

Exploring the Influence of Artificial Intelligence Adaptation on Pre-Service Science Teachers' Pedagogical Content Knowledge

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ABSTRACT

Background and Objectives: In the 21st century learning environment, the integration of emerging technologies has transformed the educational landscape. For pre-service science teachers, the challenge lies in developing strong pedagogical content knowledge (PCK) while also adapting to rapidly evolving technologies. This study aimed to explore how Artificial Intelligence (AI) tools influence the development of PCK among pre-service science teachers in the fields of physical and biological sciences. Specifically, it investigated their lived experiences of adapting to AI in lesson planning, instruction, and assessment, contributing to the broader discourse on AI integration in teacher education.

Methodology: This qualitative study employed a descriptive phenomenological approach to capture the authentic experiences of six (n = 6) fourth-year pre-service science teachers specializing in physical and biological sciences at a state university in Bataan, Philippines. Participants were selected via purposive sampling based on their documented experience with AI tools in coursework and teaching demonstrations. Data were analyzed using descriptive phenomenological procedures, including bracketing, horizontalization, clustering, and textualization to identify the essence of participants' experiences.

Results: The findings revealed that AI has a significant influence on all five domains of PCK. In teaching orientation, pre-service teachers embraced learner-centered strategies but raised concerns about AI's pedagogical implications. For curricular knowledge, AI was useful in aligning instruction with standards, though participants emphasized its limitations in content depth. Instructional strategies were enhanced through AI-powered simulations and visuals, promoting interactivity. In the assessment, AI improved accuracy and efficiency, yet participants stressed the importance of teachers' professional judgment. Lastly, regarding understanding learners, AI was seen

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as supportive, but concerns remained about its ability to address emotional and contextual learning factors.

Discussions: AI is instrumental in supporting learner-centered approaches, promoting differentiated instruction, and aligning lesson plans with curricular standards. These themes indicate that AI can enhance teacher preparedness by offering practical solutions for instructional planning and responding to the diverse needs of learners. Pre-service teachers leverage AI to create meaningful learning experiences and more efficient assessments, yet they also express valid concerns about overreliance, equity, and the need for human judgment. The themes collectively underscore the dual role of AI as an enabler of innovation and as a potential source of pedagogical tension. These findings emphasize the importance of integrating training in AI use within teacher education to inform policy at the classroom and institutional levels, promoting ethical and pedagogically sound practices.

Conclusions: Pre-service science teachers view AI as a helpful tool for lesson planning, assessment, and tailoring instruction to learner needs. AI supported teachers in generating materials, aligning lessons with curricular standards, and providing differentiated strategies. However, challenges such as overreliance on AI, risks to learners' critical thinking, and the need for teacher oversight were also identified. While AI can enhance pedagogical content knowledge (PCK) and classroom practice, its effectiveness depends on thoughtful integration and continued professional development. These findings have implications, especially for educators and policymakers in comparable teacher education contexts, emphasizing the need to bridge the gap between technological advancement and pedagogical effectiveness.

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Introduction

Background and Rationale

AI technology adoption is evident across multiple sectors in the Philippines, including education. The integration of artificial intelligence (AI) into education represents a significant transformation, holding the potential to reshape teaching and learning across various disciplines. Broadly, AI in education encompasses various forms, including generative AI (GenAI) for content creation and instructional design, predictive AI for learner performance analytics, and adaptive learning systems that tailor educational pathways to individual needs. This is particularly critical in science education, where pedagogical content knowledge (PCK) plays a

pivotal role in ensuring effective and meaningful instruction (Almonacid-Fierro et al., 2023). As AI continues to drive innovation and productivity in various aspects of society, its integration into science education is not merely an option but a necessity for preparing future generations of scientists and innovators. The importance of its integration lies in its capacity to enhance teaching methodologies, personalize learning experiences, and develop critical thinking among learners (Onesi-Ozigun et al., 2024).

Pedagogical content knowledge is a multifaceted construct that embodies a teacher's professional expertise, encompassing knowledge of subject matter, understanding of teaching and learning principles, and the ability to translate this knowledge into effective instructional practices (Ning et al., 2024). More specifically, PCK includes understanding learning requirements, identifying learners' areas of difficulty, utilizing science-specific strategies, selecting appropriate assessment methods, interpreting assessment results, and possessing a clear orientation to science teaching (Ligsanan & Peria, 2024). In doing so, PCK requires an equal mastery of core scientific content alongside these pedagogical strategies, ensuring teachers can navigate complex subject matter accurately. In the context of AI integration, pre-service teachers face the dual challenge of developing strong PCK, deepening both their subject matter expertise and instructional methods, while simultaneously adapting to rapidly evolving technologies. This adaptation necessitates integrating AI technologies into their developing PCK to enhance their understanding of teaching, learning, and the representation of complex science content. The integration of AI into science education requires a new framework, Artificial Intelligence-Technological, Pedagogical, and Content Knowledge (AI-TPACK), that explores the complex connections between technology, pedagogy, and content knowledge (Ning et al., 2024).

Despite the potential benefits of AI in science education, significant challenges persist in its effective integration and its impact on PCK development among pre-service science teachers. One of the primary challenges is the potential for overreliance on AI and the need for clear assessment guidelines (Anselmo et al., 2025). Additionally, concerns about academic integrity arise as learners may rely too heavily on AI, resulting in work that does not reflect their own understanding (Wirzal et al., 2024). Furthermore, Park et al. (2023) noted that increasing teachers' professionalism and efficacy in AI knowledge, skills, and tools is the most urgent and fundamental task. Another challenge lies in the limitations of AI in addressing the complexities of curriculum improvement, emphasizing the ongoing need for human judgment and expertise alongside AI support (Kotsis, 2024). These challenges stress the importance of carefully considering the pedagogical implications of AI integration and developing strategies to mitigate potential negative consequences.

In teacher education programs at a state university in Bataan, Philippines, pre-service science teachers are currently navigating the transition from theoretical training to the practical demands of the classroom. They face persistent challenges in developing strong PCK, especially in aligning lessons with curriculum standards, addressing learners' misconceptions, and applying higher-order thinking skills (HOTS) in science teaching (Orbe et al., 2018). These developmental hurdles highlight a significant disconnect between the rapidly evolving expectations of the modern science curriculum and the traditional methods of teacher preparation. Although AI tools such as ChatGPT, Gemini, and educational simulations are increasingly accessible, their integration into pre-service teacher education remains limited. Pre-service teachers often explore AI independently, without structured training in its

pedagogical or ethical use, which compromises the authenticity of their instructional design. This raises risks of underutilization or overreliance, which may hinder the balanced development of PCK during their formative professional years.

Despite growing international scholarship on AI and teacher competencies (Blonder et al., 2025; Ning et al., 2024), localized studies examining how AI adaptation shapes pre-service teachers' PCK in the Philippine context are scarce. This gap emphasizes the need for research that captures the lived experiences of pre-service science teachers as they engage with AI, thereby informing curriculum innovation and teacher preparation programs.

Addressing this gap, the study explores how pre-service science teachers in a state university in Bataan adapt AI tools in lesson planning, instruction, and assessment, and how such experiences influence their developing PCK. This study is expected to generate an enhanced understanding of how AI influences the development of pre-service science teachers' PCK. Findings may contribute to the formulation of an AI-integrated PCK framework and practical guidelines for teacher education institutions, bridging gaps between curriculum expectations and actual classroom preparation. Therefore, these insights may inform the design of structured AI training modules for pre-service teachers and in-service teachers, curriculum revisions in science education programs, and policy directions promoting ethical, equitable, and pedagogically sound AI use.

Objectives of the Study

1. To describe how pre-service science teachers perceive, interpret, and integrate AI technologies into their developing PCK.
2. To examine the impact of AI adaptation on pre-service science teachers' understanding of teaching, learning, and subject matter, ultimately contributing to a deeper understanding of how AI can be effectively leveraged in teacher education to enhance PCK.

Review of Literature

While numerous studies have explored PCK, there is a notable gap in research specifically focusing on modeling and developing PCK for science teachers in the context of AI integration (Blonder et al., 2025). The existing literature offers insights into the general facets of PCK and the challenges faced by science teachers, but lacks a comprehensive examination of how AI adaptation influences the development of pre-service science teachers' PCK while maintaining teacher agency and professional judgment. These experiences elaborate on the complex and multifaceted nature of AI integration in science education and the importance of knowledge components (Ning et al., 2024). Studies reveal that core knowledge elements (PK, CK, and AI-TK) indirectly influence AI-TPACK through composite knowledge elements like PCK, with technology-related components showing greater explanatory power than non-technical elements (Ning et al., 2024). AI technologies, particularly Artificial Intelligence in General Context (AIGC), demonstrate effectiveness in creating personalized learning experiences and enhancing learner engagement in PCK teaching, especially in higher education contexts like biochemistry courses (Su et al., 2024). Generative AI tools offer transformative opportunities for evaluating and developing PCK among pre-service science teachers through interactive dialogues that reveal their understanding of content and pedagogy (Blonder et al., 2025).

