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Exploring the Influence of Learning Styles on the Development of Critical Thinking Skills in Mathematics

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ABSTRACT

Background: Critical thinking in mathematics is a vital skill for solving complex problems. However, students' ability to think critically in mathematics varies according to their learning styles. This study investigates how auditory, visual, and kinesthetic learning styles influence students' critical thinking abilities in mathematical contexts.
Aims: The goal of this research is to explore how different learning styles affect the development of critical thinking skills in mathematics and to determine how these styles influence students' performance in tasks requiring mathematical reasoning.
Methods: A descriptive qualitative research design was used. The participants were middle school students selected using purposive sampling. Data collection involved critical thinking tests, learning style surveys, and interviews. The collected data were analyzed through presentation, reduction, and conclusion drawing, with triangulation employed to ensure data reliability.
Results: The results revealed that students with visual learning styles showed the highest level of mathematical critical thinking, particularly in evaluation, analysis, interpretation, and inference. Auditory learners performed reasonably well in evaluation and analysis but faced challenges with interpretation. Kinesthetic learners demonstrated potential but required further improvement in analysis and evaluation.
Conclusion: The study concluded that learning styles have a significant impact on the development of mathematical critical thinking skills. Visual learners performed the best, while auditory and kinesthetic learners exhibited potential but need additional support to enhance their abilities in critical thinking tasks. The findings highlight the importance of incorporating diverse teaching strategies that cater to various learning styles.

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INTRODUCTION

In the 21st century, rapid technological advancements have significantly transformed how education is delivered and received. Students are required to quickly adapt to new ways of thinking, processing information, and solving real-world problems (Kwangmuang et al., 2021; Rohm et al., 2021). Education today is not merely about acquiring knowledge, but also about developing essential skills for life and the workforce (García-Pérez et al., 2021; Khan et al., 2022; L. Li, 2024). One of the most crucial skills expected across all disciplines is critical thinking (Bellaera et al., 2021; Calma & and Davies, 2021; Cruz et al., 2021) . To meet the demands of the global era, schools must focus not only on mastering subject matter but also on fostering students' cognitive development (Bhardwaj et al., 2025; Zhao et al., 2024). Learners must be equipped with the ability to analyze, interpret, evaluate, and make sound decisions. These skills allow students to approach problems from various perspectives and formulate logical solutions. Therefore, educational institutions are challenged to ensure that students can think independently and reason effectively.

Mathematics has long been recognized as a subject that fosters logical and systematic thinking (Just & Siller, 2022; Sibgatullin et al., 2022). It trains learners to approach problems analytically and to use reasoning in drawing conclusions (Spaska et al., 2021). Mathematical skills are essential not only in academic settings but also in daily life, the workforce, and technological advancement (García-Pérez et al., 2021; Kohen & Orenstein, 2021; Yu, 2023). Proficiency in mathematics is considered a key factor in educational success and a foundation for scientific literacy. Nevertheless, many students continue to struggle with applying mathematical knowledge, especially when problems require reasoning beyond memorized formulas. Many of them face difficulties in solving complex problems that demand deep understanding and structured thinking (Lawrence et al., 2022; Smith et al., 2022; Y. Walter, 2024). This highlights the need to shift the focus from merely solving problems to strengthening reasoning abilities. Therefore, integrating critical thinking into mathematics learning is highly important.

Critical thinking in mathematics involves several core components, such as interpretation, analysis, evaluation, and inference. These components help students develop a deeper approach to mathematical tasks, allowing them to justify the solutions they provide (Manfreda Kolar & Hodnik, 2021). With these skills, students can not only solve problems but also explain the logic behind their answers (Alasadi & Baiz, 2023; Kasneci et al., 2023; Kwangmuang et al., 2021). Critical thinking also encourages the development of intellectual discipline, enabling learners to assess assumptions, question arguments, and identify connections between concepts (Indrašienė et al., 2021; Plummer et al., 2022). It enhances learning outcomes by fostering greater engagement with the subject matter. This skill also nurtures curiosity and the habit of deep thinking in students. Mathematics classrooms that support the development of critical thinking are more likely to produce learners who can transfer their knowledge to real-life contexts. Thus, the implementation of critical thinking skills in the curriculum is essential for meaningful learning.

