



E-ISSN 2654-9948

ALGORITMA Journal of Mathematics Education (AJME)

<http://journal.uinjkt.ac.id/index.php/algorithm>

Vol. 8 No. 1 – 2026, hal. 30-46

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## AI-MEDIATED LEARNING IN ADVANCED MATHEMATICS: HOW PRE-SERVICE TEACHERS DEVELOP EMERGING PEDAGOGICAL THINKING

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### Abstract

Since the use of artificial intelligence (AI) in education continues to broadly expand, understanding its role in pre-service teacher development has become increasingly important. This study explores how AI used in Advanced Mathematics courses contributes to the development of pedagogical thinking among pre-service mathematics teachers. A qualitative approach was employed involving 51 students. Data were collected through questionnaires and follow-up interviews, then analyzed using thematic analysis. The findings indicate that students use AI to support their understanding of abstract mathematical concepts and solve problems through simplified explanations and structured solution steps. Students' engagement with AI is characterized by several tensions between efficiency and understanding, assistance and dependency, and ease of use and prompt accuracy. These tensions foster reflection, metacognitive awareness, and more critical use of AI. The findings also reveal the emergence of pedagogical thinking, although it remains limited in addressing learner diversity and the complexity of instructional contexts.

**Keywords:** *advanced mathematics courses; artificial intelligence; pedagogical thinking; pre-service teachers*

### Abstrak

Seiring dengan semakin meluasnya penggunaan kecerdasan buatan (AI) dalam pendidikan, pemahaman mengenai perannya dalam perkembangan calon guru menjadi semakin penting. Penelitian ini bertujuan mengeksplorasi bagaimana penggunaan AI dalam mata kuliah matematika lanjut berkontribusi terhadap perkembangan pemikiran pedagogis mahasiswa calon guru matematika. Penelitian menggunakan pendekatan kualitatif dengan melibatkan 51 mahasiswa. Data dikumpulkan melalui kuesioner dan wawancara lanjutan, kemudian dianalisis menggunakan analisis tematik. Hasil penelitian menunjukkan bahwa mahasiswa memanfaatkan AI untuk memahami konsep matematika abstrak dan menyelesaikan masalah melalui penjelasan yang lebih sederhana serta langkah-langkah yang terstruktur. Keterlibatan mahasiswa dalam penggunaan AI diwarnai oleh beberapa ketegangan antara efisiensi dan pemahaman, bantuan dan ketergantungan, serta kemudahan penggunaan dan ketepatan prompt. Ketegangan tersebut mendorong refleksi belajar, kesadaran metakognitif, dan penggunaan AI yang lebih kritis. Temuan juga menunjukkan munculnya pemikiran pedagogis, meskipun masih terbatas dalam mempertimbangkan keragaman peserta didik dan kompleksitas situasi pembelajaran.

**Kata kunci:** *kecerdasan buatan; mahasiswa calon guru; matematika tingkat lanjut; pedagogical thinking*

**How to Cite:** Dirgantoro, K.P.S., Soesanto, R.H., & Saragih, M.J. (2026). AI-Mediated Learning in Advanced Mathematics: How Pre-Service Teachers Develop Emerging Pedagogical Thinking. *ALGORITMA Journal of Mathematics Education*, 8 (1), 30-46.

Permalink/DOI: <http://dx.doi.org/10.15408/ajme.v8i1.50881>

Received: April 2026; Accepted: June 2026; Published: June 2026

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## **INTRODUCTION**

The rapid development of artificial intelligence (AI) technology, particularly generative AI, has significantly transformed learning practices across disciplines, including mathematics education at the higher education context (Awang et al., 2025; Kasneci et al., 2023). In this context, AI enables students to obtain instant explanations, systematic step-by-step solutions, as well as sample questions and discussions that can be tailored to their learning needs. Previous studies suggest that AI has the potential to enhance learning engagement, provide immediate feedback, and support independent learning in mathematics (Wardat et al., 2023). Furthermore, the integration of AI in higher education not only expands access to knowledge, but also begins to shape how students represent and interpret mathematical concepts through AI-generated forms of explanation and solution patterns (Vieriu & Petrea, 2025).

Despite the optimism, the use of AI in higher mathematics education warrants critical examination. Although AI adoption rate among higher education students is increasing, empirical evidence regarding its impact on students' mathematical thinking remains limited (Turmuzi et al., 2026). On the other hand, AI systems do not always produce accurate or reliable outputs, specifically for mathematics problems requiring advanced reasoning and deep conceptual understanding (Wardat et al., 2023). This condition shows that students' interaction with AI is not only related to the efficiency of obtaining answers, but also has the potential to affect the way they process, evaluate, and interpret mathematical concepts (Holmes et al., 2019). Consequently, AI presents not only opportunities to support learning but also the possibility of reshaping students' understanding about mathematics itself. This shows that the impact of AI on mathematics learning in college should not be viewed as uniform, but rather needs to be analyzed contextually according to the characteristics of the discipline being studied.