Another study identified a critical gap in examining the extensive and long-term impacts of AI usage in education, emphasizing the need for in-depth inquiry into whether AI integration aligns with educational values, such as fostering critical thinking (Christou, 2024). A qualitative study reveals mixed responses to AI integration, with teachers anticipating significant shifts in their pedagogical roles while expressing concerns about ethical implications and educational equity (Alshehri, 2023). Meanwhile, Kumar (2025) emphasizes that, despite the opportunities AI offers to enhance learners' assessment methods and learning experiences, careful consideration of effective and responsible integration remains a challenge that requires developing AI literacy among future educators.

More recently, pre-service teachers primarily utilize AI tools for lesson planning, conceptual clarification, and designing differentiated instruction, with AI serving as cognitive partners in educational preparation (Spasopoulos et al., 2025). Teachers' pedagogical orientations significantly influence their AI adoption patterns, with some viewing AI as a supporting tool while others perceive it as a teaching assistant and pedagogical collaborator (Shi et al., 2024). However, integration remains fragmented and experimental, often confined to technology-related courses without structured pedagogical guidance, leading to superficial use and limited critical evaluation of AI-generated content (Spasopoulos et al., 2025). Teacher readiness varies considerably based on gender, educational background, and concerns over data privacy, with significant barriers including limited resource access and insufficient professional development (Alshorman, 2024). These findings signify the need for targeted training programs, institutional frameworks, policy development, and AI literacy development to support effective integration.

Methodology

Research Design

This study employed a phenomenological research design, which was particularly suited for exploring the lived experiences of individuals in a specific context. Phenomenology seeks to understand and describe the subjective experiences of participants, focusing on the meaning and essence of these experiences (Moustakas, 1994). This approach was ideal for this study as it aimed to capture the nuanced experiences of pre-service science teachers integrating AI into their pedagogical practices, allowing for a deep understanding of how AI influences their PCK.

Sampling

This study employed purposive sampling, a method where participants were selected based on their relevance to the research question. Purposive sampling is particularly suitable for phenomenological research, as it ensures that participants possess the necessary experiences to provide rich, detailed data (Creswell, J. W. & Creswell, J. D., 2017). In this case, participants were chosen because they are pre-service teachers with experience in integrating AI into their teaching practices, aligning with the inclusion criteria.

Participants were included if they were pre-service teachers specializing in science within the Bachelor of Secondary Education program at a state university in Bataan. Specifically, the study involved six participants: three majoring in physical sciences and three in biological sciences. Participants were required to have experience with AI tools in their teaching practices. Exclusion criteria included pre-service teachers without experience in AI integration and those

specializing in non-science fields (e.g., linguistics, social sciences) to ensure the study's scope remains focused on the scientific field.

Participants' Profile

Table 1
Participants' Demographic Information

No.	Code Name	Gender	Age	Grade Level Taught	Specialization
P1	Teacher A	Female	22	Grade 9	Biology
P2	Teacher B	Male	23	Grade 10	Physics
P3	Teacher C	Male	22	Grade 10	Biology
P4	Teacher D	Female	25	Grade 7	Biology
P5	Teacher E	Female	22	Grade 7	Physics
P6	Teacher F	Female	21	Grade 8	Physics

Table 1 provides a comprehensive overview of the participants' demographic information, their specialization, and the grade levels of the learners they taught. The sample consists of four females and two males, ranging in age from 21 to 25 years old. All participants were fourth-year pre-service teachers with an equal distribution of specializations, three from the biology group and another three from the physics group. In terms of their field experience, two taught Grade 7, two taught Grade 10, one taught Grade 9, and one taught Grade 8 in different public secondary schools. This diverse sample ensured a varied and broad perspective from pre-service teachers engaged in teaching practice.

Instrument

The study utilized a semi-structured interview protocol as the primary research instrument. It was designed to systematically explore how pre-service science teachers integrate AI into their PCK. The protocol was developed to capture participants' lived experiences across five core domains: Orientation in Teaching Science, Knowledge of the Curriculum, Knowledge of Strategies, Knowledge of Students in Learning Science, and Knowledge of Assessment. The instrument underwent an expert review by three science education experts to ensure content validity and refine question clarity and flow. Table 2 presents the key interview domains and representative questions used.

Table 2
Semi-Structured Interview Protocol Domains and Sample Questions

PCK Domain	Sample Question
Orientation in Teaching Science	In what ways do you think AI can support or enhance your teaching orientation?
Knowledge of the Curriculum	Can you provide examples of how AI could assist in identifying gaps or areas for improvement within the curriculum?

Table 2*(Cont.)*

PCK Domain	Sample Question
Knowledge of Strategies	How do you think AI tools could support these strategies? For example, could they assist in creating simulations or interactive models?
Knowledge of Learners in Learning Science	How might AI tools help you better understand individual learner needs or learning styles?
Knowledge of Assessment	What are your concerns about using AI for assessment purposes, such as fairness or accuracy?

To ensure the trustworthiness of the findings, the study employed several qualitative rigor strategies. Member checking was conducted by providing participants with summaries of their interview transcripts to verify the accuracy of their accounts. Peer debriefing was facilitated through regular discussions with colleagues to challenge researchers' interpretations and minimize bias. Finally, an audit trail was maintained, documenting all data collection steps, coding decisions, and thematic developments to ensure transparency and dependability of the analytical process.

Data Collection Procedures

Phase 1 Securing Authorization

The study began by securing authorization from the campus director of Dinalupihan Campus of Bataan Peninsula State University. This step was crucial for ensuring that the research aligned with institutional policies and procedures.

Phase 2 Acquiring Consent

Participants were provided with an informed consent form that outlined the purpose of the study, the procedures involved, potential risks and benefits, and their rights as participants. The consent process adhered to research ethics guidelines, ensuring that participants understand they can withdraw at any time without penalty. Participants signed the consent form before proceeding with the study.

Phase 3 Scheduling the Interviews

A semi-structured interview protocol guided the conversations, structured to systematically explore pre-service science teachers' integration of AI into five core domains of PCK: Orientation in Teaching Science, Knowledge of the Curriculum, Knowledge of Strategies, Knowledge of Learners in Learning Science, and Knowledge of Assessment. The protocol utilized open-ended, non-leading questions designed to elicit deep insights into participants' lived experiences, perceptions, and pedagogical decision-making processes regarding AI tools. Interviews were scheduled at times convenient for the participants, lasting approximately one hour each. This approach allowed for flexibility and depth in exploring participants' experiences with AI integration.

Phase 4 Debriefing Session

In the event that participants experience distress during the interviews, a debriefing session was conducted with the support of a registered guidance counselor. This ensured that participants received necessary support and care, aligning with ethical research practices.

Data Analysis

Data analysis included a descriptive phenomenological approach, focusing on identifying and describing the essence of participants' experiences with AI integration. This involved coding and thematic analysis to uncover patterns and themes in the data, ensuring that the findings are grounded in participants' lived experiences (Moustakas, 1994). Descriptive phenomenology, as outlined by Moustakas (1994), provides a detailed and accurate account of a participant's lived experiences with a phenomenon, specifically aiming to capture its pure essence without imposing external interpretations or assumptions. This required the researchers to rigorously practice bracketing, which is a continuous process of setting aside all previous understandings, biases, scientific theories, claims, and personal views to ensure the analysis was based solely on the participants' perspective. While bracketing was rigorously employed to minimize researcher bias, it was important to acknowledge that phenomenological research inherently relies on participants' subjective accounts and the researcher's interpretive process. Consequently, the findings may have been shaped by researcher subjectivity and the limitations of self-reported data. To uphold methodological transparency and trustworthiness, the researchers critically examined their assumptions throughout the coding and thematic development phases to ensure the analysis remained as grounded as possible in the raw data. The analysis followed four key steps that start with: (1) Bracketing, which involved disregarding researcher biases, followed by (2) Horizontalization (treating every participant statement as equally important), (3) Clustering (grouping similar statements into emergent themes), and finally, (4) Textualization (producing a comprehensive, essential description of the phenomenon).

