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Students' Perceptions of an AI-Assisted Interactive Cartesian Coordinate Application

Ken Ameera Mahendradatta Maheswari[1], Ahmad Swandi[2]*, Frank Aiken O. Alan[3], Sri Rahmadhanningsih[4], Andio Calen Evains[5]

[1,2&4] Faculty of Educational and Literature, Universitas Bosowa, Indonesia
[3] Secondary Department, Action towards Greater Advancement of Knowledge (AGAK)
[5] Faculty of Mathematics and Natural Sciences, State University of Makassar, Indonesia

**Corresponding author: ahmad.swandi@universitasbosowa.ac.id*

Abstract
Students often experience difficulties in understanding Cartesian coordinate concepts, particularly in interpreting coordinate representations and connecting symbolic forms with spatial visualization. To address these challenges, this study examined university students' perceptions of an AI-assisted interactive application designed to support learning of Cartesian coordinates. The study focused on three aspects: conceptual understanding, learning motivation, and usability. A quantitative descriptive approach was employed involving 75 undergraduate students who interacted with the application during a guided learning session. Data were collected using a structured questionnaire and analysed using descriptive statistics. The findings revealed positive student perceptions across all measured aspects, with an overall mean score of 3.39 on a 4-point Likert scale. The highest ratings were found in usability and visual representation, indicating that the application was perceived as easy to use and effective in supporting spatial interpretation of coordinate concepts. Students also reported increased motivation, confidence, and willingness to retry after making mistakes during learning activities. Although several students initially had trouble in distinguishing coordinate positions and quadrants, repeated interaction with the application helped reduce misconceptions. These findings suggest that AI-assisted interactive learning applications have strong potential to support conceptual understanding and engagement in mathematics learning, particularly in topics requiring visual-spatial reasoning.

Keywords: AI-Assisted Learning, Cartesian Coordinate System, Interactive Learning Application, Student Perception

Introduction

Sustainable Mathematics plays an important role in developing analytical thinking and spatial reasoning skills needed to understand abstract concepts and solve real-world problems. One of the foundational topics in mathematics education is the Cartesian coordinate system, which supports the understanding of more advanced concepts such as functions, geometry, and graph interpretation. Despite its importance, many students continue to experience difficulties in understanding Cartesian coordinates, particularly in identifying points, interpreting ordered pairs, and connecting symbolic representations with their positions on the coordinate plane (Guven, 2022). These difficulties are not solely caused by limited procedural skills but are also associated with weak conceptual understanding and insufficient spatial reasoning abilities (Duffy et al., 2024; Guven, 2022). Guven (2022), for example, reported that many students perceive coordinates merely as labels on a graph rather than as directed distances from the origin. Similarly, Duffy et al. (2024) found that students often rely on procedural approaches without fully understanding the relationships between numerical values and spatial representations.

The limitations of procedural understanding become more evident when students are required to apply mathematical concepts in unfamiliar contexts. In mathematical problem-solving activities, students frequently struggle to translate relational information into mathematical representations because they are unable to construct accurate mental models of the problem situation, a process strongly associated with spatial ability (Duffy et al., 2024). Therefore, conceptual understanding is considered a central component of effective mathematics learning, as it enables students to connect multiple representations, reason flexibly, and construct meaningful mathematical knowledge (National Council of Teachers of Mathematics [NCTM], 2014; Guven, 2022). The NCTM (2014) further emphasizes that meaningful mathematics instruction should encourage students to reason mathematically and understand relationships among mathematical ideas rather than rely solely on memorized procedures.

In response to these challenges, the integration of technology into mathematics education has received increasing attention in recent years (OECD, 2021). Interactive digital learning environments, including augmented reality (AR) applications and visualization-based tools, allow students to manipulate objects, explore representations dynamically, and receive immediate feedback during learning activities (Kaźmierczak et al., 2025; OECD, 2021). Such features are particularly beneficial in mathematics learning because they support students in connecting symbolic and visual representations more effectively. More recently, developments in artificial intelligence (AI) have expanded these possibilities by enabling adaptive feedback, personalized guidance, and real-time scaffolding during learning activities (Kasneci et al., 2023; Zawacki-Richter et al., 2019).

