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Teacher Readiness and Challenges in AI-Based Geometry Learning: A Phenomenological Study

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ABSTRACT

Artificial Intelligence (AI) has emerged as a transformative technology in mathematics education by supporting adaptive learning, interactive visualization, and personalized instruction. Although numerous studies have examined the effectiveness of AI in improving students' mathematical achievement, limited attention has been given to teachers' readiness to integrate AI into geometry learning, particularly in semi-urban educational contexts. This study aimed to explore junior high school mathematics teachers' perceptions, readiness, challenges, and expectations regarding the implementation of AI-based geometry learning. This study employed a qualitative phenomenological approach involving 15 junior high school mathematics teachers from Tana Toraja Regency, Indonesia, selected through purposive sampling. Data were collected using semi-structured interviews, non-participant observations, and document analysis. The data were analyzed thematically through open coding, axial coding, category development, and theme identification, supported by NVivo 15. Credibility was enhanced through source and method triangulation, member checking, and audit trails. Four major themes emerged: positive perceptions of AI integration, varying levels of teacher readiness, infrastructural and competency-related challenges, and expectations for institutional support and continuous professional development. Teachers recognized AI as a valuable tool for enhancing students' spatial visualization, conceptual understanding, and engagement in geometry learning. However, inadequate digital infrastructure, limited AI literacy, insufficient professional training, and concerns regarding reduced human interaction and data privacy constrained effective implementation. The findings indicate that successful AI integration in geometry learning depends on the interaction between teachers' pedagogical readiness, technological competence, institutional support, and educational policy. This study contributes to the discourse on AI in mathematics education by extending understanding of teacher readiness in semi-urban contexts and providing practical recommendations for sustainable professional development, infrastructure improvement, and context-sensitive AI integration in secondary education.

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1. INTRODUCTION

Geometry learning at the junior high school level continues to present significant challenges, particularly in developing students' spatial reasoning, visualization, and conceptual understanding. Many students experience difficulties in relating two dimensional representations to three dimensional objects and interpreting geometric transformations conceptually. These difficulties are often associated with instructional practices that remain teacher-centered and procedural, limiting students' opportunities to actively construct mathematical understanding through exploration and visualization. As a result, geometry is frequently perceived as an abstract and difficult subject by learners.

Previous studies have emphasized that meaningful geometry learning requires interactive, contextual, and visual learning experiences that support students in developing spatial thinking skills more effectively (Putra & Ramadhani, 2022). Conventional instructional approaches, such as lectures and repetitive exercises, are considered insufficient to address these learning challenges. In many classrooms, instructional media remain passive and are not fully adapted to students' diverse learning characteristics and spatial abilities. Students with low spatial reasoning skills particularly require visual and interactive learning environments to understand geometric relationships concretely (Riyanto et al., 2023).

Therefore, innovative learning approaches integrating visualization, interactivity, and adaptive learning support are increasingly needed to improve students' engagement and conceptual understanding in geometry learning. In recent years, the rapid development of Artificial Intelligence (AI) has created new opportunities for transforming educational practices, including mathematics learning. AI-based learning systems can provide personalized instruction, adaptive feedback, automatic assessment, and interactive visualizations tailored to students' individual learning needs. Research has shown that AI integration in mathematics education can improve students' motivation, engagement, problem-solving abilities, and conceptual understanding because learning becomes more responsive and student-centered (Hwang & Chang, 2021).

Furthermore, AI-supported visualization technologies have significant potential to facilitate abstract geometry concepts through dynamic and interactive representations. Several international studies have explored the implementation of AI in mathematics and digital learning environments. For example, Holmes et al. (2022) explained that AI can support adaptive learning pathways and improve personalized educational experiences. Similarly, Zawacki-Richter et al. (2019) highlighted the growing role of AI in enhancing teaching effectiveness and learning analytics in higher and secondary education. In mathematics education specifically, AI-assisted learning platforms have been reported to positively influence students' learning performance and engagement through intelligent tutoring systems and automated feedback mechanisms. However, most previous studies primarily focused on students' learning outcomes, technological development, or the effectiveness of AI-based applications in controlled environments.