Ethical Considerations

This phenomenological study on the influence of AI adaptation on pre-service teachers' PCK adhered to ethical standards to ensure the well-being and rights of participants were protected.

Protection Mechanisms for Vulnerable Participants

Although the participants were not typically considered vulnerable, appropriate mechanisms were in place to protect them. A debriefing session with a registered guidance counselor was available if participants experienced distress during the interviews. This ensured that participants received the necessary support and care, aligned with ethical research practices.

Probable Risks to Human Participants

The probable risks to human participants in this study were minimal, primarily related to potential emotional distress during the interviews. However, the risk was considered low given the nature of the questions and the availability of support mechanisms.

Risk/Benefit Balance

The protocol adequately addressed the risk/benefit balance. The benefits of the study, including contributing to the understanding of AI integration in education and enhancing teacher preparation, outweighed the minimal risks involved. Participants gained insights into their practices and contributed to educational research, which could inform future teacher education programs.

Informed Consent Procedure

The informed consent procedure was conducted following the ethical guidelines. Participants were provided with a detailed consent form that outlined the purpose of the study, the procedures involved, potential risks and benefits, and their rights as participants. They were advised of their right to withdraw from the study at any time without penalty. The consent form was culturally appropriate and accessible to ensure participants fully understood their involvement.

Training and Experience of Researchers

All researchers involved in this study were science professors at a state university, ensuring they had a deep understanding of educational contexts and research methodologies. One of the researchers was also a member of the ethics committee, providing additional expertise in ensuring that ethical standards were met throughout the study. This combination of academic and ethical expertise ensured that the study was conducted with integrity and respect for participants.

Appropriateness of Research Facility

The research facility was appropriate for conducting in-depth interviews. The setting was comfortable and private, ensuring participants felt secure and able to share their experiences openly. The facility was equipped with the necessary amenities to support the interviews and any subsequent debriefing sessions.

Findings

The interview transcripts were meticulously coded, yielding a total of 185 distinct codes. These codes were then grouped to develop key themes across different facets of PCK. For orientation to science teaching, 43 codes were used to identify key themes, while 39 codes contributed to key themes related to knowledge of the curriculum. Knowledge of strategies was represented by 36 codes, and knowledge of learners in learning science was informed by 35 codes. Finally, 34 codes were used to produce key themes concerning knowledge of assessment. This thorough coding process allowed for a comprehensive understanding of the various facets of teachers' professional knowledge and the integration of AI into their developing PCK. The facets of PCK include teachers' orientation in teaching science, knowledge of the curriculum, knowledge of strategies, knowledge of students in learning science, and knowledge of assessment (Ligsanan & Peria, 2024). This served as one of the theoretical references leading the study in a certain direction. To clarify the influence of AI on these domains, the following sections synthesize participant experiences, emphasizing how AI functions as both a structural scaffold and a source of pedagogical tension.

Influence of AI on Orientation to Science Teaching

This study investigated science teachers' orientations toward science teaching, focusing on their instructional practices and the integration of AI tools within their pedagogy. The qualitative data provided valuable insights into how teachers conceptualized and enacted their teaching orientation, balancing learner-centered and activity-driven approaches with the practical use of AI to support and enhance learning. The first key theme was structured into four subthemes: (1) their commitment to learner-centered science teaching practices, (2) their adaptive strategies to address diverse learner needs, (3) AI as a practical support tool in science teaching, and (4) their concerns and challenges related to AI use in science education.

Table 3

AI Integration within Orientation to Science Teaching

AI Adaptation Strategy	Impact on PCK Domain	Pedagogical Tension
Generating interactive engagement ideas	Enhanced learner-centered active learning	Over-reliance vs. human-guided inquiry
Drafting lesson scripts and visual aids	Increased instructional efficiency	Need for local context adjustments

Commitment to Learner-Centered Science Teaching Practices

The findings revealed that teachers strongly emphasize active learner participation as a cornerstone of effective science teaching. Participants consistently described fostering an environment where learners are not passive recipients but active contributors to their learning. This conforms to the study of Palaguyan and Abusama (2025), indicating that inquiry-based instruction, a learner-centered approach, produced significantly higher engagement and much greater gains in conceptual knowledge than conventional teaching in Grade 8 Biology. For instance, Teacher A noted, "I made sure that during my discussion, they were all active and participative." This highlights the deliberate effort to engage learners continuously. This aligns with the broader learner-centered teaching philosophy, where learners are empowered to take ownership of their educational journey as reflected in the answers of Teacher C, Teacher D, and Teacher E, respectively: "I am committed to creating a learner-centered environment where students are active participants in their own learning," Teacher C explained. "I am practicing student-centered teaching," Teacher D shared. "My overall approach to teaching science is centered on creating an engaging, student-centered learning environment where students actively participate in their learning process," Teacher E noted.

Complementing active participation, teachers also prioritize hands-on and activity-driven learning. The use of interactive games, recitations, and visual aids was frequently mentioned as strategies to make science lessons meaningful and relatable. Teacher E emphasized, "I believe that science should be hands-on, interactive, and meaningful." This underscores the importance of experiential learning. This approach not only stimulates curiosity but also helps learners connect abstract scientific concepts to real-life experiences, thereby deepening understanding. As stated by Teacher A, "I made sure that we will have interactive games, recitation activities." Teacher D also mentioned, "By learning through hands-on

activities.” Teacher E subsequently elaborated, “Visual aids, videos, and activities are important in my teaching.”

An educator’s personal history with a subject deeply shapes their teaching orientation. Teacher E, who initially struggled with science, focused her philosophy on replacing abstract memorization with evidence-based curiosity. She tests this inside the classroom using concrete, sensory activities. She explained, “During our discussion about insulators and conductors, I brought spoons made of metal, plastic, and wood. I soaked them in hot water and then had the students hold the spoons. They were curious why the metal felt hotter. I observed that the students remember the lesson better when they are engaged.” Together, these practices reflect a robust, learner-centered approach that prioritizes engagement, participation, and relevance, supporting existing literature that advocates for learner-centered pedagogies in science education (Laid & Adlaon, 2025). Through a PCK lens, this shows an intentional use of technology to support a specific pedagogical goal. Teacher E used AI as a creative generator to sustain student interest. However, she protected her hands-on philosophy by making sure these AI-suggested games were anchored in physical, sensory experiences, ensuring that digital play does not replace physical science exploration.

Adaptive Strategies to Address Diverse Learner Needs

Teachers were committed to adapting their teaching methods to address the diverse needs of their learners. This adaptability was evident in their use of varied instructional strategies and efforts to create a supportive learning environment. This aligns with the report of Bonner et al. (2018) that teachers showed a strong sense of efficacy in teaching diverse learners and proactively addressing their needs. Teacher B reflected, “I follow different approaches and philosophies to cater to the needs of my students.” It illustrates an intentional responsiveness to learners’ diversity. Moreover, participants emphasized making scientific concepts relevant to students’ everyday lives, which facilitated deeper engagement and comprehension. As stated by Teacher C, “Whether it’s Boyle’s Law or the complexities of carbohydrates, I aim to make each concept meaningful and relevant to students’ everyday lives.” Teacher E added, “Students learn best when they can connect what they are learning to real-life situations and experiences.”

Essentially, the use of differentiated strategies also aimed to promote a healthy and inclusive classroom environment conducive to learning. As stated by Teacher D, “I am also using different teaching strategies to meet the needs of my students.” This adaptability is crucial in science education, where students come with varying backgrounds and learning preferences. The findings echo prior research highlighting the need for flexible, differentiated teaching approaches to maximize student learning outcomes (Kara & Tekindur, 2025). Importantly, teachers’ ability to adapt also appeared to be shaped by their self-reflection on their own instructional strengths and limitations. Several teachers acknowledged areas for improvement and expressed a need for continued professional development (Masharipova, 2025). Teacher F shared in detail, “I rate myself 7/10; I am not confident enough with my current skills, but I am still in progress and will master them someday.” This reflective attitude indicated a growth mindset, which is essential for continuous improvement and effective curriculum delivery. Such self-awareness enables teachers to critically evaluate their instructional methods and seek resources or strategies to enhance their effectiveness, thus positively impacting student learning (Masharipova, 2025).