One of the relevant and interesting contexts to be studied further is the learning of advanced mathematics courses (AMC) in college. AMC courses such as Real Analysis and Abstract Algebra require students to engage with abstract concepts, construct formal proofs, and develop rigorous deductive reasoning. In this context, learning mathematics goes beyond obtaining correct answers, but involves the process of building logical arguments, understanding the structure of concepts, and formally validating truth claims. The use of AI in this context has the potential to influence how students engage with the reasoning process, including how they evaluate the validity of a mathematical argument (Yoon et al., 2024). On the other hand, AI tends to be superior in solving procedural problems compared to problems that require formal proof and abstract reasoning, which is precisely the core nature of AMC. Therefore, it is important to understand how students interpret the use of AI in a mathematical context that epistemically demands depth of thinking.

This complexity becomes even more significant in the context of pre-service mathematics teachers education. Pre-service teacher students are in the transition phase from math learners to individuals who will teach math in the school environment. Therefore, they are not only required to understand mathematical concepts in depth, but also to develop a thinking way about how mathematical ideas can be explained, represented, and understood by others. The learning experiences they have during lectures, including interactions with AI, have the potential to shape the way they explain concepts, design examples, and facilitate students' future understanding.

In addition, students' interaction with AI not only affects conceptual understanding but can also mediate how students begin to reflect and develop pedagogical thinking, which is related to the way teachers understand, represent, and transform knowledge for teaching purposes (Shulman, 1987). AI can function not only as a learning aid, but also as a source of knowledge representations that implicitly offer explanatory models, solution structures, and ways to construct mathematical arguments. However, these influences do not occur linearly, but emerge through an interaction process involving learning experiences, tension, and reflection. Through such interactions, students may encounter divers ways of preparing explanations and strategies for delivering material, which ultimately contributes to the formation of their pedagogical thinking as pre-service teachers. At the same time, the use of AI carries various risks, including overdependence, lack of critical reflection, and the potential for a decrease in cognitive engagement in the learning process (Lagon, 2025; Selwyn, 2019). This tension between potential and risk suggests that the role of AI in shaping pedagogical thinking is complex and requires more in-depth study, especially in the context of teacher education in higher education.

Several studies indicate that AI is increasingly being utilized not only as a cognitive aid but also as a resource for designing learning experiences, creating assessment items, and developing teaching strategies (Luckin et al., 2016; Pepin et al., 2025). However, existing research has predominantly focused on students' perceptions, acceptance, and use of AI, as well as its effectiveness in supporting learning outcomes. Studies involving pre-service teachers have also examined issues such as attitudes toward AI, technological readiness, and the instructional potential of AI tools. While these studies provide valuable insights into the adoption and educational use of AI, less attention has been given to how AI-mediated learning experiences contribute to the development of pedagogical thinking among pre-service mathematics teachers. This is particularly relevant in the context of Advanced Mathematics Courses (AMC), where learning involves abstract concepts, complex reasoning, and intensive problem-solving processes. Consequently, the role of AI-supported learning experiences in shaping the early development of pedagogical thinking within this context remains insufficiently understood.

Furthermore, this study is grounded on the assumption that the pedagogical impact of AI lies not merely in its capacity to provide information or generate solutions, but in the tensions that emerge through its use, which subsequently trigger students' reflection on ways of learning and teaching. These tensions are significant because they can encourage students to evaluate the role of technology in learning and its implications for future teaching practices.

Based on this background, this study aims to examine how AI-mediated learning experiences in AMC contribute to the pedagogical development of pre-service teachers. Specifically, this study explores (1) how students utilize AI in building their understanding of mathematical concepts, (2) the epistemic and pedagogical tensions that arise when AI functions simultaneously as a learning tool and a semi-pedagogical agent, and (3) how these experiences and tensions shape students' emerging pedagogical thinking. By focusing on the transition from mathematics learners to pre-service teachers, this study seeks to understand how AI-mediated learning experiences, tensions, and reflective processes interact to support the development of pedagogical thinking in the context of AMC.