Despite the growing body of literature, limited studies have specifically investigated teachers' readiness, perceptions, and expectations regarding AI integration in geometry learning, particularly within semi-urban secondary school contexts in developing countries such as Indonesia. Existing research often overlooks teachers' perspectives, even though teachers play a central role in determining how educational technology is implemented, adapted, and sustained in classroom practice. Teachers' technological competence, pedagogical beliefs, and institutional support significantly influence the successful adoption of AI based learning innovations. Without adequate teacher readiness, the implementation of AI technology in classrooms may remain ineffective despite the availability of technological tools. In the Indonesian context, the implementation of AI-based learning remains relatively limited due to infrastructural constraints, limited digital literacy, and insufficient professional development opportunities for teachers (Suharsono & Ningsih, 2024). Although the Independent Curriculum emphasizes digital transformation and the strengthening of computational thinking skills, many schools are still in the early stages of technology integration (Rahmawati & Sari, 2023; Santoso & Utami, 2022). This condition demonstrates a gap between educational policy expectations and practical implementation in schools. Moreover, few studies have examined how mathematics teachers perceive

AI based geometry learning and what challenges they encounter in integrating AI into classroom instruction. Based on these limitations, this study aims to investigate mathematics teachers' perceptions, readiness, barriers, and expectations regarding the implementation of Artificial Intelligence-based geometry learning at the junior high school level. This research seeks to fill the existing gap by focusing on teachers as key agents of educational innovation in semi-urban school contexts. The findings are expected to contribute theoretically to the growing discourse on AI integration in mathematics education from the perspective of teacher readiness and practically to provide recommendations for designing sustainable teacher training programs, strengthening digital learning infrastructure, and developing contextually relevant educational policies for AI-supported learning in Indonesia.

2. METHODS

This study employed a qualitative approach with an exploratory phenomenological design to investigate mathematics teachers' experiences, perceptions, and expectations regarding the implementation of Artificial Intelligence (AI) based geometry learning. The phenomenological approach was selected to capture participants' lived experiences and interpretations related to the integration of AI in mathematics instruction within their actual teaching contexts (Creswell & Poth, 2018).

The research was conducted in Tana Toraja Regency, South Sulawesi, Indonesia, representing a semi-urban educational context with varying levels of technological accessibility and digital readiness. Data collection was carried out from January to March 2025. The participants consisted of 15 junior high school mathematics teachers selected through purposive sampling. The inclusion criteria were: (1) having at least three years of teaching experience, (2) possessing basic knowledge or interest in AI-based educational technology, and (3) being willing to participate voluntarily in the research process. Data were collected through semi-structured interviews, non-participant observations, and document analysis.

Each interview lasted approximately 45–60 minutes and was conducted individually to explore teachers' perceptions, readiness, challenges, and expectations regarding AI integration in geometry learning. In total, 15 interviews and 10 classroom observations were conducted. The observation process focused on classroom instructional practices, technology utilization, and teacher-student interactions during mathematics learning activities. Documentation analysis included lesson plans, teaching materials, and digital learning media used by participants. The researcher acted as the primary research instrument, supported by interview guidelines, observation sheets, and documentation protocols.