Orientation to Science Teaching: AI as a Practical Support Tool in Science Teaching

Participants viewed Artificial Intelligence (AI) as a valuable resource that enhances various aspects of science teaching. Teachers reported that AI tools significantly assisted in lesson planning and material preparation, making these processes more efficient and less time-consuming (Spasopoulos et al., 2025). For instance, Teacher B noted, “AI supports teaching through instructional materials, lesson planning, and easing the making of PowerPoint and other visual aids.” Teacher D agreed, “AI improves lesson plans, and she added that AI facilitates the creation of visual aids. AI’s proofreading capabilities were also appreciated, as Teacher F mentioned, “You can generate content of students’ grades to proofread.” However, she emphasized that AI-generated outputs were revised to match learners’ comprehension levels: “I used AI sometimes for help, such as ideas to generate games, instruction, and activity, and I revised some of the content to be at the level of comprehension of the students that I disseminate.” Beyond planning, AI was recognized for its role in enhancing student engagement and teaching strategies. Teachers highlighted AI’s ability to suggest interactive games, activities, and examples that make complex scientific concepts accessible and engaging. As Teacher E stated, “[AI] reduces the time I spend thinking about how to effectively teach a lesson.” And then she said, “It provides suggestions for activities, teaching strategies.”

Teacher D, who guides Grade 7 learners, describes her teaching stance as explicitly explanatory: “I am practicing a student-centered teaching wherein I am encouraging my students to explore the subject by learning through hands-on activities... I am into hands-on activities wherein I let my students explore and learn on their own first, and later on will discuss it in class.” To support this learner-centered approach, she uses AI to design more engaging lessons: “It can support or enhance my teaching orientation through making my lesson plans better, by making more engaging and interactive lessons, like using simulations in my teaching.” This aligns with the growing body of research supporting AI’s role in personalized and adaptive learning environments (Onesi-Ozigagun et al., 2024). From a PCK perspective, AI appears to support the implementation of learner-centered learning activities. Rather than using AI to generate lecture-based presentations, Teacher D and Teacher F used it to design exploratory activities that encouraged learners to develop their own understanding before formal instruction.

Teacher F emphasized that AI supports, rather than dictates, classroom instruction. Instead, she treats AI as an unfiltered data source, executing a conscious “re-authoring” phase where she adjusts the language complexity to match her students’ specific developmental capacities. Furthermore, teachers expressed a positive perception of AI, viewing it as a reliable and supportive tool within their pedagogical framework. Teacher D confidently remarked, “I don’t foresee any challenges because AI tools will serve as a support in my teaching philosophy.” This optimism suggests readiness among educators to integrate AI meaningfully into their teaching practices. However, readiness varies based on backgrounds, and limited resources remain a hindrance (Alshorman, 2024).

Concerns and Challenges Related to AI Use in Science Education

Despite the benefits, teachers expressed concerns about students’ overreliance on AI. Several participants worried that easy access to AI tools might lead students to bypass critical thinking and independent problem-solving (Anselmo et al., 2025; Wirzal et al., 2024). For instance, Teacher C shared, “There is a possibility that students will not explore the ‘how’ and ‘why’ because they can easily ask AI.” Others noted that many students generate most of their

work using AI, raising questions about academic integrity and learning authenticity (Wirzal et al., 2024). Meanwhile, Teacher F revealed, “Because almost all of their work is generated from AI.” Additionally, Teacher C feared that excessive AI use might diminish students’ appreciation for the beauty and complexity of science. As Teacher C noted, “As a science teacher, I sometimes imagine my students in the future not enjoying the beauty of Science anymore because they abuse the use of AI.” Furthermore, Teacher E added, “One might no longer be truly creative by thinking independently.” These concerns underscore the importance of balancing AI integration with pedagogical strategies that promote independent inquiry. In response, teachers emphasized their role in guiding proper AI use, recognizing the need to educate learners on ethical and effective AI engagement. As Teacher C stated, “As a teacher, I should be the one who reminds them how to use the platform properly.”

This highlights the evolving responsibility of educators to mediate technology use in classrooms. As shown in Table 3, the primary tension identified in the orientation to science teaching is the balance between using AI for efficiency and maintaining human-guided inquiry. While the teachers leverage AI to generate interactive games, the findings confirm that this must be anchored by physical, sensory experiences, such as Teacher E’s use of metal and wood spoons, to ensure that digital play does not replace physical science exploration.

Influence of AI on Knowledge of the Curriculum

This key theme encompasses five subthemes, which include (1) curriculum familiarity and understanding, (2) awareness and exploration of AI tools in education, (3) AI application in lesson planning and curriculum alignment, (4) teacher reflection and lesson plan refinement using AI, and (5) limitations and challenges of AI in curriculum understanding. These subthemes detail how teachers transition from initial curriculum study to actively using AI as an analytical filter while navigating the tension between algorithmic assistance and the necessity of human judgment.

Table 4

AI Integration within the Knowledge of the Curriculum

AI Adaptation Strategy	Impact on PCK Domain	Pedagogical Tension
Automated curriculum mapping	Improved alignment with standards	AI’s inability to grasp pedagogical history
Gap analysis of lesson objectives	Enhanced lesson plan comprehensiveness	Risk of algorithmic bias in content

The analysis of the transcripts reveals several key themes related to teachers’ familiarity with the curriculum and their use of AI tools to support lesson planning and instructional effectiveness (Spasopoulos et al., 2025).

Curriculum Familiarity and Understanding

Teachers’ familiarity with the curriculum varied widely, ranging from those who were still in the early stages of learning and understanding the curriculum to those who demonstrated advanced knowledge. Some participants expressed that they were not yet fully confident or

proficient with the curriculum, indicating an ongoing process of familiarization and study of learning competencies and performance standards (Kotsis, 2024). For example, Teacher A shared, “I am still familiarizing myself with and learning the curriculum for the grade levels I plan to teach.” While Teacher B added, “I am still studying the learning competencies, performance standards, and contents.” Others reported intermediate familiarity, acknowledging that they had a basic understanding but were still deepening their knowledge through practice and reflection (Ning et al., 2024). Teacher C noted, “I can say I am familiar with the curriculum.” Teacher F rated herself as somewhat confident, saying, “It is 8 out of 10 in familiarity with the Science Curriculum.” Additionally, some began studying the curriculum during their internship deployment. Teacher A noted, “During the internship deployment, I began studying the science curriculum for each grade level.”

A subset of teachers showed advanced familiarity, particularly with specific curricula such as the Science Curriculum or the MATATAG Curriculum, which they actively used during their practice teaching. The recalibration of the Science curriculum in the Philippines draws from and supports the DepEd MATATAG agenda, which sets the new direction in resolving basic education challenges through the four critical components: (1) MAKing the curriculum relevant to produce competent and job-ready, active, and responsible citizens; (2) TAKing steps to accelerate delivery of basic education facilities and services; (3) TAKing good care of learners by promoting learner well-being, inclusive education, and a positive learning environment; and (4) GIVING support to teachers to teach better. For instance, Teacher B specified, “I am very familiar with the Science Curriculum.” Teacher E said, “I am familiar with the MATATAG Curriculum because that is actually the curriculum, we are currently using for practice teaching.” Cooperating teachers played an important role in helping novice teachers understand curriculum expectations. Teacher C explained, “Because it was introduced and discussed to me by my cooperating teacher.” Conversely, some participants admitted to having little familiarity with certain curricula, underscoring the need for further support and training (Ning et al., 2024). More so, Teacher D reiterated, “Shows little familiarity in the Science Curriculum.”

Awareness and Exploration of AI Tools in Education

Across the transcripts, there was a general awareness of AI tools available for educational purposes, with many participants acknowledging the growing presence of AI in lesson planning (Spasopoulos et al., 2025). Teacher A commented, “There are a lot of AI websites that can help in preparing and aligning lesson plans with curriculum standards.” Several teachers had begun exploring AI platforms such as ChatGPT and Gemini, recognizing their potential to assist in aligning lesson plans with curriculum standards and generating instructional content (Spasopoulos et al., 2025). For example, Teacher D admitted, “Yes, I have explored it, and Teacher B said, “Yes, by using ChatGPT and Gemini.” The preference for these tools was also noted by Teacher D: “Since AI tools like ChatGPT and Gemini can assist us by analyzing curriculum requirements.”

AI Application in Lesson Planning and Curriculum Alignment

Participants described multiple ways in which AI was integrated into their lesson planning workflows. Many utilized AI to generate complete lesson plans by providing topics, objectives, and competencies, which AI then expanded into detailed instructional plans (Spasopoulos et al.,

2025). Teacher A explained, “You will just give your topics, objectives, and the competencies and standards from the curriculum, then AI will generate it.”