## **METHOD**

### ***Research Design***

This study conducted a descriptive qualitative approach with thematic analysis to explore how the use of AI in AMC learning shapes the pedagogical thinking of pre-service mathematics teacher students. This approach was considered to deeply gain and comprehend students' experiences, perceptions, and reflections in the context of learning technology used, especially in courses that require abstract reasoning and formal proof. A descriptive qualitative approach was also performed align with the focus of the research which is to describe and interpret phenomena based on participants' experiences contextually (Creswell, 2014). Thematic analysis was implemented as a key technique because it provided flexibility in identifying, analyzing, and interpreting patterns of meaning in complex qualitative data (Braun & Clarke, 2006, 2019). To enhance the transparency and accessibility of the findings, the occurrence of each theme is also presented using frequencies and percentages. These numerical summaries are not intended for statistical inference or generalization but rather to help readers understand the relative prominence of themes across participants and to provide additional context for interpreting the qualitative findings. Through this approach, the study sought to understand how students interpret AI not only as a learning aid but also as a resource that has the potential to influence how they understand and construct mathematical explanations.

### Participants

Participants in this study were higher education students from mathematics education study program who have taken AMC courses, such as Real Analysis and Abstract Algebra. The selection of participants was carried out by purposive sampling, considering the suitability of the participants' experiences to the focus of the research, namely, students who have used AI in the mathematics learning process. This approach was used because qualitative research prioritizes the richness and relevance of information over statistical representativeness of a larger population (Patton, 2001). Although the study involved 51 participants, analytical depth was achieved through the collection of detailed open-ended responses and follow-up interviews that enabled participants to elaborate on their experiences, perceptions, and reflections regarding AI use in AMC learning. From an interpretive qualitative perspective, the richness of data is determined not by the number of participants alone but by the extent to which participants provide meaningful accounts that illuminate the phenomenon under investigation. The relatively larger number of participants was intended to capture a wider range of experiences and perspectives, while thematic analysis was used to examine these experiences in depth and identify recurring patterns of meaning.

Participants were selected because they were in the transitional phase from mathematics learners to pre-service teachers, thus possessing relevant experience in linking AI use to the learning process as well as the development of pedagogical thinking. With these characteristics, participants were expected to provide rich reflections on how AI influences mathematical concept understanding and its implications for how they viewed future teaching practices. Based on the participant selection criteria, the number of respondents involved in this study was 51, whose demographics are shown in the Figure 1.

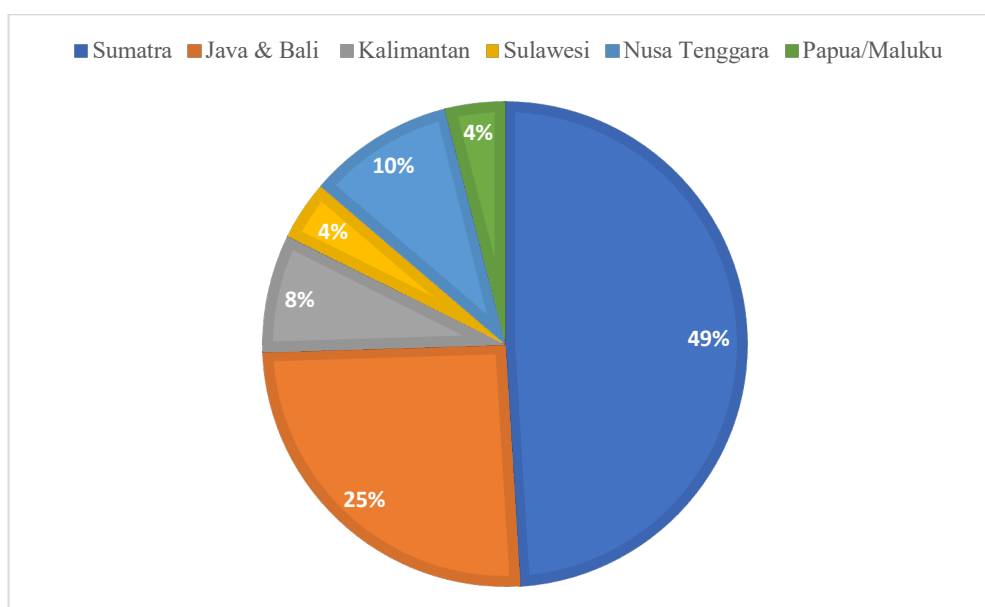


Figure 1. Regional Distribution of Pre-Service Mathematics Teacher Respondents

### ***Data Collection***

Data were collected through open-ended questionnaires and semi-structured interviews. The open-ended questionnaire was used as an initial instrument to obtain a broad overview of students' experiences using AI in AMC learning. The questions in the questionnaire were designed to explore the types of AI platforms used, the forms of AI use in learning, the learning experiences encountered, perceptions of AI's impact on learning autonomy and engagement, views on policies regarding AI use in learning, and students' reflections on their readiness as pre-service mathematics teachers. Additionally, respondents were asked to provide their views on how they would guide students' use of AI in the future. The use of an open-ended questionnaire allows participants to provide reflective, contextual, and diverse responses based on their individual experiences (Creswell & Poth, 2018).