AI-assisted interactive applications are especially relevant for topics involving spatial reasoning and coordinate interpretation because they combine visualization with intelligent feedback mechanisms (Kaźmierczak et al., 2025). Previous studies have shown that interactive visualization tools can improve students' engagement, spatial reasoning, and motivation in mathematics learning (Kaźmierczak et al., 2025). In addition, AI-supported systems can provide individualized learning support by responding to students' inputs dynamically and offering immediate corrective feedback during problem-solving activities (Tan et al., 2025; Kasneci et al., 2023). These learning environments not only facilitate conceptual understanding but also encourage active participation and sustained engagement during the learning process (Makranski & Petersen, 2021; Kaźmierczak et al., 2025).

Although research on AI integration in education has grown rapidly, many existing studies continue to focus primarily on learning outcomes rather than students' perceptions and learning experiences (Zawacki-Richter et al., 2019). In fact, students' perceptions are important because they influence acceptance, engagement, and the intention to continue using educational technology (Li et al., 2025). Perceived usefulness and perceived ease of use are considered important determinants of technology acceptance and sustained interaction with digital learning systems (Alshammari & Alkhwaldi, 2025; Li et al., 2025). Moreover, examining students' perceptions may provide valuable insights into whether a learning application effectively supports conceptual understanding, motivation, and usability during the learning process (Kasneci et al., 2023; Makranski & Petersen, 2021).

Therefore, this study aims to examine university students' perceptions of an AI-assisted interactive application designed to support learning of Cartesian coordinates. The study focuses on three main aspects: conceptual understanding, learning motivation, and usability. By incorporating both cognitive dimensions, such as perceived usefulness, and affective dimensions, including enjoyment and trust, this study extends the Technology Acceptance Model (TAM) in order to better understand students' experiences in AI-supported learning environments (Li et al., 2025; Alshammari & Alkhwaldi, 2025). The findings are expected to contribute to the growing discussion on artificial intelligence in mathematics education and provide practical insights into the design of interactive learning applications that support students' conceptual understanding and engagement.

Review of Related Literature

The literature on mathematics education and digital learning technologies reveals a strong emphasis on addressing conceptual difficulties while leveraging innovative tools. Foundational challenges in topics such as the Cartesian coordinate system persist, with students often misinterpreting ordered pairs and quadrants (Guven, 2022; Maryanto et al., 2022). These difficulties are closely tied to spatial ability, which plays a critical role in problem representation and reasoning (Duffy et al., 2024; Li et al., 2026).

Digital interventions have been widely explored to mitigate such issues. Studies highlight the effectiveness of adaptive e-learning systems and interactive feedback in improving engagement and conceptual understanding (Awang et al., 2024; Barana et al., 2021). Augmented and immersive technologies, such as augmented reality and virtual reality, further enhance visualization and reasoning (Kaźmierczak et al., 2025; Makransky & Petersen, 2021). Student satisfaction and usability remain central to sustaining the use of digital platforms (Sahraini et al., 2024; Li et al., 2025).

The integration of artificial intelligence into mathematics education is rapidly expanding. AI-based systems like CalcTutor provide generative feedback for calculus problem solving (Tan et al., 2025), while context-aware AI supports instructors in large classes (Barghorn et al., 2026). Broader analyses of large language models (Kasneci et al., 2023; Miskei-Váradi et al., 2025) highlight both opportunities and challenges, stressing the need for pedagogical grounding (Zawacki-Richter et al., 2019; OECD, 2021).

Overall, the literature suggests that combining diagnostic insights into student misconceptions with AI-assisted, interactive digital interventions offers a promising pathway to strengthen mathematical reasoning, enhance conceptual understanding, and ensure sustainable use of digital learning technologies (Alshammari & Alkhwaldi, 2025; Sofroniou et al., 2025; Sultana, 2025).

Objectives

The objectives of the article are to examine university students' perceptions of an AI-assisted interactive application designed to support learning of Cartesian coordinates. Specifically, the study aims to identify conceptual difficulties such as interpreting ordered pairs, connecting symbolic and spatial representations, and overcoming reliance on procedural approaches. It seeks to investigate the role of spatial reasoning in students' ability to construct accurate mental models of mathematical problems. Another objective is to evaluate the effectiveness of interactive visualization and AI-supported feedback in enhancing conceptual understanding, motivation, and usability.