Others leveraged AI to enhance and improve their original lesson plans by identifying gaps or missing elements related to curriculum competencies and standards (Onesi-Ozigagun et al., 2024). Teacher A elucidated, “By scanning your lesson plan and AI will see or identify certain competencies or standards from the curriculum are missing and not being addressed.” AI was also reported to be effective in aligning lesson plans with curriculum standards, ensuring that objectives and activities matched the required learning outcomes. For example, Teacher C elaborated, “They can easily align the lesson plans for the topic you will teach.” Teacher E mentioned, “Yes, I have explored how AI can help align lesson plans with the curriculum standards.” Teacher D utilizes conversational AI engines to manage this process: “Yes, I have explored it since AI tools like ChatGPT and Gemini can assist us by analyzing curriculum requirements and suggesting relevant resources, activities, and assessments for lesson planning.” She further notes that AI targets internal curriculum optimization by “suggesting different strategies and techniques that I can use for the improvement within the curriculum, like what are the tools I can use to meet the needs of my students.” Additionally, AI tools suggested appropriate lesson objectives, activities, and assessments tailored to the curriculum and student needs. Teacher E further answered, “AI helps me create lesson objectives, suggest appropriate activities.” She highlights this alignment process within the context of the current Philippine educational framework, “I am familiar with the MATATAG Curriculum dahil ayun naman talaga yung curriculum na ginagamit naming ngayon na practice teaching [because that is the actual curriculum we use in our practice teaching now].” She uses AI to audit this framework by checking “if the objectives align with the lesson, and if the activities and performance tasks cater to the different skills or knowledge of the students.”

Importantly, AI was noted for its ability to identify areas needing clarification or alignment, as well as for recommending diverse instructional strategies and techniques to enhance teaching effectiveness and maximize student potential (Su et al., 2024). Teacher C shared, “these tools not only pointed out areas that needed clarification or alignment, but also added relevant information that I hadn’t initially included.” Teacher B stated, “AI assists me by suggesting different strategies that I can use.” He supplemented, “I can use to maximize the potential of my students using the current curriculum.” Teachers also emphasized AI’s role in checking whether lesson components catered to different skill levels and knowledge bases among students. In fact, Teacher E revealed, “Whether the activities and performance tasks cater to the different skills or knowledge of the students.”

These findings suggest that teachers use AI not only to access curriculum documents but also to support curriculum planning and alignment. The pre-service science teacher utilizes the generative platform as an analytical filter that reads raw curriculum competencies and outputs contextualized resource bundles, helping her choose appropriate tools to meet her students’ needs. This interactive workflow shows an advanced application of Curricular Knowledge. The pre-service science teacher does not rely on AI to write her lessons blindly. Instead, she uses the platform to analyze the specific demands of the MATATAG framework, treating the technology as an automated compliance auditor that checks if her lesson objectives and tasks are balanced and inclusive.

Teacher Reflection and Lesson Plan Refinement Using AI

The interaction with AI tools was not passive; teachers actively reviewed and reflected on AI-generated suggestions before deciding which to incorporate into their lesson plans. Teacher C described, “This allowed me to review and reflect on the suggestions, determine which ones were beneficial, and decide whether to incorporate them into my lesson.” This reflective process allowed them to critically assess the relevance and quality of AI inputs, leading to more comprehensive and effective lesson plans tailored to their students’ needs. As Teacher C indicated, “Through this process, I was able to refine my plan and ensure it was more comprehensive and effective for my students.” The collaborative dynamic between teacher expertise and AI assistance was thus a key factor in lesson plan refinement. This corroborates Setyaningsih (2024)’s emphasis on the need for “critical teacher oversight” as AI accelerates lesson planning and supports creativity.

Limitations and Challenges of AI in Curriculum Understanding

Despite the benefits, participants acknowledged limitations in AI’s capacity to fully understand the complexities of curriculum improvement. Teacher F believed, “Because the curriculum has a long history, it can only be understood by humans who have experience with teaching.” She further emphasized that alignment requires human experience based on what the students need the most and not. While attempting to align lessons using technology, Teacher F classified the automated output as an operational failure: “I explored it to align with the lesson plan just to get an idea to make my lesson plan, but it was a failure. Some own work with witty knowledge to integrate in a lesson plan for student engagement can’t generate an AI, because we humans have emotions to feel the need for students to catch their interest and attention according to the trends, but the AI is not capable of doing it.”

This emphasizes the ongoing need for human judgment and expertise alongside AI support. This thematic analysis underscores the evolving relationship between teacher curriculum knowledge and the integration of AI tools in educational planning. Within the domain of Curricular Knowledge, a critical tension arises regarding whether algorithmic engines can capture the nuanced, felt reality of a live classroom. The pre-service science teacher identifies a major boundary of AI: its inability to perceive local subcultures or feel empathy. She argues that curriculum design requires ongoing, emotionally responsive understanding of human reality. This is something that code cannot replicate. While AI offers promising support in generating, aligning, and refining lesson plans, teacher familiarity with the curriculum and critical reflection remains essential to optimizing instructional outcomes (Kumar, 2025).

As synthesized in Table 4, AI serves as an analytical filter for curriculum mapping. However, the qualitative evidence suggests that AI acts as an “automated compliance auditor” rather than a curriculum expert. It confirms that human judgment remains the final authority in interpreting the nuanced history and local requirements of the curriculum.

Influence of AI on Knowledge of Strategies

This key theme is divided into five subthemes: (1) use of visual aids and active learning strategies, (2) flexible and purposeful use of AI tools in teaching, (3) AI’s role in enhancing simulations and interactive learning, (4) concerns about overreliance on AI and student learning integrity, and (5) AI’s effectiveness and limitations in supporting instruction. These subthemes

detail how pre-service science teachers strategically leverage AI to bridge resource gaps and boost engagement while maintaining a critical awareness of digital limitations.

Table 5

AI Integration within the Knowledge of Strategies

AI Adaptation Strategy	Impact on PCK Domain	Pedagogical Tension
Generating digital simulations	Bridging laboratory resource gaps	Loss of tactile/physical engagement
Creating multimedia/interactive hooks	Increased engagement in trending topics	Ensuring alignment with learning goals

The transcripts on knowledge of strategies reveal rich insights into how teachers employ various instructional strategies, including the use of visual aids, active learning, multimedia, and AI tools, to enhance science teaching and learning. The findings are organized into key thematic areas supported by direct participant quotes (Onesi-Ozigagun et al., 2024).

Use of Visual Aids and Active Learning Strategies

Teachers consistently emphasized the importance of visual aids and active learning to help conceptual understanding in science. Teacher A described “I used visual aids, such as showing pictures or diagrams, that help students to visualize and understand scientific concepts.” Complementing this, active learning approaches such as group activities, interactive games, and simulations were highlighted (Palaguyan & Abusama, 2025). Teacher A highlighted, “I also used active learning, where students have group activities, and they will have interactive games and simulations.” While both Teacher B and Teacher C noted the integration of multimedia tools, stating, “Using PowerPoint, PhET Simulation, and online games.” Inquiry-based and cooperative learning were also prominent. For example, Teacher E shared, “Inquiry-Based Learning, where the children get a chance to ask questions through hands-on activities.” She also mentioned, “Cooperative Learning, where they form groups and share ideas after discussing in front of the class.” Game-based learning was recognized for its engagement value (Palaguyan & Abusama, 2025). Teacher E further signified, “The last approach I used is Game-Based Learning, where I really saw that the children enjoyed themselves while learning at the same time.”

Flexible and Purposeful Use of AI Tools in Teaching

Teachers reported selectively and flexibly integrating AI tools to supplement teaching materials and strategies (Park et al., 2023). Teacher A expressed, “Sometimes I used it, implying purposeful and situational use of AI.” AI was employed to create simulations and interactive models to support science concepts. Teacher A agreed, “AI can assist in creating simulations and interactive models.” She also shared, “I’m just going to ask [AI] to give me some website I can use for simulations.” Teacher D emphasizes how AI-driven strategies can bypass these physical limitations: “AI tools could support these strategies by making simulations and interactive models. For example, when we do not have access to different materials in the laboratory for a science experiment, we use the simulations instead.” AI-generated visual aids,

such as pictures and models, were also utilized. She further said, “Then the AI will provide, and sometimes it gives me pictures or models that I can use in my discussion.” Teacher A acknowledged AI’s ability to suggest diverse teaching strategies tailored for a diverse classroom: “I think the effective use of AI is providing different strategies and instructions that I can use in a diverse classroom.” AI also supported multimedia-enhanced teaching by assisting in creating PowerPoint presentations (Park et al., 2023). This was corroborated by participants’ submitted teaching artifacts, which demonstrated structured lesson designs generated through AI platforms such as ChatGPT and Gemini (Spasopoulos et al., 2025).