Semi-structured interviews were conducted as a follow-up to deepen the findings of the questionnaire, particularly in understanding how students interpret the role of AI in AMC learning and its relationship to the role of lecturers. The interviews involved 9 pre-service teacher students who were purposively selected to represent a variety of academic achievements in AMC. Participants were grouped into three categories, which were determined based on the average grades obtained across the Advanced Mathematics Courses (AMC) they had previously completed, including courses such as Real Analysis and Abstract Algebra. Participants were ranked according to their AMC grade averages and then selected to represent the high-, medium-, and low-achievement groups, with three students in each category. This selection aims to gain diverse perspectives related to students' experiences and ways of interpreting the use of AI in mathematics learning. The categorization was intended to ensure variation in academic backgrounds and learning experiences rather than to facilitate statistical comparison between groups. The interviews focused on exploring students' perceptions of whether AI can replace the role of lecturers, as well as the reasons behind this view. Questions are developed flexibly during the interview process to delve deeper into students' experiences, reflections, and considerations. This approach allows researchers to gain a richer understanding of students' thinking processes in interpreting the use of AI in the context of mathematics learning (Kvale, 2007).

### ***Data Analysis***

Data were analyzed using thematic analysis techniques by following the stages developed by Braun & Clarke (2006). The analysis process begins with reading all the data repeatedly to understand the context and meaning contained in the participants' answers. Furthermore, an open coding process is carried out to identify units of meaning that are relevant to the focus of the research. Meaningful segments of data were assigned initial codes that captured the central ideas expressed by participants. For example, responses describing AI as providing simpler explanations

for difficult mathematical concepts were coded as “conceptual clarification,” whereas responses emphasizing step-by-step assistance in solving mathematical problems were coded as “procedural support.” Codes that have similar meanings are then grouped into initial categories, such as conceptual support and problem-solving support, which are further developed into main themes. The development from codes to categories and themes was conducted through an iterative process of comparison, refinement, and interpretation to ensure that the resulting themes accurately represented participants’ experiences. This process is done iteratively to ensure consistency and interconnectedness between themes. The final stage of analysis is carried out by interpreting themes that arise in relation to the concept of pedagogical thinking, especially in seeing how students interpret the use of AI in understanding, explaining, and designing the delivery of mathematical concepts. The analysis focuses not only on the frequency of occurrence of the theme, but also on the depth of meaning and variety of experiences shown by the participants.

### ***Trustworthiness***

To ensure the quality of the research, trustworthiness criteria were applied, encompassing credibility, dependability, confirmability, and transferability (Lincoln & Guba, 1985). Credibility is maintained through triangulation of data sources, namely by comparing findings from questionnaires and interviews. Dependability is achieved by systematically and transparently documenting the analysis process. Confirmability is done by ensuring that the resulting interpretation is based on empirical data, not the researchers' assumptions. Meanwhile, transferability is supported through the presentation of detailed descriptions of the research context, which allows readers to assess the relevance of the findings to other contexts.

## **RESULTS AND DISCUSSION**

Based on the results of the questionnaire, the majority of students use AI as the main tool in AMC learning. The most dominant platform used is ChatGPT, followed by several other platforms such as Mathway, Wolfram Alpha, Photomath, and Perplexity. Figure 2 shows the various AI platforms used by students during the AMC course.