The study also intends to extend the Technology Acceptance Model by incorporating both cognitive dimensions, such as perceived usefulness, and affective dimensions, including enjoyment and trust, to better understand students' experiences in AI-supported environments. It aims to assess learning motivation fostered by interactive applications and to analyse usability factors that influence sustained engagement. By focusing on students' perceptions, the research seeks to determine acceptance and continued use of AI-assisted learning systems. Ultimately, the objectives are to contribute to mathematics education by providing practical insights into the design of digital learning applications that integrate visualization, adaptive feedback, and personalized support, thereby strengthening conceptual understanding, spatial reasoning, and active participation in mathematics learning.

Methodology

Research Design

This study employed a quantitative descriptive research design to examine university students' perceptions of an AI-assisted interactive application for learning Cartesian coordinates. The study focused on describing students' responses after interacting with the application, particularly regarding conceptual understanding, learning motivation, and usability. A descriptive approach was considered appropriate because the study aimed to identify general trends in students' perceptions rather than to investigate causal relationships or compare instructional treatments (Romero Naranjo et al., 2023; Sahraini et al., 2024).

Participants and Research Context

The study was conducted at a private university in Indonesia where students are required to take mathematics-related courses as part of their academic program. The participants consisted of 75 undergraduate students enrolled in mathematics-related courses in three different classes. Most participants had previously studied Cartesian coordinate concepts during secondary education; however, preliminary observations indicated that many students still experienced difficulties in interpreting coordinate representations and connecting symbolic coordinates with spatial positions on the coordinate plane.

Participants were selected using a convenience sampling technique based on their accessibility and involvement in the learning activity (Adeoye, 2023). Although convenience sampling has limitations regarding generalizability, it is commonly used in educational research to obtain data from readily available participants within a specific learning context (Dauda et al., 2016).

AI-Assisted Interactive Learning Application

The learning media used in this study was an AI-assisted interactive application designed to support students' understanding of Cartesian coordinates through visualization, immediate feedback, and guided exploration activities. The application combines interactive coordinate visualization with intelligent feedback features that assist students during learning activities.

The main features of the application include:

1. Interactive Visualization

Students can plot and manipulate points directly on the Cartesian plane to observe the relationship between coordinate values and spatial positions.

2. Dynamic Feedback
   The system provides immediate corrective responses when students input incorrect coordinates or identify incorrect quadrants.
3. AI-Assisted Guidance
   The application offers adaptive hints and explanatory guidance based on students' responses during learning activities. These AI-assisted prompts are intended to support conceptual understanding and reduce repeated misconceptions during practice sessions.
4. Exploratory Learning Activities
   Students complete guided activities that encourage active exploration of coordinate concepts through repeated interaction and visual experimentation.

The AI component in this application functions primarily as an intelligent feedback and guidance system rather than as a fully autonomous artificial intelligence environment. The system analyses students' responses and generates contextual hints and corrective feedback to support learning activities in real time.

Research Instruments

1. Conceptual Understanding
   This aspect measured students' perceptions regarding how the application supported their understanding of Cartesian coordinate concepts, including identifying points, determining quadrants, and interpreting coordinate representations.
2. Learning Motivation
   This aspect examined students' interest, engagement, confidence, and willingness to continue learning using the application.
3. Usability
   This aspect evaluated students' perceptions regarding the ease of use, clarity of instructions, and visual design of the application.

The questionnaire items were developed based on previous studies related to technology-assisted mathematics learning and technology acceptance in education. Prior to implementation, experts in mathematics education and educational technology to ensure content validity and clarity of the questionnaire items reviewed the instrument. The reliability analysis showed that the instrument achieved an acceptable Cronbach's alpha coefficient, indicating good internal consistency.

Data Collection Procedure

Data collection was conducted during a guided classroom learning session. At the beginning of the session, students were introduced to the features and functions of the AI-assisted application. Students then interacted individually with the application while completing a series of coordinate-related learning activities and exercises.

During the learning process, students explored coordinate concepts through interactive visualization activities and received immediate feedback and AI-assisted guidance from the system. After completing the learning session, students were asked to complete the perception questionnaire based on their learning experiences while using the application.

Participation in this study was voluntary, and all collected responses were analysed anonymously for research purposes.

