$), highest educational attainment ($F = 2.549$, $p = 0.0424$), and years of teaching experience ($F = 2.774$, $p = 0.0299$).

From the table, the result shows that sex found be significant with TPACK synergy, this indicates that male and female teachers differ in how well they integrate AI with teaching strategies and subject content. The post hoc analysis found in Appendix C, further explains this difference. The result shows that male teachers ($M = 4.2865$) have higher TPACK synergy compared to female teachers ($M = 4.0044$), with a mean difference of -0.2821 ($p = 0.0044$). This suggests that male teachers in this group are better able to combine AI with pedagogy and content. These differences could be influenced by factors such as confidence in using technology, prior experience with AI tools, or access to professional learning, rather than actual teaching ability.

This result supports previous studies which indicate that gender differences can affect teachers' confidence and engagement with new technologies, and these factors can influence how technology is integrated into teaching practices (Venkatesh et al., 2016; Scherer et al., 2019).

On the other hand with respect to age, teachers of different ages do not show the same level of AI integration in teaching. As reflected in Appendix C, the post hoc analysis for age, indicates that the significant differences, mainly occur between younger teachers and those aged 51 and above. Specifically, teachers aged 30 and below and those aged 31-40 demonstrated significantly higher TPACK synergy compared to teachers aged 51 and above ($p = 0.0097$; $p = 0.0187$). No significant differences were found among the younger and middle aged groups. This suggests that older teachers may experience more difficulty integrating AI into instruction, this is because they had less exposure to digital and AI based technologies during their initial training. Studies show that age can affect teachers' ability to adapt to new technologies, and that younger teachers often show higher digital confidence and fluency in technology rich learning environments (Scherer et al., 2019; Mishra & Koehler, 2006).

Highest educational attainment also shows a significant difference in teachers' TPACK synergy ($F = 2.549$, $p = 0.0424$). This means that teachers with higher academic qualifications generally demonstrate stronger ability to integrate AI with teaching strategies and subject content. The post hoc analysis in Appendic C shows that doctorate degree holders ($M = 4.3558$) have significantly higher TPACK synergy than master's degree holders ($M = 3.8703$) ($p = 0.0225$). In addition, teachers with units in a master's degree ($M = 4.1712$) also show higher TPACK synergy compared to full master's graduates ($p = 0.0084$). These results suggest that continued academic study and advanced education help teachers improve their ability to use AI effectively in teaching. Higher levels of education may expose teachers to research based practices, innovation, and reflective thinking, which support stronger TPACK synergy. This finding agrees with previous studies showing that advanced professional and academic preparation strengthens teachers' instructional skills and technology integration abilities (Darling Hammond et al., 2017; Bond et al., 2023).

Lastly, years of teaching experience is found also significant which means that teachers' ability to integrate AI with teaching methods and content varies depending on how long they have been teaching. The post hoc analysis found in Appendix C indicates that teachers with 1-5 years and 6-10 years of teaching experience have significantly higher TPACK synergy than those with 21 years or more of experience ($p = 0.0070$; $p = 0.0060$). No significant differences were found among teachers with fewer than 20 years of experience. This suggests that early career and mid-career teachers may find it easier to integrate AI because they are more exposed to technology supported teacher education and modern teaching practices.

Study shows that while teaching experience strengthens instructional skills, ongoing professional learning is important for effectively using new technologies such as AI (Scherer et al., 2019; Mishra & Koehler, 2006).

Table 4b. Comparison between the self-efficacy of teachers in using AI in teaching when grouped according to profile variables

Profile Variables	**F/t-value**	**p-value**	**Statistical Inference**
Sex	1.257	0.2109	Not Significant
Age	0.971	0.4084	Not Significant
Civil Status	0.289	0.7734	Not Significant
Highest Educational Attainment	0.626	0.6448	Not Significant
Field of Specialization	1.643	0.1294	Not Significant
Years of Teaching Experience	0.955	0.4348	Not Significant

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Plantilla Position	1.084	0.3672	Not Significant
Grade level taught	0.813	0.4889	Not Significant
No. of Professional Development/Training in ICT or AI 2	0.154	0.8779	Not Significant

Tested at 0.05 level of significance

Table 4b shows the comparison between teachers' self-efficacy in using AI for teaching based and their profile variables. The result indicates that there are no significant differences among the groups of variables.

This means that teachers have similar levels of AI self-efficacy in using AI tools regardless of their personal or professional backgrounds. This also suggests that teachers' AI self -efficacy could be influenced more by shared experiences, school environments, and access to AI resources. Hence, it is through individual's personal characteristics, as confidence in technology use often develops through common learning opportunities and supportive contexts (Bandura, 2018; Scherer et al., 2019).