Teacher B mentioned, “AI can definitely support these strategies by assisting in creating PowerPoint,” while simultaneously using platforms like ZipGrade to automate grading and item analysis, thereby increasing both efficiency and assessment accuracy. Furthermore, Teacher F utilizes AI to design culturally relevant hooks, stating, “I used instructional strategies to catch my students’ interest in the trending topics with TikTok that they can relate themselves to, and I will integrate it with games that will be connected to the topic.” While she used AI to generate the sequential operational rules: “to generate instructions for the next activity,” she highlights a critical boundary in strategic execution: “AI is particularly effective in asking for information because the knowledge of AI can surpass the knowledge from Google, but AI is ineffective in terms of asking for real-life experience that humans are only capable of answering.” This “re-authoring” process, where teachers filter AI-generated content to match local developmental capacities, aligns with recent evidence suggesting that AI serves best as a scaffold rather than a replacement for teacher agency (Setyaningsih et al., 2024). This application is vital to Strategic PCK under challenging conditions. Teacher D does not view digital simulations merely as software options. She uses them as an essential replacement for missing physical laboratory equipment. When traditional, material-dependent chemistry or physics experiments are impossible due to a lack of supplies, Teacher D uses AI-mapped simulations to preserve the experiential core of science learning, transforming a logistical constraint into a digital learning opportunity. This distinction is vital to Strategic PCK. Teacher F isolates AI’s utility as a high-speed text repository, while maintaining that true instructional engagement must be anchored by human narrative and authentic shared experiences. She uses technology to structure the steps of an activity, but also relies on human culture to supply the engagement.

AI’s Role in Enhancing Simulations and Interactive Learning

Teachers valued AI’s capacity to recommend simulations that fit students’ needs and to assist students struggling with simulations. Teacher C emphasized, “AI can help suggest simulations that fit the students’ needs.” She added, “It can also help students understand the simulation better if they are struggling.” AI was described as a source of innovative ideas, enhancing lesson planning and interactive activities. He added, “Every time AI suggests innovative ideas to enhance my work, such as lesson planning or interactive activities, I find it to be highly effective.” Teacher E balances a wide range of strategies, including Inquiry-Based Learning, Cooperative Learning, and Flipped Classrooms, but offers a sharp critique of relying too much on digital simulations like PhET: “AI tools can assist in developing simulations, just like PhET... [but] it becomes ineffective in some ways because, since it is a simulator, it is not the students themselves doing the actual experiment. They do not get that hands-on experience, and there is a possibility they won’t fully get the lesson. Also, the interaction between groupmates is lost.”

However, some concerns were raised regarding AI's limitations. Teacher C cautioned, "AI becomes ineffective in teaching science when students rely on it for problem-solving, as it diminishes their critical thinking skills." He also noted technical inaccuracies: "There are instances where the mathematical symbols in AI platforms may be inaccurate, which can lead to confusion and hinder learning." This critique reveals a deep development of Strategic PCK. Teacher E points out a major limitation of digital science tools. While virtual models help students visualize concepts, they lack the physical, tactile feedback of a real experiment and cut down on peer collaboration. By identifying this flaw, Teacher E showed that her strategic choices are guided by real pedagogical goals rather than a superficial infatuation with technology.

Concerns about Overreliance on AI and Student Learning Integrity

Teachers expressed concerns about students potentially over-relying on AI for completing assignments, which could impair their understanding (Anselmo et al., 2025). Teacher E observed, "For take-home activities, there is also a possibility that they will just rely purely on AI to do the work." She added, "Which means there's a chance they won't understand it because they weren't the ones who made or answered it."

AI's Effectiveness and Limitations in Supporting Instruction

Participants recognized AI's effectiveness in generating assessments and visual aids. Teacher D said, "I believe AI might be effective in generating an assessment of learning." She continued, "I believe AI might be effective in generating visual learning strategies." AI was also praised for its ability to provide instructional improvements. Teacher F commented, "Providing some ideas to improve it and also to generate instructions for the next activity," and for answering questions efficiently, she added: "AI is particularly effective at asking for information because the knowledge of AI can surpass the knowledge from Google."

Nonetheless, AI's inability to replicate human real-life experience was noted as a limitation. She, however, argued, "AI is ineffective in terms of asking for real-life experience that humans are only capable of answering." This thematic analysis highlights teachers' dynamic use of traditional and AI-enhanced instructional strategies in science education. While AI offers valuable support in simulations, visual aids, and lesson planning, teachers remain mindful of its limitations and the importance of fostering student critical thinking and authentic learning (Anselmo et al., 2025; Kotsis, 2024). Table 5 highlights the strategic dualism of AI. While AI effectively provides a scaffold for simulations, particularly when physical resources are absent, teachers emphasize that digital tools are ineffective at replacing the interpersonal dynamics and emotional resonance of live classroom instruction.

Influence of AI on Knowledge of Assessment

This key theme is categorized into five subthemes: (1) use of formative, summative, and performance assessments, (2) AI's role in enhancing assessment accuracy, fairness, and efficiency, (3) concerns and limitations regarding AI in assessment, (4) importance of teacher review and human judgment, and (5) integration of real-life applications in assessment. These subthemes illustrate that while teachers leverage AI for grading efficiency and item analysis, they maintain a vigilant approach to address potential biases in algorithmic evaluations.

Table 6*AI Integration within Knowledge of Assessment*

AI Adaptation Strategy	Impact on PCK Domain	Pedagogical Tension
Generating objective test items	Improved grading efficiency	Inaccuracy in evaluating creative work
Automated item analysis/statistics	Data-driven instructional refinement	Maintaining academic integrity

The transcripts on knowledge of assessment provide valuable insights into how teachers implement various assessment strategies to gauge student understanding and how AI tools are integrated to enhance assessment accuracy, fairness, and efficiency (Kumar, 2025). The findings are organized into key thematic areas supported by direct participant quotations.

Use of Formative, Summative, and Performance Assessments

Teachers emphasized the importance of using a balanced mix of assessment types to evaluate student learning comprehensively. Teacher C explained, “I use a balanced mix of formative, summative, and performance assessments to assess student learning.” Formative assessments, such as quizzes administered at the end of lessons, were highlighted as essential tools for gauging understanding and identifying areas needing further clarification. Teacher C also mentioned, “At the end of each lesson, I give a brief formative quiz to assess if students have understood the material clearly,” and she reasoned, “This allows me to quickly identify areas that need further clarification before moving on.”

Summative assessments were described as a means to review prior lessons after completing a module. She further narrates, “Once we complete a module, I administer a summative assessment. This serves as a way to review prior lessons.” Group performance tasks were also incorporated to develop students’ communication and collaboration skills, as Teacher A shared, “Additionally, by giving a group performance task to practice their communication and collaboration skills.” The use of paper-and-pen assessments and essay-type questions remained a common practice. Teacher B specified, “Pen and Paper, and ...and essay type...” Short quizzes on specific days, such as Fridays, were also used to monitor retention. As stated by Teacher E, “I usually have a short quiz on Fridays.” This helps to identify students who understand or retain the lesson.

AI’s Role in Enhancing Assessment Accuracy, Fairness, and Efficiency

Teachers recognized AI’s potential to improve assessment practices by increasing accuracy and fairness. Teacher A noted, “AI can enhance these assessment practices by making these assessments more accurate.” This is supported by research showing AI’s ability to harmonize grading and detect inconsistencies that humans might miss (Kotsis, 2024). She added, “Making these assessments more accurate and fair.” AI’s ability to generate assessment questions was also valued: Teacher B indicated, “AI can help and enhance assessment by helping in creating assessment questions.” And he added, “AI can also help in formatting the assessment.”

AI was further praised for providing statistical data, such as item analysis, significantly reducing teachers' workload related to assessment evaluation. Teacher B further shared, "And provides statistics like item analysis, which significantly reduces the work of a teacher related to assessment." Teacher D explains that AI can support and improve assessment by generating questions to lessen the work of teachers. It can also assist in organizing and formatting assessments, as well as providing useful data like item analysis. Teachers also used applications like ZipGrade and Xepto to streamline grading and manage workload more effectively. As stated by Teacher C, "As a teacher utilizing applications like ZipGrade and Xepto in my assessment practices, I've found many benefits," which he then added, "Makes a teacher's workload more manageable," and also "Enable more focus on teaching and student engagement." Within the domain of Assessment Knowledge, Teacher D's perspective provides a critical understanding. The teacher used AI to streamline testing workflows, such as formatting tests and generating item analysis data, but deliberately limits its role. By treating AI strictly as an operational tool, she preserves her time and emotional energy to build authentic relationships with her students, ensuring that data-driven testing does not replace genuine human connection.