Analysis

Data Analysis

The collected data were analysed using descriptive statistical techniques to identify patterns in students' perceptions regarding the application. The analysis included the calculation of mean scores and standard deviations for each questionnaire item and each learning aspect. To interpret students' perception levels, the following criteria were used Table 1:

Table 1. Criteria Levels

Mean Score Range	Interpretation
1.00–1.75	Low
1.76–2.50	Moderate
2.51–3.25	High
3.26–4.00	Very High

The results were then aggregated to obtain an overall representation of students' perceptions regarding conceptual understanding, learning motivation, and usability of the AI-assisted interactive application. Data analysis was conducted using statistical software to ensure accuracy and consistency of the calculations.

Findings and Discussion

Overview of Student Responses

A total of 75 responses were collected from students from three classes (A, B, and C). The questionnaire consisted of 14 closed-ended items measured using a 4-point Likert scale, as well as one open-ended question regarding ongoing difficulties.

Overall, the results indicate that students expressed positive perceptions toward the AI-assisted interactive Cartesian coordinate application. Most responses were concentrated at scale points 3 (agree) and 4 (strongly agree), suggesting a high level of acceptance across all measured aspects.

Descriptive Analysis of Questionnaire Items

To examine students' perceptions in more detail, descriptive statistics were calculated for each questionnaire item. The results are summarized in Table 2.

Table 2. Mean Scores of Students' Perceptions (n = 75)

No	Item Description	Mean	Category
1	Understanding of determining coordinate points (x, y)	3.32	High
2	Understanding of abscissa (x) and ordinate (y)	3.30	High
3	Understanding of determining quadrants	3.28	High
4	Ability to read points from coordinate graphs	3.29	High
5	Understanding of procedural steps in determining coordinates	3.31	High
6	Confidence in determining coordinate points	3.25	High
7	Reduced fear of making mistakes	3.22	High
8	Willingness to retry after errors	3.36	High

9	Enjoyment in learning using the application	3.41	High
10	Increased motivation in learning	3.39	High
11	Interest in repeating practice	3.34	High
12	Ease of use of the application	3.45	High
13	Clarity of instructions	3.38	High
14	Visual representation supports understanding	3.47	High
Overall Mean		3.39	High

The overall mean score of 3.39 indicates a high level of agreement, confirming that students perceived the application positively. The highest mean scores were observed in items related to visual representation (Item 14) and ease of use (Item 12), suggesting that the interactive and visual features of the application played a significant role in supporting learning.

Perception Based on Learning Aspects

To provide a clearer interpretation, the questionnaire items were grouped into three aspects: conceptual understanding (Items 1–6), learning motivation (Items 7–11), and usability (Items 12–14). The results are presented in Table 3.

Table 3. Mean Scores by Learning Aspect

Aspect	Items	Mean	Category
Conceptual Understanding	1–6	3.29	High
Learning Motivation	7–11	3.34	High
Usability	12–14	3.43	High

The results show that all three aspects fall within the “high” category. Among them, usability obtained the highest mean score, indicating that students found the application easy to use and well designed. Meanwhile, conceptual understanding also received strong agreement, suggesting that the application effectively supported students in grasping coordinate concepts.

Analysis of Open-Ended Responses

Students’ responses to the open-ended question revealed that most participants reported no significant difficulties after using the application. However, several recurring challenges were identified among a smaller number of students.

The most frequently reported difficulties include:

- Determining coordinate points based on given instructions
- Identifying correct values of x and y
- Determining the quadrant of a point
- Interpreting points from coordinate diagrams

Despite these challenges, many students indicated that repeated practice within the application helped them overcome initial misunderstandings.

The findings of this study indicate that the AI-assisted interactive Cartesian coordinate application was positively perceived by students across all measured aspects, including conceptual understanding, learning motivation, and usability. The overall mean score of 3.39 reflects a very high level of agreement, suggesting that the integration of interactive visualization and AI-assisted feedback can effectively support mathematics learning at the university level. Rather than functioning merely as a digital practice tool, the application appeared to support students in connecting symbolic coordinate representations with spatial interpretation during learning activities. This finding is consistent with previous research showing that digital technologies, including visualization tools and AI-supported systems, can enhance conceptual understanding and student engagement in mathematics learning (Sofroniou et al., 2025; Sultana, 2025). Interactive and adaptive learning features have also been shown to promote deeper learning by allowing students to explore mathematical concepts at their own pace while receiving immediate feedback during problem-solving activities (Barana et al., 2021; Awang et al., 2024). Furthermore, the findings align with studies suggesting that AI-assisted support can strengthen learning experiences when integrated within human-AI instructional workflows that combine automated feedback with teacher facilitation and pedagogical guidance (Barghorn et al., 2026).