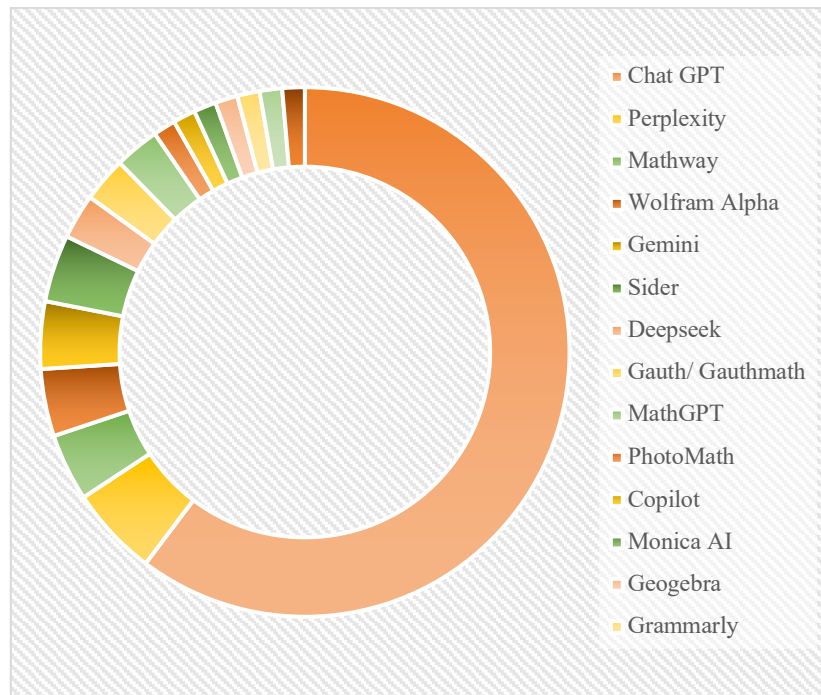


Figure 2. AI Platforms Used By Pre-service Mathematics Teachers

The use of AI was not limited to a single function but extended to various learning activities, including conceptual understanding, problem solving, and information seeking. The findings are organized into three themes corresponding to the study objectives: (1) the role of AI in supporting mathematical understanding, (2) tensions arising from AI-mediated learning experiences, and (3) the emergence of pedagogical thinking from these experiences.

**Theme 1. The Role of AI in the Learning Process of Pre-service Mathematics Teachers**

An analysis of student responses was conducted to identify patterns of experience in utilizing AI during the AMC learning process. Each response was analyzed using a thematic coding approach to unfold key themes representing the functions and roles of AI in supporting student learning activities. The distribution of themes obtained from the coding results is presented in Table 1, which shows the frequency of occurrence of each theme across all student responses.

**Table 1. Distribution of Themes on the Use of AI in Supporting AMC Learning (N = 51)**

| No. | Theme   | N  | (%)  |
|-----|---|----|------|
| 1   | AI for conceptual clarification   | 36 | 70.6 |
| 2   | AI for problem-solving (procedural support)                               | 19 | 37.3 |
| 3   | AI for self-regulated learning support                                    | 8  | 15.7 |
| 4   | AI as a linguistic mediator (linguistic support)                          | 9  | 17.6 |
| 5   | AI as a substitute for instructor explanations (instructional gap filler) | 4  | 7.8  |
| 6   | Critical awareness of AI limitations                                      | 2  | 3.9  |

Based on Table 1, the most frequently reported function of AI was conceptual clarification (70.6%), followed by procedural support in problem solving (37.3%). Participants described AI as

helping them understand abstract mathematical concepts by providing explanations in simpler language and presenting solution procedures in a more structured manner.

One participant explained that AI *“makes it easier for me to understand the concepts being studied.”* Additionally, AI is also used to help solve problems by presenting step-by-step solutions. Several participants also reported using AI to support independent learning, seek additional references, and overcome difficulties in understanding academic texts.

Results from follow-up interviews indicate that the use of AI is inseparable from the instructor’s role in the learning process. The high category (H) students put AI as a companion, not a replacement, as it was revealed that *“we can not only use AI... So it's not 100% AI.”* Medium (M) students show a more flexible position, where AI can be the main source in certain conditions because it is considered capable of providing simpler explanations. Meanwhile, low-category (L) students still emphasize the importance of lecturers, especially in providing learning experiences that cannot be replaced by AI, such as *“active interaction”* and *“human touch”* in learning.

Overall, the findings indicate that students primarily use AI to support conceptual understanding and mathematical problem solving. Although AI is widely utilized during AMC learning, participants consistently described its role as complementary rather than substitutive in relation to lecturers.

### ***Theme 2. Tension as a Mechanism for Shaping Pedagogical Thinking***

While it provides ease of access and understanding, the use of AI does not always result in a linear impact on the student learning process. Analysis of students' responses revealed tensions in their learning experiences. This tension arises from the interaction between the ease that AI offers and the various limitations that are perceived during its use. Therefore, the analysis focuses on the patterns of tension reflected in the student experience, both related to the technical aspects of the use of AI and its impact on the learning process. The forms of tension identified from the thematic coding results are presented in Table 2.

**Table 2. Distribution of Tensions in the Use of AI in AMC Learning (N = 51)**

| No. | Theme  | Empirical Indications  | N  | (%)  |
|-----|--|--|----|------|
| 1   | Ease of access vs. AI inaccuracy             | Quick responses but often incorrect/inappropriate            | 18 | 35.3 |
| 2   | Ease of use vs. Prompt-writing skills        | AI is easy to use but depends on the quality of instructions | 9  | 17.6 |
| 3   | Flexibility of use vs. Technical limitations | AI aids learning but is constrained by symbols/equations     | 8  | 15.7 |
| 4   | Accessibility vs. System limitations         | Ease of access is limited by quotas/free versions            | 5  | 9.8  |
| 5   | Learning support vs. Potential dependency    | AI aids learning but may reduce critical thinking effort     | 17 | 33.3 |
| 6   | Increased engagement vs. conditional impact  | AI can increase engagement depending on how it is used       | 7  | 13.7 |

Based on Table 2, the most prominent tensions reported by participants involved the contrast between ease of access and AI inaccuracy (35.3%), followed by concerns regarding potential dependency on AI (33.3%). Participants frequently acknowledged the convenience of obtaining immediate responses while simultaneously expressing concerns about the reliability of those responses.