To ensure content validity, the interview protocol was reviewed through expert judgment prior to data collection. In addition, member checking was conducted to confirm the accuracy and credibility of participants' responses. Data analysis was conducted thematically following several stages: data transcription, open coding, axial coding, category development, and theme identification. Open coding was used to identify initial concepts emerging from the interview and observation data, while axial coding was applied to connect related categories and identify broader thematic relationships. The final themes were interpreted inductively to capture patterns of meaning related to teachers' experiences and readiness in AI-based geometry learning. NVivo 15 software was utilized as a supporting tool to organize, manage, and visualize qualitative data systematically; however, the interpretation and thematic analysis were fully conducted by the researchers. To ensure trustworthiness, this study applied source triangulation, method triangulation, member checking, and audit trails. Ethical considerations were also carefully addressed throughout the research process. All participants provided informed consent prior to participation, and their identities were anonymized to maintain confidentiality and privacy. Participants were informed that their involvement was voluntary and that they could withdraw from the study at any stage without consequences.

3. FINDINGS AND DISCUSSION

The thematic analysis conducted using NVivo 15 identified four major themes related to mathematics teachers' perspectives on the implementation of Artificial Intelligence (AI)-based geometry learning: (1) teachers' perceptions of AI, (2) teacher readiness, (3) challenges in AI implementation, and (4) expectations for future development. These themes emerged from interview transcripts, classroom observations, and document analysis, revealing the complex relationship between teachers' positive attitudes toward AI and the practical constraints they encounter in classroom implementation.

3.1 Teachers' Perceptions of AI in Geometry Learning

Most participants demonstrated positive perceptions toward the integration of AI in geometry learning. Teachers believed that AI-based applications could support students' spatial visualization abilities, facilitate interactive learning experiences, and improve conceptual understanding of abstract geometric concepts. One participant stated: *"AI can help students imagine three-dimensional objects more clearly because students can directly see moving visualizations and simulations."* (Teacher 4) Another teacher explained: "*Students usually find geometry difficult because they cannot imagine the shapes. If AI applications are used, learning becomes more interesting and easier to understand."* (Teacher 9)

These findings indicate that teachers perceive AI not merely as a technological tool but as a potential pedagogical medium capable of improving geometry instruction. The emphasis on visualization and interactivity aligns with previous studies showing that AI-supported learning environments can strengthen students' motivation and conceptual understanding in mathematics learning (Lee et al., 2020; Hwang & Chang, 2021).

However, although teachers viewed AI positively, their understanding of AI concepts remained relatively limited. Most participants associated AI only with automation tools or digital applications rather than adaptive learning systems capable of analyzing student performance and providing personalized feedback. This suggests that teachers' conceptual literacy regarding AI pedagogy is still underdeveloped. The finding supports Hwang and Chang's (2021) argument that successful AI integration requires not only technical familiarity but also pedagogical understanding of how AI can support learning processes.

3.2 Teacher Readiness and Digital Competence

The second theme concerns teacher readiness in implementing AI-based learning. Teachers generally expressed enthusiasm toward educational technology and recognized the importance of adapting to digital transformation in education. Nevertheless, many participants acknowledged limited digital competence and insufficient experience in using AI-based learning platforms. One participant stated: *"I am interested in using AI, but honestly I still do not fully understand how to integrate it into mathematics lessons."* (Teacher 7). Similarly, another teacher explained: *"We are expected to use digital technology, but there is still minimal training related to AI applications in learning."* (Teacher 2).

These findings suggest that teachers' readiness is still dominated by affective readiness (motivation and positive attitudes) rather than technical and pedagogical readiness. From the perspective of Teacher Readiness Theory (Rahmawati & Sari, 2023), teacher readiness consists of cognitive, affective, and instrumental dimensions. In this study, the affective dimension appeared relatively strong, while the cognitive and instrumental dimensions remained limited due to inadequate training and technological exposure. The findings also reinforce the Technology Acceptance Model (TAM) proposed. Teachers generally perceived AI as useful for improving learning effectiveness, particularly in geometry visualization and interactive instruction. However, the perceived ease of use remained low because many teachers lacked sufficient technological competence and practical guidance. This condition explains why teachers simultaneously perceive AI as beneficial yet difficult to implement in actual classroom settings.