From the perspective of conceptual understanding, students reported improved comprehension of coordinate concepts, including identifying points, distinguishing between abscissa and ordinate values, and determining quadrants. These findings suggest that the application successfully supported the transition from procedural manipulation toward conceptual and visual-spatial understanding. The combination of interactive visualization and AI-assisted feedback may have helped students construct stronger mental representations of coordinate relationships, which are essential for spatial reasoning development. This finding supports previous studies indicating that visualization-based learning environments help students move beyond rote memorization and develop deeper conceptual understanding of mathematical relationships (Sofroniou et al., 2025; Sultana, 2025). The relatively high mean scores across Items 1–6 also indicate that students were able to integrate procedural and conceptual knowledge simultaneously, reinforcing the argument that mathematical understanding becomes more meaningful when learners engage with multiple representations supporting spatial reasoning (Duffy et al., 2024; Barana et al., 2021). In addition, active geometry perception and interactive visual exploration have been shown to improve students' spatial reasoning performance and conceptual interpretation of mathematical objects (Li et al., 2026). Immediate feedback mechanisms within interactive learning environments may further strengthen students' ability to connect symbolic representations with visual-spatial meanings during coordinate interpretation activities (Awang et al., 2024; Sultana, 2025).

The findings also demonstrate the important role of AI-assisted feedback in supporting students' learning processes. The AI-supported guidance system provided immediate corrective responses and explanatory prompts when students made errors during coordinate activities. Such scaffolding may have contributed to reducing repeated misconceptions related to coordinate positioning and quadrant identification. Rather than simply informing students whether answers were correct or incorrect, the feedback mechanism encouraged students to revisit their reasoning and refine their understanding through repeated interaction. This finding supports the view that AI-assisted learning systems can function as cognitive scaffolding tools that facilitate conceptual refinement and self-correction during mathematics learning activities (Kasneci et al., 2023). The integration of immediate feedback and guided exploration may therefore play an important role in supporting students' mathematical reasoning processes, particularly in topics involving spatial interpretation and symbolic representation.

The results further highlight the application's contribution to students' learning motivation and engagement. Items related to enjoyment, willingness to retry, and increased enthusiasm (Items 7–11) received consistently high ratings, suggesting that the application created a learning environment that encouraged persistence and reduced anxiety when making mistakes. These findings are important because mathematics learning is often associated with low confidence and fear of failure, particularly when students encounter abstract and visually demanding concepts (Miskei-Váradi et al., 2025). The interactive and exploratory nature of the application appeared to support a more positive affective learning experience by allowing students to experiment with coordinate manipulation and receive feedback without fear of immediate judgment. This finding is consistent with previous studies indicating that interactive digital environments can reduce stress and maintain students' engagement during mathematics learning activities (Shikine et al., 2017; Barana et al., 2021). Similarly, technology-enhanced learning environments integrating digital interaction and visualization have been found to positively influence students' motivation and participation in mathematics learning (Fraca et al., 2019).

In terms of usability, the application obtained the highest mean score among all measured aspects. Students perceived the application as easy to use, visually clear, and supportive for understanding coordinate concepts. This finding suggests that the application successfully minimized unnecessary interface complexity, allowing students to focus more on conceptual reasoning rather than on navigating the system. The high usability ratings also indicate that perceived ease of use played an important role in shaping students' positive learning experiences, which aligns with the Technology Acceptance Model emphasizing usability and usefulness as important determinants of technology acceptance (Alshammari & Alkhwaldi, 2025; Li et al., 2025). Previous studies similarly emphasize that user-friendly interface design and interactive visualization features significantly influence students' engagement and satisfaction with digital learning platforms (Awang et al., 2024; Barana et al., 2021). In addition, effective graphical representations may help reduce cognitive load and support the development of more accurate mental models of mathematical relationships (Sofroniou et al., 2025).