One participant stated: *"AI isn't always right... I have to double-check."* In addition, tensions also arise between the ease of use of AI and the demands of the ability to compose prompts, where students realize that AI outcomes are highly dependent on the clarity of the instructions given. This tension shows that the use of AI does not automatically improve the quality of learning, but rather gives rise to new dynamics in the way students manage their learning process.

This tension is further seen in the results of interviews that show differences in responses between groups of students. High category (H) students tend to respond critically and selectively to the limitations of AI, by placing AI as a tool that needs to be controlled for its use, as it is revealed that AI is used *"to provide assistance... so it's not AI entirely."* Medium (M) students show a tug-of-war between ease and instantaneous potential, where AI helps understand the material, but also has the potential to encourage more practical use without deepening, especially when explanations are considered *"simpler"* compared to other sources. Meanwhile, students in the low category (L) highlighted the limitations of AI in supporting the learning process as a whole, both in terms of explanatory structure and learning experience, such as stating that the use of AI *"cannot get a feel from the learning experience directly"*.

In addition, the tension between activeness and dependency was also evident in the questionnaire responses, where some students felt that AI made them more active because they could *"ask questions over and over again without limitations"*, while others stated that AI actually *"makes people less active in learning because they rely on answers practically"*. In other words, the convenience offered by AI actually poses new challenges in maintaining the quality of the thought process.

These findings indicate that students' experiences with AI are characterized by both opportunities and challenges. Rather than experiencing AI solely as a beneficial tool, participants encountered tensions that required them to evaluate its advantages, limitations, and appropriate uses within the learning process.

### ***Theme 3. Emerging Pedagogical Thinking from AI-Mediated Learning Experiences***

To address the third research objective concerning how AI-mediated learning experiences contribute to pedagogical thinking, participants' responses were analyzed to identify how their experiences as learners were translated into views about future teaching practices. The distribution of pedagogical orientations is presented in Table 3.

**Table 3. Distribution of Students' Pedagogical Orientations Toward the Use of AI in Mathematics Learning (N = 51)**

| No. | Theme   | N  | (%)  |
|-----|---|----|------|
| 1   | AI as a tool that should be encouraged with pedagogical controls and limitations      | 34 | 66.7 |
| 2   | AI as a supportive tool that enhances teaching readiness                              | 32 | 62.7 |
| 3   | AI as a tool that should be used critically and not lead to dependency                | 35 | 68.6 |
| 4   | AI as a tool whose use is contextual (depending on the material/student conditions)   | 9  | 17.6 |
| 5   | AI as a tool that has the potential to disrupt the learning process if not controlled | 9  | 17.6 |

Table 3 shows that most participants confirmed that AI should be encouraged in learning but accompanied by pedagogical controls and limitations (66.7%). Similarly, many participants viewed AI as a tool that could support teaching readiness (62.7%) while emphasizing the need for critical and responsible use (68.6%).

Participants reported that their experiences using AI had influenced how they thought about explaining mathematical concepts to future students. Several participants noted that exposure to multiple AI-generated explanations helped them recognize alternative ways of presenting mathematical ideas. One participant explained that AI provided "*different ways to explain concepts that might be easier for students to understand.*"

These findings are reinforced by the results of interviews that show how students are starting to project their experiential teaching principles. The high category (H) students emphasized the importance of using AI in a limited and controlled manner in learning, such as stating that AI is "*used as a tool in learning, not as the main solution*", and the importance of ensuring that the learning process remains oriented towards understanding, not practicality alone. Medium (M) students show adaptive tendencies, where AI is seen as a helpful resource in developing ideas and learning approaches, for example, as a means to "*convey new ideas, including how to make learning more effective*". Meanwhile, students in the low category (L) emphasized the need for control in the use of AI to prevent dependence, such as stating that the use of AI needs to be limited so as not to "*make us dependent*". In addition, in projections as pre-service teachers, students also emphasize that students need to be directed to use AI wisely, for example, by not "*copying AI answers*" but understanding the process.

Across all achievement groups, participants consistently emphasized the importance of using AI critically and responsibly. They highlighted the need for students to evaluate AI-generated information, understand mathematical reasoning, and maintain active engagement in learning. These responses suggest that participants were beginning to extend their experiences as learners into considerations about future teaching practices.