Concerns and Limitations Regarding AI in Assessment

Despite the benefits, concerns about AI's use in assessment were expressed. Teacher A acknowledged, "Yes..." when asked about concerns related to AI in assessment. Specific worries included fairness and accuracy. Teacher D expressed, "I believe yes, there are concerns, especially in fairness and accuracy." The potential for AI to provide vague or misunderstood answers, especially for creative or opinion-based questions, was also noted. Teacher E noted, "AI may misunderstand creative answers, especially with open-ended questions and those that are more opinion-based."

This perspective strengthens her Assessment Knowledge. The pre-service science teacher identifies a major limitation. AI's rigid algorithms struggle to evaluate unique or creative student expressions. By pointing out that automated grading can misinterpret valid, non-standard student responses, she emphasizes the need to preserve human oversight to ensure grading remains fair and contextually accurate. Issues of academic integrity were raised (Wirzal et al., 2024), with teachers cautioning that students might rely too heavily on AI, resulting in work that does not reflect their own understanding. For instance, Teacher E explained, "For take-home activities, there is also a possibility that they will just rely purely on AI to do the work," and she added, "Which means there's a chance they won't understand it because they weren't the ones who made or answered it." Likewise, Teacher F confirmed, "Activities and essays are not accurate because the work they presented is not their work." Moreover, she expressed deep concerns over systemic misuse of AI, noting that it strips away opportunities for basic skill development: "...using too many AI tools will forget the essence of learning, for example, from the students using AI to generate essays, they will not have training and prior knowledge on how to construct proper sentences in an essay." The diagnostic insight fundamentally shifts Assessment Knowledge. The pre-service science teacher recognizes that unchecked AI use acts as a cognitive shield for the student, masking their true writing deficiencies and conceptual gaps. For the educator, this turns assessment design into a battle for authenticity, forcing them to look past the polished surface of AI-generated prose to accurately assess a student's true understanding.

Importance of Teacher Review and Human Judgment

Teachers emphasized the critical role of reviewing assessments created or assisted by AI to ensure quality and appropriateness (Kotsis, 2024). Teacher B stated, “None, as long as we review the assessment created using AI.” This highlights the necessity of human oversight in maintaining assessment validity and reliability.

Integration of Real-Life Applications in Assessment

In addition to traditional and AI-supported assessments, teachers integrated real-life applications into lessons to help students connect learning to the real world. Teacher C showed, “In addition to these assessments, I consistently put real-life applications into each lesson. By doing this, I help students understand how what they learn can be applied beyond the classroom.” This thematic analysis demonstrates that teachers employ a variety of assessment strategies to monitor and support student learning, with AI tools increasingly integrated to enhance accuracy, fairness, and efficiency. However, concerns about AI’s limitations (Wirzal et al., 2024) and the importance of teacher oversight remain critical to ensuring authentic and effective assessment practices (Kumar, 2025). As presented in Table 6, AI optimizes the administrative burden of assessment. However, teachers identify a critical “diagnostic barrier,” where AI’s rigid algorithms struggle to evaluate open-ended or creative student responses, necessitating rigorous human intervention to preserve fairness.

Influence of AI on Knowledge of Learners

This key theme is organized into four subthemes: (1) learner difficulties in science learning, (2) impact of external factors on learning, (3) AI’s role in supporting students’ learning and teaching, and (4) limitations and concerns regarding AI use. These subthemes emphasize a complex pedagogical landscape where AI acts as a diagnostic scaffold to tailor instruction and reinforce memory yet is recognized as insufficient for overcoming student apathy and motivation deficits.

Table 7

AI Integration within Knowledge of Learners

AI Adaptation Strategy	Impact on PCK Domain	Pedagogical Tension
Analyzing student progress data	Tailoring instruction to diverse needs	Cannot solve motivation deficits
Generating alternative explanations	Reinforcing memory and retention	Risk of student passivity

The transcripts reveal a range of challenges students face in learning science, particularly in problem-solving and concept retention, alongside teachers’ perspectives on how AI tools can support instruction and address some of these difficulties (Orbe et al., 2018).

Learner Difficulties in Science Learning

Teachers consistently observed that students struggle with problem-solving, especially in physics, and often face confusion with basic mathematical symbols essential for

understanding scientific concepts (Orbe et al., 2018). Teacher A noted, “In my own experiences and observation, students struggle or have difficulty learning science when it involves problem-solving, like in physics.” She also agrees, “They easily get confused about basic mathematics symbols...” A common issue highlighted was students’ tendency to memorize concepts and terminologies without genuine understanding. Teacher A further argued, “In terms of concepts and terminologies, students are more into memorization without understanding it.”

Further challenges included students’ unfamiliarity with foundational concepts required for current lessons and their difficulty retaining information from previous lessons, resembling short-term memory loss. Teacher B shared, “Unfamiliarity of basic concepts needed for the present lesson,” and he observed, “...and easy to forget the past lesson.” This was echoed by Teacher D: “Based on my experience, one common challenge students face when learning science is difficulty retaining information...” And she further elaborated, “...they often seem to forget what they learned, almost like short-term memory loss.”

Teacher F identified a fundamental cognitive barrier among her science students, noting that they struggle when trying to learn advanced content without first mastering prerequisite ideas: “Based on my experience and observations, students frequently challenge learning science by not learning the basic information first before proceeding with further information.” Teachers also reported students’ lack of engagement and participation during recitations. For instance, Teacher C narrates, “By this, every time we are having recitation, most of them are inactive and couldn’t tell the answer.” A lack of interest and willingness to learn was identified as a fundamental barrier: As Teacher E stated, “If a child is really not interested in learning and is not willing to learn, they simply won’t learn.” Teacher E concluded, “The real challenge is the lack of interest in learning, even if the teaching and methods used by the teacher are interesting.” When asked if AI can fix this, she states clearly, “I think no kasi nasa bata na talaga yung problem kasi even may AI naka-include sa teaching method ng teaching talagang ayaw matuto hindi masosolve ng AI yung problem na yon [I think no, because the problem is with the student... AI cannot solve that problem].”

The diagnostic insight modifies the teacher’s understanding of her students. Within the domain of Knowledge of Learners, Teacher D recognizes that young learners need multiple, varied exposures to a concept to move information from short-term to long-term memory. She uses AI to quickly generate diverse review tasks and alternative explanations, actively addressing student forgetfulness and reinforcing foundational concepts. Conversely, Teacher E looks past the idealist view that adding digital elements automatically creates engagement. She recognizes that while AI can optimize lesson delivery, it cannot fix internal motivation deficits or student apathy, showing a realistic understanding of how technology interacts with real classroom behavior. Within the domain of Knowledge of Learners, Teacher E rejects technological determinism. She recognizes that while AI can provide content variations, the actual cognitive architecture of diagnosing student comprehension styles requires active human evaluation and metacognition.

Impact of External Factors on Learning

The lack of proper school equipment and facilities was noted (Alshorman, 2024) as a significant obstacle to effective science teaching and experiential learning. Teacher C pointed out, “Another factor is the lack of school equipment.” He expounded, “I believe that students learn from experience, and it becomes a challenge when the facility lacks proper equipment to

teach the lesson effectively.” Teacher C emphasized that such challenges cannot be resolved by AI alone: “AI cannot help in challenges because the users are the problem.”

AI's Role in Supporting Students' Learning and Teaching

Teachers expressed optimism about AI's potential to support student learning by enhancing comprehension, memory retention, and problem-solving skills. For instance, Teacher A noted, “Students can improve problem-solving skills through more practice with the help of AI.” She adds, “If there is something they can't understand about the concepts of science, they can also ask AI to explain it in a simpler way.”

AI was also seen as a valuable tool for recommending examples and teaching strategies tailored to students' learning styles and progress (Su et al., 2024). Teacher A further specified, “Based on the students' progress and learning styles, I will ask AI to help me recommend some examples,” and “...other strategies...” She adds, “...resources that can match their learning styles.” Teachers appreciated AI's ability to analyze data to better understand individual student needs and learning styles: Teacher C agreed, “By using AI as a tool to analyze the data I will give and assess what kind of learning style or needs a student need.” He also mentioned, “AI tools might help me better understand the individual needs of my students...”