Table 5. Correlation between the TPACK synergy among the teachers in using AI in teaching with that of their level of self-efficacy in utilizing AI tools in instruction

	r-value	**p-value**	**Statistical Inference**
Level of self-efficacy in utilizing AI tools in instruction	**0.7022**	**0.0001***	**Significant**

Tested @ 0.05 level of significance

The table 5 presents the correlation between the TPACK synergy of teachers in using AI in teaching and their level of self-efficacy in utilizing AI tools in instruction. The results indicate that AI self-efficacy have a significant and strong positive relationship with TPACK, as shown by the high correlation coefficients for self-efficacy (r = 0.7022, p = 0.0001). This means that teachers who feel more confident in using AI tools are better able to combine AI with teaching strategies and subject content.

Self-efficacy plays an important role in developing effective AI supported teaching. When teachers believe they can use AI well, they are more willing to try AI tools, use it their lessons, and connect them to learning goals. Bandura's (2018) self-efficacy theory, highlights confidence as a key factor influencing behavior and persistence. TPACK framework also emphasizes that effective technology integration requires confidence in applying knowledge across technology, pedagogy, and content (Mishra & Koehler, 2006).

Challenges and coping strategies do teachers have along the use of AI in instruction

Table 6a. Challenges encountered of teachers have along the use of AI in instruction

Statement	**Weighted Mean**	**Descriptive Value**
I feel inadequately trained to use AI tools effectively in my teaching practice.	3.93	Serious Challenge
Insufficient digital literacy skills make AI integration in teaching difficult.	4.03	Serious Challenge
The cost of acquiring and maintaining AI tools is a major challenge for my institution.	3.95	Serious Challenge
Access to the necessary infrastructure (e.g., hardware, stable internet) is limited.	4.02	Serious Challenge
I am concerned about data privacy and security when using AI in teaching.	4.14	Serious Challenge
Using AI tools reduces face-to-face interaction with students.	4.01	Serious Challenge
I worry that students become overly reliant on AI instead of developing critical thinking.	4.26	Very Serious Challenge
I find that AI sometimes provides inaccurate or biased outputs that affect teaching.	4.08	Serious Challenge
It is difficult to evaluate students' learning accurately when AI tools are used frequently.	4.15	Serious Challenge
There is a lack of policies or guidelines to govern the ethical use of AI in education.	4.15	Serious Challenge
AI tools are not always accessible to all students, leading to unequal learning opportunities.	4.13	Serious Challenge
I find AI tools difficult to integrate with existing classroom curriculum and activities.	3.89	Serious Challenge
The use of AI increases my workload because I must monitor and correct automated outputs.	3.88	Serious Challenge
AI implementation has created ethical concerns about academic honesty and cheating.	4.12	Serious Challenge
I am worried that the increasing use of AI might change the traditional role of the teacher negatively.	4.08	Serious Challenge
Category Mean	**4.05**	**Serious Challenge**

The challenges teachers experience in using AI for instruction are shown in Table 6a. it can be reflected that the weighted mean scores obtained ranged from 3.88 to 4.26, with most items rated as a Serious Challenge and one item rated as a Very Serious Challenge. While the overall category mean of 4.05, interpreted as

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a Serious Challenge, indicates that teachers view AI related challenges as significant and influential to their teaching practices.

From the table, the highest average score (4.26) was related to the concern that students become overly dependent on AI instead of developing their critical thinking skills. This shows that teachers have strong ethical and pedagogical concerns, as they worry that excessive AI use may reduce students' thinking, engagement, and independent learning. This concern is supported by earlier studies that caution against unguided AI use and emphasize the important role of teachers in developing higher order thinking skills (Zawacki Richter et al., 2019).

The lowest average score (3.88) obtained in contrast was associated with the increased workload involved in reviewing and correcting AI generated outputs. This indicates that workload concerns are less critical than ethical and learning related issues. Research indicates that workload concerns may lessen as teachers gain more experience and as AI tools become more accurate and reliable (Bond et al., 2023).

From the responses of teachers gathered from the open ended questions, the following challenges were also mentioned in relation to the scaled responses, "lack of proper training," "lack of devices and facilities", "unreliable and slow internet connection," "difficulty checking AI generated answers," and "students copying AI outputs without understanding." These statements further support the result of the survey pertaining to challenges encountered in using AI during instruction.

In general pertaining to challenges encountered, The results show that ethical issues, lack of skills, and limited infrastructure remain ongoing challenges in AI supported education. Teachers' experiences highlight the need for balanced use of AI, supported by effective teaching practices, strong institutional support, and clear policies to make sure AI improves rather than disrupts teaching and learning.(Holmes et al., 2019; UNESCO, 2021).