3.3 Challenges in AI Implementation

The third theme identified significant barriers to AI integration in schools. The most frequently reported obstacles included limited digital infrastructure, unstable internet connectivity, lack of technological devices, and insufficient institutional support. One participant explained: *"Sometimes the internet connection is unstable, so it is difficult to use digital learning applications consistently."* (Teacher 11) Another teacher stated: *"Not all schools have adequate facilities. Some classrooms still lack projectors or proper computer access."* (Teacher 5). These findings indicate that technological readiness in schools remains uneven, particularly in semi-urban educational contexts. This situation suggests that the success of AI integration cannot depend solely on teacher motivation but also requires structural and institutional support. The findings support Suharsono and Ningsih (2024), who argued that teachers' technology adoption is strongly influenced by infrastructure availability and organizational support systems. In addition to technical barriers, several teachers expressed concerns regarding the ethical and social implications of AI implementation. Participants worried that excessive dependence on AI could reduce human interaction in learning and raise issues related to student data privacy. One teacher noted: *"Technology is important, but teachers should not lose their role in guiding students directly."* (Teacher 8). This finding indicates that teachers still position human interaction as a central component of mathematics learning. Therefore, AI is perceived as a complementary instructional tool rather than a replacement for teachers' pedagogical roles.

3.4 Expectations for AI-Based Learning Development

The final theme relates to teachers' expectations regarding the future implementation of AI in mathematics education. Most participants emphasized the need for continuous professional training, institutional mentoring, curriculum adaptation, and stronger educational policies supporting digital innovation. One participant stated: *"If schools provide training and technical support, teachers will be more confident in using AI-based learning."* (Teacher 1). Another participant explained: *"The government should provide clear guidelines so teachers know how AI can be integrated into the curriculum."* (Teacher 13). These findings suggest that sustainable AI integration requires collaboration among teachers, schools, policymakers, and technology developers. Teachers expect AI implementation to be accompanied by systematic capacity-building programs rather than isolated technological initiatives. This supports previous research emphasizing that educational innovation becomes more effective when institutional policies and professional development programs operate simultaneously (Santoso & Utami, 2022).

3.5 Revised Thematic Analysis Table

Table 1. Summary of Thematic Findings on AI-Based Geometry Learning

Theme	Main Findings	Coding Frequency
Teachers' Perceptions	AI improves visualization, engagement, and conceptual understanding in geometry learning	42 references
Teacher Readiness	Teachers show high motivation but limited technical and pedagogical competence	37 references
Implementation Challenges	Infrastructure limitations, unstable internet access, and lack of institutional support hinder AI integration	45 references
Ethical Concerns	Teachers are concerned about reduced human interaction and student data privacy	18 references

The findings of this study demonstrate that the successful integration of AI in geometry learning is influenced by the interaction among pedagogical readiness, technological competence, institutional support, and educational policy. Although teachers perceive AI as highly beneficial for improving students' spatial understanding and learning engagement, practical implementation remains constrained by infrastructural limitations and insufficient professional preparation. This indicates that AI integration in mathematics education should not be viewed merely as technological adoption but as a comprehensive educational transformation requiring systemic support and sustainable teacher development programs. This study contributes theoretically by strengthening the application of

Teacher Readiness Theory and the Technology Acceptance Model within the context of AI-supported mathematics education. Practically, the findings provide recommendations for policymakers and educational institutions to develop structured training programs, improve digital infrastructure, and formulate adaptive policies that support sustainable AI integration in Indonesian secondary schools.

Beyond the four major themes identified in this study, the findings also reveal broader implications regarding the transformation of mathematics education in the digital era. The integration of Artificial Intelligence (AI) into geometry learning does not merely represent the introduction of new technological tools, but also reflects a shift in pedagogical orientation from conventional teacher-centered instruction toward more adaptive, student-centered, and data-driven learning environments. This transformation requires teachers to reposition their roles, not only as knowledge transmitters but also as facilitators, learning designers, and mediators of technology-supported instruction (Holmes et al., 2022; Zawacki-Richter et al., 2019).