Taken together, the three themes reveal a coherent pattern in participants' experiences with AI during Advanced Mathematics Courses. The findings show that AI initially functions as a resource for conceptual understanding and problem solving, while simultaneously generating tensions related to accuracy, dependency, and learning quality. These tensions encourage participants to reflect on their learning experiences and the role of AI in mathematics learning. Through this reflective process, participants begin to formulate pedagogical considerations regarding how mathematical concepts should be explained and how AI should be used in educational contexts. The following discussion interprets these findings in relation to existing literature and explores their implications for the development of pedagogical thinking among pre-service mathematics teachers.

### ***AI as a Cognitive Mediator in Advanced Mathematics Learning***

The findings indicate that AI functions primarily as a cognitive mediator that supports students' understanding of abstract mathematical concepts. Participants frequently described AI as providing simplified explanations and structured solution processes that helped them navigate the conceptual demands of AMC. This finding is particularly relevant because AMC learning requires engagement with abstract reasoning, formal proof, and rigorous mathematical argumentation rather than merely obtaining correct answers.

The role of AI identified in this study extends beyond information retrieval. Students interacted with multiple forms of explanation generated by AI, allowing them to encounter alternative representations of mathematical concepts. In this sense, AI served as an intermediary that expanded students' access to mathematical explanations and problem-solving approaches. This finding supports previous studies suggesting that AI can enhance learning by providing immediate feedback, adaptive explanations, and multiple representations of knowledge (Förster et al., 2025; Wardat et al., 2023).

However, the findings also reveal that students did not position AI as a substitute for lecturers. Instead, lecturers continued to be viewed as essential sources of conceptual clarification, validation, and learning experiences that AI could not fully replicate. This finding aligns with the argument that educational technologies do not replace teachers but rather reshape the learning environment in which teaching and learning occur (Holmes et al., 2019). Within AMC learning, AI appears to complement rather than replace the pedagogical role of lecturers.

### ***Tension as a Catalyst for Reflection and Metacognitive Awareness***

A central finding of this study is that students' experiences with AI were characterized by multiple tensions. Rather than experiencing AI as an unambiguously beneficial tool, students encountered contradictions between convenience and accuracy, support and dependency, and

accessibility and cognitive effort. These tensions played an important role in shaping how students evaluated and regulated their own learning processes.

From the perspective of self-regulated learning, students are required not only to access information but also to monitor understanding, evaluate information sources, and regulate learning strategies (Zimmerman, 2000). The tensions identified in this study suggest that AI functions as an ambivalent learning tool. While AI can facilitate rapid access to information and support independent learning, it may also reduce cognitive engagement when used without sufficient reflection. Consequently, the educational value of AI appears to depend not only on the technology itself but also on how learners manage their interactions with it.

Importantly, the findings suggest that tensions did not merely function as obstacles. Instead, they became triggers for reflection. Participants demonstrated increasing awareness of the limitations of AI, the need to verify information, and the importance of maintaining conceptual understanding. Such reflections indicate the emergence of metacognitive awareness regarding the appropriate use of AI in mathematics learning. This finding is consistent with research suggesting that reflective engagement with digital technologies can strengthen metacognitive processes and support more adaptive learning behaviours (Fahrni et al., 2025).

### ***From Learning Experiences to Emerging Pedagogical Thinking***

The findings further indicate that students' reflections on AI-mediated learning experiences began to extend beyond their roles as learners and into their emerging identities as future teachers. Participants did not merely evaluate whether AI was useful for learning mathematics; they also began to consider how mathematical concepts should be explained, how students should use AI, and how technology should be integrated into learning processes.

This finding is significant because it suggests that pedagogical thinking may begin to develop through students' experiences as learners. Exposure to multiple explanations generated by AI encouraged students to consider alternative ways of representing mathematical concepts. Simultaneously, their experiences with the limitations of AI led them to formulate principles regarding the responsible and critical use of technology in teaching.

Nevertheless, the findings also indicate that this pedagogical development remains at an early stage. Participants generally focused on issues such as explanation quality, conceptual understanding, and dependency on technology. However, they rarely discussed broader pedagogical considerations, including learner diversity, classroom interactions, assessment practices, or the contextual factors that influence teaching decisions. Consequently, the findings do not suggest a substantial transformation of pedagogical thinking but rather the emergence of initial pedagogical orientations that are still developing.

This interpretation is consistent with Shulman's (1987) concept of pedagogical content knowledge (PCK), which emphasizes that effective teaching requires not only content knowledge but also an understanding of how knowledge can be transformed into forms that are accessible to learners. While AI exposed students to various explanatory approaches, lecturers continued to play a crucial role in modelling how explanations are selected, adapted, and implemented within authentic teaching situations.