Table 6b. Teacher's coping strategies along the use of AI in instruction

Statement	**Weighted Mean**	**Descriptive Value**
I seek out professional development opportunities to improve my AI teaching skills.	4.15	Effective
I collaborate with colleagues to share effective AI teaching practices.	4.12	Effective
I adjust my lesson plans to include meaningful roles for AI tools.	3.95	Effective
I use AI to reduce routine administrative tasks so I can focus on teaching.	4.05	Effective
I help students understand how to use AI responsibly and ethically.	4.11	Effective
When I encounter technical issues with AI tools, I practice problem-solving to find solutions.	4.04	Effective
I reflect on my experiences after using AI in class to improve future practices.	4.08	Effective
I integrate AI use guidelines or class policies to manage AI use by students.	3.94	Effective
I adapt instructional strategies to ensure AI supports critical thinking, not replaces it.	3.96	Effective
I seek feedback from students about how AI tools affect their learning.	4.02	Effective
I steadily build my confidence in using AI through trial and experience.	4.01	Effective
I balance AI use with human-centered teaching to maintain engagement.	4.11	Effective
I follow ethical principles and data privacy standards when using AI.	4.08	Effective
I use AI tools to personalize instruction based on students' individual needs.	3.98	Effective
I stay updated with research and best practices on AI in education.	3.91	Effective
Category Mean	***4.03***	***Effective***

Table 6b presents the coping strategies employed by teachers in using AI in instruction. It can be seen from the table that, the weighted mean scores range from 3.91 to 4.15, all interpreted as Effective. While, the computed category mean has a value of 4.03 described also as Effective. This indicates that teachers usually use proactive and thoughtful approaches to handle the challenges of using AI, focusing on improving their skills, working with others, following ethical practices, and using AI in a balanced way during instruction.

Focusing on the highest average score (4.15) which is seeking for professional development to improve AI teaching skills. This result shows that teachers understand the importance of continuous learning in handling AI related challenges. On the other hand, the lowest average score (3.91) was for keeping up with AI research and best practices. Although still effective, this suggest that teachers face time limits and limited access to research resources, which is common among practicing educators (Bond et al., 2023).

Recorded responses from the open ended questions also further reinforce the results on coping strategies in using AI. Teachers reported strategies such as "attending webinars and trainings," "asking help from colleagues," "setting clear rules on AI use," and "guiding students to think critically rather than just copying AI answers." Others also written "trial first before using," "self-study using YouTube," and "balancing AI with traditional teaching." These responses show that teachers mainly depend on continuous professional learning, support from colleagues, reflection on their teaching practices, and ethical guidelines to make sure that AI supports meaningful learning rather than replaces it.

In general, successful use of AI use depends not only in technical skills but also reflection, ethical awareness, and collaboration. Teachers' responses show that human judgment remains important in guiding how AI is used, making sure that technology supports teaching goals instead of weakening them. (Holmes et al., 2019; UNESCO, 2021).

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Conclusion

The study established that teachers from the junior high school in Aparri possess high self-efficacy and strong pedagogical foundations toward the use of Artificial Intelligence (AI) in teaching. It also indicates the readiness of teachers for AI supported instruction. However, the developing level of AI related TPACK and the presence of ethical, teaching, and contextual challenges show that teachers need to be more organized with continuous support. The strong relationships between TPACK and self-efficacy suggest that by increasing their confidence to use AI effectively in teaching this will improve the teachers' integrated AI skills eventually.

Recommendations

Based on the study's findings, it is recommended that the Schools Division Office of Cagayan design and implement sustained, PPST-aligned professional development programs focused on enhancing teachers' AI-related TPACK domains (AI TK, AI TCK, AI TPK, and AI TPACK) through hands-on, classroom-embedded, and ethically guided training. Teachers should actively engage in continuous professional learning, including peer mentoring and reflective practices, to strengthen their AI self-efficacy. School administrators are encouraged to establish clear school-based policies on the ethical and responsible use of AI, addressing concerns such as academic dishonesty, data privacy, and student overreliance. ICT coordinators should lead capacity-building initiatives by conducting regular workshops and coaching sessions on AI tools, while DepEd and policymakers must ensure access to appropriate AI technologies, reliable infrastructure, and technical support. Future researchers may further examine the long-term impact of AI-TPACK-focused professional development across different grade levels, subject areas, and educational contexts.

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The author hereby declares that this paper is his original work and there is no any conflict of interest.

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