The findings demonstrate that teachers tend to perceive AI positively because geometry is closely related to visualization and spatial reasoning, areas in which students commonly experience difficulties. In traditional classroom settings, abstract concepts such as three-dimensional shapes, geometric transformations, and spatial relationships are often difficult to explain through static images or verbal explanations alone. Therefore, teachers consider AI-supported applications capable of bridging the gap between abstract mathematical concepts and students' concrete understanding through dynamic visualization and interactive simulations. This indicates that teachers recognize the pedagogical potential of AI in facilitating conceptual learning processes that are difficult to achieve through conventional instructional approaches (Lee et al., 2020; Hwang & Chang, 2021).

Furthermore, the positive perception toward AI also reflects teachers' awareness of ongoing digital transformation in education. Teachers understand that students in the current digital generation are increasingly familiar with technology-based learning environments. Consequently, integrating AI into mathematics instruction is perceived as an effort to make learning more relevant, engaging, and aligned with students' learning characteristics. This finding supports the argument that educational technology adoption is often influenced by teachers' beliefs regarding its relevance to students' needs and future educational demands (Teo, 2011). In this context, AI is not only perceived as a technological innovation but also as an educational necessity in preparing students for digital society and future workforce challenges (UNESCO, 2021).

However, despite recognizing the benefits of AI, teachers still experience uncertainty regarding its practical implementation. This condition indicates a discrepancy between perceived usefulness and implementation readiness. From the perspective of the Technology Acceptance Model (TAM), teachers demonstrate high perceived usefulness because they believe AI can improve instructional quality and student engagement. Nevertheless, perceived ease of use remains relatively low due to limited technical competence, insufficient training, and lack of practical experience (Davis, 1989). As a result, teachers experience ambivalence: they are enthusiastic about AI innovation while simultaneously feeling unprepared to implement it effectively in classroom practice.

This phenomenon is particularly important because it highlights that technological innovation in education cannot succeed solely through positive attitudes toward technology. The successful implementation of AI also requires pedagogical confidence, technological self-efficacy, and continuous institutional support (Ertmer & Ottenbreit-Leftwich, 2010). Teachers who lack sufficient training may perceive AI as complex and difficult to integrate into lesson planning, classroom management and assessment processes. Therefore, the findings suggest that professional development programs should not only focus on technical operation of AI tools but also emphasize pedagogical integration strategies that are relevant to mathematics instruction (Koehler & Mishra, 2009).

The issue of teacher readiness identified in this study also reflects broader structural inequalities in educational technology access, particularly in semi-urban educational contexts. Limited internet connectivity, inadequate technological devices, and restricted access to digital learning resources remain major barriers to AI implementation. This suggests that educational digitalization in Indonesia is still characterized by unequal infrastructural readiness among schools. While educational policies increasingly encourage digital transformation, many schools continue to face practical challenges that hinder the effective adoption of advanced technologies such as AI (Suharsono & Ningsih, 2024; Rahmawati & Sari, 2023).

The findings therefore indicate that AI integration should not be viewed as an isolated classroom innovation but rather as part of a systemic educational ecosystem involving infrastructure, institutional leadership, policy support, and teacher capacity development. Without adequate institutional support, teachers may struggle to sustain technology-based innovation despite having positive attitudes toward digital learning. This finding reinforces previous studies emphasizing that educational technology adoption is strongly influenced by organizational culture and institutional readiness (Fullan, 2016; Tondeur et al., 2017).

Another important finding emerging from this study concerns teachers' ethical concerns regarding AI implementation. Although teachers appreciate the instructional benefits of AI, several participants expressed concerns about the potential reduction of human interaction in the learning process. Teachers emphasized that emotional support, moral guidance, and direct interaction remain essential components of mathematics learning that cannot be fully replaced by technology. This suggests that teachers perceive AI as a complementary instructional resource rather than a substitute for human pedagogical roles (Holmes et al., 2022).