### ***Theoretical Contribution***

This study contributes to the growing literature on AI in mathematics teacher education by proposing a process-oriented explanation of how pedagogical thinking begins to emerge through AI-mediated learning experiences. Previous studies have primarily examined students' perceptions of AI, technological acceptance, learning outcomes, or readiness to adopt AI in educational settings. In contrast, the present study focuses on the developmental processes through which AI-supported learning experiences contribute to pedagogical thinking among pre-service mathematics teachers.

Based on the findings, the emergence of pedagogical thinking can be understood as a progression from AI-mediated learning experiences to pedagogical reflection. Initially, AI functions as a cognitive resource that supports conceptual understanding and problem solving by providing explanations, examples, and alternative solution strategies. However, students' interactions with AI are not uniformly positive. As demonstrated in this study, learners encounter various tensions, including concerns about accuracy, dependency, prompt-writing skills, and the quality of learning.

These tensions appear to play an important role in stimulating reflective processes. Rather than accepting AI outputs uncritically, students begin to evaluate the strengths and limitations of AI, reconsider their learning strategies, and reflect on the conditions under which AI can support meaningful learning. Through this reflection, students gradually move beyond concerns related to their own learning and begin to consider broader pedagogical questions, such as how mathematical concepts should be explained, how students should use AI responsibly, and what role AI should play in classroom learning.

Accordingly, this study proposes a conceptual pathway in which AI-mediated learning experiences generate tensions, tensions trigger reflective evaluation, and reflection contributes to the emergence of initial pedagogical orientations. In this process, pedagogical thinking does not develop directly from AI use itself, but from learners' reflective engagement with the opportunities and challenges created by AI-supported learning experiences.

This conceptualization extends existing research by suggesting that the educational significance of AI in teacher education may lie not only in its capacity to support learning outcomes

but also in its potential to create reflective experiences that contribute to the early development of pedagogical thinking among pre-service mathematics teachers.

### ***Implications for Mathematics Teacher Education***

The findings have important implications for the design of Advanced Mathematics Courses in mathematics teacher education programs. The results suggest that AI integration should be guided by explicit pedagogical objectives rather than being treated merely as a technological resource for obtaining answers. Instructors can design learning activities that encourage students to critically evaluate AI-generated explanations, compare them with formal mathematical reasoning, and reflect on the strengths and limitations of AI in supporting conceptual understanding.

Such activities may help students move beyond procedural use of AI and engage in deeper reflection regarding mathematical reasoning and teaching. In this way, AI can function not only as a cognitive support tool but also as a resource that supports the development of reflective and pedagogically informed future mathematics teachers.

## **CONCLUSION**

This study shows that the use of AI in AMC learning contributes to the emerging pedagogical thinking of pre-service teacher students through a non-linear process. Students use AI to understand abstract mathematical concepts, while also being exposed to different ways of explaining these concepts. However, this experience does not stand alone, as lecturers continue to play a key role in building conceptual understanding and providing models of teaching practices. The research findings also show that the use of AI raises various tensions, such as between efficiency and depth of understanding and between assistance and dependency. This tension encourages students to reflect on the way they learn, which in turn leads to the development of metacognitive awareness in managing the use of AI more critically and independently. Through the interaction between the experience of using AI, the tensions that arise, and the reflection that is carried out, students begin to develop pedagogical ways of thinking, especially in considering how mathematical concepts can be explained to others. Thus, this study proposes that the initial development of students' pedagogical thinking can be understood as a result of the interaction between the experience of using AI, the tension in the learning process, and the reflection on the experience. Nevertheless, this study was limited to pre-service mathematics teachers who had experience using AI in Advanced Mathematics Courses and relied primarily on participants' self-reported experiences and reflections. As a result, the findings capture participants' perceptions of the role of AI in shaping pedagogical thinking but do not directly examine how such thinking is enacted in actual teaching practice. Future research could investigate the development of

pedagogical thinking across different stages of teacher education and explore how AI-supported learning experiences influence instructional decision-making in authentic classroom contexts. Longitudinal studies may also provide deeper insights into how pedagogical thinking evolves over time as pre-service teachers gain greater experience with both AI and teaching practice.

These findings imply that the integration of AI in mathematics learning needs to be pedagogically directed, so that AI not only serves as a tool to obtain answers, but also as a means to develop conceptual understanding, mathematical thinking, and pedagogical readiness of students as pre-service teachers. In the context of Advanced Mathematics Courses, lecturers should provide opportunities for students to critically evaluate AI-generated explanations, compare them with formal mathematical reasoning, and reflect on the strengths and limitations of AI in supporting learning. Such activities may help students move beyond procedural use of AI and foster the reflective processes that contribute to the development of pedagogical thinking.

## ACKNOWLEDGMENTS

The authors are grateful to the Universitas Pelita Harapan for all their support, both in terms of permits and funding for this study. This study was conducted under a performance contract with number P-045-INT-FIP/VII/2025, dated July 1, 2025.

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