This knowledge informed teachers' selection of specific instructional strategies. As Teacher D stated, “...being knowledgeable enough on what specific strategies and techniques I will use in my teaching to help meet their needs.” AI also helped reinforce learning and support memory retention through interactive engagement. Teacher B expressed, “Yes, by helping the student's memory retention through interaction to AI.” Additionally, AI-assisted teachers in understanding student differences and aligning activities appropriately (Su et al., 2024). Teacher B also reported, “...that are helpful in understanding differences among students,” and Teacher D stated, “AI helps in a way that it really suggests aligned or appropriate activities for the children.”

Limitations and Concerns Regarding AI Use

Despite AI's benefits, teachers cautioned that overreliance on AI (Anselmo et al., 2025) might negatively affect students' curiosity and motivation to learn science independently. As Teacher C stated, “As students depends on AI more often, their curiosity in learning from school about science is slowly fading .” Furthermore, some teachers believed AI could not solve fundamental problems related to student motivation and interest. Teacher E argued, “I think no, because the problem really lies in the students themselves. Even if AI is included in the teaching methods, if they really don't want to learn, AI cannot solve that problem.” Teachers also noted that students' attention, focus, and understanding often remain low despite direct teaching efforts. She [Teacher E] also emphasized, “Based on my experience, their attention, focus, and the way they understand the lesson, even if you spoon-feed them the lesson and the answers, still isn't there.” Furthermore, Teacher F heavily caveats the platform's role in diagnosing student learning variations, “AI tools can help us better to understand the information we need but it is not capable of assessing our learning style, it's up to us on how we learned a particular topic.”

The integration of AI, therefore, serves as a critical pedagogical diagnostic tool. While teachers identified risks of overreliance and student passivity, these very concerns emphasize the necessity for AI to act as a scaffold rather than a substitute for teaching. By identifying where AI fails to engage students, such as in sustaining intrinsic motivation or addressing complex

emotional learning factors, pre-service science teachers are compelled to strengthen their PCK by intentionally designing interventions that prioritize human-centered instructional strategies. Thus, AI improves PCK not simply by providing information but by highlighting the limitations of automated instruction, thereby challenging teachers to exercise professional judgment to foster genuine critical thinking and authentic learning outcomes that technology alone cannot achieve (Kotsis, 2024; Su et al., 2024). Collectively, while AI is a promising tool for personalized support and efficiency, its effectiveness is limited by external factors such as inadequate facilities (Alshorman, 2024) and intrinsic student needs, which require ongoing human intervention and support beyond technological solutions.

Table 7 demonstrates that although AI offers diagnostic support for identifying learning needs, it cannot replace the intrinsic motivation required for learning science. The findings emphasize that AI functions as a support tool, but is limited by the external and internal factors, such as motivation and school facilities, that only human intervention can address.

Discussion

The integration of Artificial Intelligence (AI) into the educational landscape necessitates a critical re-examination of how pre-service science teachers develop Pedagogical Content Knowledge (PCK). This study aimed to explore how AI adaptation influences the PCK of pre-service science teachers, specifically across the domains of orientation to science teaching, curricular knowledge, instructional strategies, knowledge of assessment, and knowledge of learners. The findings corroborate the existing AI-TPACK framework (Ning et al., 2024), suggesting that while AI tools offer transformative potential for efficiency and personalization, their integration within PCK is inherently characterized by a tension between technological innovation and the necessity of human pedagogical agency.

In the domain of orientation to science teaching, the findings suggest that AI functions as an operational scaffold for learner-centered discovery. Pre-service science teachers successfully utilized AI to generate interactive engagement materials, yet they actively protected their learner-centered philosophies by ensuring digital tools were anchored in physical, sensory experiences. This sits well with recent research emphasizing that AI should serve as a “cognitive partner” rather than a replacement for instructional leadership (Spasopoulos et al., 2025). The data indicate that teachers who treat AI as an unfiltered data source and engage in a conscious “re-authoring” process to adjust language and complexity demonstrate a more mature stage of PCK development than those who passively adopt AI-generated content.

Regarding curricular knowledge, the integration of AI represents a shift from static document consumption to interactive curriculum planning. Participants utilized AI as an “automated compliance auditor,” checking if lesson objectives and tasks aligned with the MATATAG curriculum framework. However, a significant thematic finding was the perceived failure of AI to grasp the historical and cultural nuances of the curriculum. Participants noted that AI lacks the capacity to perceive local subcultures or feel empathy, which are essential for true curriculum delivery. This finding emphasizes the perspective that while AI offers promising support, it cannot replicate the human judgment required to navigate the nuanced requirements of a dynamic educational environment (Kumar, 2025).

The influence of AI on instructional strategies revealed a strategic dualism. When physical laboratory resources were absent, AI-driven simulations served as essential

replacements. It transforms logistical constraints into digital learning opportunities. However, the study identifies a “diagnostic barrier” in the application of these strategies: pre-service science teachers recognized that digital simulations often lack the tactile feedback and interpersonal dynamics of live classroom interaction. Thus, the effectiveness of AI in strategy selection is contingent upon the teacher’s ability to discern when technology enhances learning and when it creates an “experiential void” that impedes deep conceptual understanding (Alshorman, 2024).

In the knowledge of assessment, AI demonstrates value in streamlining administrative burdens, such as formatting test items and generating statistical analyses. Yet, the findings emphasize that automated grading struggles with the evaluation of unique or creative student expressions. Pre-service science teachers identified that overreliance on AI for assessment could act as a “cognitive shield,” masking student deficiencies and conceptual gaps. Consequently, the development of PCK in the AI era requires teachers to look beyond the polished surface of AI-generated prose to accurately assess a student’s true understanding (Wirzal et al., 2024).

Finally, regarding the knowledge of learners, the study reveals that while AI can provide content variations and alternative explanations, it is largely ineffective in addressing intrinsic motivation deficits or emotional learning factors. Participants correctly identified that AI cannot solve the fundamental challenges of student apathy, which are rooted in individual psychology and environmental factors rather than a lack of information. This reinforces the necessity for AI to act as a supplement to, rather than a substitute for, the human-centered instructional strategies that foster student engagement (Anselmo et al., 2025).

Conclusion

This study moves beyond existing conceptualizations of technology integration by uniquely identifying how AI adaptation specifically reshapes the five core domains of Pedagogical Content Knowledge (PCK) in science education. While the findings corroborate that pre-service science teachers view AI as a helpful tool for lesson planning, assessment, and tailoring instruction to student needs, the study’s distinctive contribution lies in demonstrating the tension-filled nature of this adaptation; it serves simultaneously as a scaffold for instructional innovation and a potential disruptor of fundamental science-specific pedagogical skills, such as inquiry-based problem solving. Ultimately, this research provides a nuanced framework for understanding the ‘AI-PCK’ interface, suggesting that for pre-service teachers, the value of AI lies in its potential to sharpen professional agency through deliberate, human-guided integration.

To maximize these benefits, teacher education programs must prioritize the development of comprehensive AI literacy. This involves structured training in precise prompt design skills and the cultivation of advanced critical evaluation competencies. This ensures that teachers can rigorously discern the accuracy, quality, and pedagogical relevance of AI-generated outputs before implementation. Educators must remain the final authority in pedagogical decision-making, treating AI as a supportive scaffold rather than a replacement for human judgment. Future initiatives should bridge the gap between technological advancement and classroom effectiveness through context-specific frameworks that respect local educational settings and curriculum requirements. Consequently, institutions should establish clear policies

regarding responsible AI use, prioritizing data privacy, academic integrity, and educational equity. Future research should extend to other subject areas and other teacher education institutions (TEIs) with a wider sample to enhance the generalizability of these findings, further investigating how the longitudinal impacts of AI literacy shape teacher and learning outcomes.

Author Contributions

LSAL: Conceptualization, Methodology, Instrument Validation, Formal Analysis, Resources, Data Curation, Writing – Original Draft Preparation, Visualization, Project Administration.

RBB: Conceptualization, Methodology, Instrument Validation, Formal Analysis, Resources, Data Curation, Project Administration.

CJMM: Conceptualization, Methodology, Instrument Validation, Formal Analysis, Writing – Review and Editing, Visualization, Supervision.

Declaration of the Use of Generative AI

During the preparation of this manuscript, the authors used Gemini 3.1 Flash-Lite to assist with language editing and polishing of the draft. The tool was used solely to improve clarity, grammar, and overall readability. The authors reviewed and revised the output as necessary and take full responsibility for the content of the manuscript.

Ethics

A clear explanation of adherence to the relevant research ethical considerations was included in the manuscript under the Methodology section. Data were handled with utmost confidentiality, and anonymity was ensured to protect the identity of the participants involved.

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