This finding is significant because it reflects a critical and balanced perspective toward AI integration. Teachers do not reject technological innovation; instead, they advocate for a human-centered approach to educational technology implementation. In the context of mathematics learning, interpersonal interaction between teachers and students remains important for supporting motivation, emotional engagement, and individualized guidance. Therefore, AI implementation should be designed to strengthen teachers' instructional capacities rather than diminish their professional roles (Luckin et al., 2016).

The findings additionally reveal that teachers expect stronger collaboration between schools, policymakers, and technology developers. Participants emphasized the importance of practical training programs, curriculum integration guidelines, and mentoring systems that can help teachers adapt to rapidly evolving educational technologies. This indicates that teachers require long-term institutional commitment rather than short-term technological interventions. Sustainable AI integration depends on the existence of supportive professional learning communities and continuous pedagogical assistance (Santoso & Utami, 2022).

From a theoretical perspective, this study contributes to the development of Teacher Readiness Theory by demonstrating that teacher readiness for AI integration involves multidimensional interactions among cognitive understanding, affective acceptance, and instrumental support. The findings reveal that strong motivation alone is insufficient when technological competence and institutional support remain limited. Similarly, the study strengthens the Technology Acceptance Model by illustrating how perceived usefulness and perceived ease of use interact dynamically within educational contexts characterized by infrastructural limitations and unequal technological access (Davis, 1989; Rahmawati & Sari, 2023).

In addition, this study expands current discussions on AI integration in mathematics education by specifically focusing on geometry learning in semi-urban secondary schools, an area that remains underexplored in existing literature. Most previous studies have concentrated on technological effectiveness or student outcomes, whereas this research highlights the importance of teacher perspectives as key determinants of successful educational innovation. Since teachers function as the primary implementers of classroom technology integration, understanding their perceptions, readiness, and challenges becomes essential for designing realistic and context-sensitive educational policies (Zawacki-Richter et al., 2019; Holmes et al., 2022).

Overall, the findings suggest that the future of AI-based geometry learning in Indonesia depends on the interaction between pedagogical readiness, institutional support, technological infrastructure, and sustainable professional development. Without comprehensive support systems, AI implementation risks remaining limited to experimental or superficial technological adoption.

Therefore, educational stakeholders must ensure that AI integration is accompanied by equitable infrastructure development, continuous teacher empowerment, and adaptive educational policies capable of addressing the diverse realities of Indonesian schools in the digital era (UNESCO, 2021; Fullan, 2016).

4. CONCLUSION

This study concludes that mathematics teachers in a semi-urban junior high school context in Indonesia generally have positive perceptions of AI-based geometry learning and recognize its potential to improve students' spatial visualization, conceptual understanding, and engagement. These findings address the study's purpose by showing that teachers are open to using AI as an instructional innovation, but their readiness remains uneven due to limited digital infrastructure, insufficient technological competence, lack of professional training, and minimal institutional support. The study also shows that successful AI integration in geometry learning requires more than access to technology; it depends on teachers' digital literacy, pedagogical confidence, and the availability of systematic institutional support.

Theoretically, this study contributes to the field of mathematics education by strengthening the relevance of Teacher Readiness Theory and the Technology Acceptance Model in explaining how teachers' perceptions of usefulness, ease of use, cognitive understanding, affective acceptance, and institutional conditions shape AI adoption. Practically, the findings suggest that schools and policymakers should provide continuous professional development, adequate technological infrastructure, clear implementation guidelines, and stronger collaboration among teachers, institutions, policymakers, and technology developers. Since this study involved a limited number of participants from Tana Toraja Regency, future research should include larger and more diverse samples, use mixed-methods or research and development approaches, and examine factors such as school culture, leadership, policy support, and students' perceptions to develop more adaptive and sustainable AI-based geometry learning models.

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