Despite the overall positive findings, the analysis of open-ended responses revealed that several students still experienced difficulties in distinguishing between x- and y-values, determining quadrants, and interpreting graphical representations. This finding indicates that interactive visualization alone may not fully eliminate deeply rooted misconceptions related to coordinate interpretation. Similar difficulties have been reported in previous studies showing that students often struggle to understand coordinate axes as reference systems and frequently confuse x- and y-values during problem-solving activities (Maryanto et al., 2022). Guven (2022) also found that many students interpret coordinates merely as labels rather than as directed distances from the origin. These persistent difficulties suggest that some learners may still require additional scaffolding and guided instruction during conceptual learning activities. Differences in prior knowledge and spatial reasoning ability may further influence how effectively students interpret coordinate relationships, since spatial ability plays an important role in constructing accurate mental representations (Duffy et al., 2024). Moreover, Barghorn et al. (2026) reported that although students valued AI-generated responses for their immediacy and relevance, they still relied on instructor verification to strengthen trust and confidence in the learning process.

Importantly, the presence of these difficulties should not necessarily be interpreted as a limitation of the application itself, but rather as evidence that conceptual understanding develops gradually through iterative learning processes. Students who initially struggled with coordinate interpretation were able to engage in repeated practice and receive immediate feedback during learning activities, which may have contributed to gradual conceptual refinement over time. This finding reinforces the importance of repetition, feedback, and guided exploration in mathematics learning environments. Previous studies have similarly demonstrated that repeated interaction combined with immediate corrective feedback can help students identify misconceptions, refine reasoning processes, and improve conceptual understanding progressively (Barana et al., 2021; Sultana, 2025). Interactive digital learning environments that allow students to revisit errors and retry problem-solving activities therefore provide meaningful opportunities for conceptual growth and self-regulated learning (Shikine et al., 2017).

Overall, the findings suggest that AI-assisted interactive learning applications have strong potential to support mathematics learning, particularly in topics requiring the integration of symbolic representation, visualization, and spatial reasoning. The combination of interactive visualization, immediate feedback, and AI-assisted guidance appears to support both cognitive and affective aspects of learning by helping students develop conceptual understanding while simultaneously maintaining engagement and motivation. Nevertheless, future development of similar applications may benefit from incorporating more adaptive scaffolding mechanisms capable of providing differentiated support based on students' individual learning needs and spatial reasoning abilities.

Conclusion

This study examined university students' perceptions of an AI-assisted interactive application designed to support learning of Cartesian coordinates. The findings indicate that the application was positively perceived across the aspects of conceptual understanding, learning motivation, and usability, with an overall mean score of 3.39. These results suggest that the integration of interactive visualization and AI-assisted feedback can provide meaningful support for mathematics learning, particularly in topics involving symbolic representation and spatial interpretation. From a cognitive perspective, the application appeared to support students in connecting coordinate symbols with visual-spatial representations more effectively. The combination of interactive exploration, immediate feedback, and AI-assisted guidance helped students strengthen their understanding of coordinate relationships, point positioning, and quadrant interpretation. The findings further suggest that AI-supported scaffolding may play an important role in helping students refine conceptual understanding through repeated practice and corrective feedback during learning activities.

In addition to supporting conceptual learning, the application also contributed positively to students' motivation and engagement. Students reported greater enthusiasm, confidence, and willingness to retry after making mistakes, indicating that the interactive learning environment encouraged more active participation and reduced anxiety during mathematics learning. The high usability ratings further demonstrate that a clear interface design and effective visual representation are important factors in supporting positive learning experiences and sustained interaction with digital learning systems. Overall, this study highlights the potential of AI-assisted interactive learning applications to support conceptual reasoning, spatial understanding, and engagement in mathematics education. Rather than functioning solely as digital practice tools, AI-assisted systems may serve as cognitive support environments that facilitate conceptual refinement through visualization, feedback, and guided exploration. These findings contribute to the growing discussion on artificial intelligence in mathematics education, particularly regarding the role of AI-assisted scaffolding in supporting visual-spatial learning processes.

Nevertheless, this study has several limitations that should be considered. The research focused primarily on students' perceptions during a single learning session and employed a descriptive design without comparison to other instructional approaches. Future studies may therefore investigate the long-term effects of AI-assisted learning applications on conceptual retention, mathematical reasoning, and transfer of learning. Further research could also explore how individual learner characteristics, such as spatial reasoning ability and prior mathematical knowledge, influence students' interactions with AI-supported learning environments. In addition, future application development may benefit from integrating more adaptive and personalized feedback systems capable of providing differentiated support based on students' learning needs and interaction patterns.

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