Despite its importance, many students still show limited progress in developing critical thinking skills. Performance data from various international assessments show that most students can only solve problems at basic levels of difficulty (Matzavela & Alepis, 2021; Shute & Rahimi, 2021). Higher-order thinking tasks that involve abstract reasoning and problem interpretation remain a challenge (Lin et al., 2023; Whalen & and Paez, 2021). This situation reflects broader issues in learning environments, including instructional strategies that do not yet fully support the development of such skills (Beck et al., 2024; Cox, 2021). One contributing factor may be the misalignment between how students learn and how instruction is delivered. Every student has different preferences for receiving and processing information, commonly referred to as learning styles. These include visual, auditory, and kinesthetic styles, each of which influences how students comprehend and interact with material. When students' learning styles are not considered, they may struggle to engage optimally in the learning process.

Learning styles describe individuals' preferred methods for absorbing, processing, and retaining new information. Visual learners tend to understand better through images, diagrams, and written instructions (Castro-Alonso et al., 2021). Auditory learners benefit more from verbal explanations, discussions, or spoken directions (Chui et al., 2021; Yotta, 2023). Kinesthetic learners need direct physical engagement to grasp concepts effectively. Each learning style has its own strengths that can be optimized through appropriate teaching strategies. When instructional methods align with students' learning preferences, both motivation and understanding are likely to improve (Reeve & and Cheon, 2021; Ruiz-Ledesma et al., 2025; Wei, 2023). It also enables students to think in ways that are most natural to them. Recognizing and accommodating learning styles can enhance overall learning outcomes. Therefore, learning styles play a significant role in shaping students' mathematical performance.

The development of critical thinking in mathematics may vary depending on each student's learning style. Some may find it easier to understand and evaluate information visually, while others may require oral explanations or hands-on experiences (Eysenbach, 2023; Kizilaslan et al., 2021). These differences affect how students approach mathematical problems and how they express their reasoning (Hansen, 2022). Thus, it is important to analyze the relationship between learning styles and students' critical thinking skills (Shorey et al., 2021). Such analysis can help identify the types of learning environments that best support specific thinking processes. The findings can also provide educators with insights into designing inclusive and effective learning experiences. This understanding will lead to more targeted and adaptive instructional planning. Therefore, investigating how each learning style supports the development of mathematical thinking is essential.

Classroom practices still tend to use uniform teaching methods and often overlook the diversity in students' learning preferences. This limits the opportunity for some students to fully develop their thinking potential (Cope et al., 2021; Michel-Villarreal et al., 2023). A one-size-fits-all teaching approach fails to consider individual differences in how students absorb and apply knowledge (Fariani et al., 2023). In classrooms that do not adapt instruction to students' preferences, critical thinking skills may not develop optimally (Lo, 2023; Yuan & and Liao, 2023). As a result, students become disengaged and tend to rely solely on rote memorization. To address this issue, a deliberate effort is needed to align instructional strategies with students' cognitive characteristics. This not only supports the development of thinking skills but also fosters a more inclusive learning culture. Therefore, adapting instructional strategies to students' learning styles is a crucial step toward meaningful and equitable education.

This study is urgently needed because critical thinking remains an essential 21st-century skill that has yet to be fully developed among junior high school students, as reflected in Indonesia's low PISA results. Each student possesses a different learning style—visual, auditory, or kinesthetic, which influences how they understand and solve mathematical problems. However, classroom instruction often applies a uniform method without adequately considering these differences, limiting the development of students' critical thinking potential (Charalambous et al., 2021; Y. Walter, 2024). By examining the relationship between learning styles and mathematical critical thinking skills, this study can serve as a foundation for designing more personalized and effective teaching strategies that enhance the overall quality of mathematics education. Furthermore, the findings are expected to contribute to the advancement of differentiated instruction practices (Pozas et al., 2022). The results may also inform curriculum developers and policymakers in designing more adaptive educational frameworks (Dimmock et al., 2021; Tetzlaff et al., 2021). Therefore, this research holds both theoretical and practical relevance within the Indonesian educational context. Understanding these dynamics is vital to building a more responsive education system focused on developing essential student competencies.

Research on learning styles in mathematics education has revealed significant variations in students' conceptual understanding, problem-solving, and critical thinking performance depending on whether they are visual, auditory, or kinesthetic learners (Emylia & Setyaningsih, 2025; Nuari et al., 2025; Pramuditya & Masduki, 2025; Putri et al., 2024). Personalized and STEAM-based instruction has shown promise in enhancing mathematical engagement, especially when aligned with learners' cognitive styles (Cao, 2025; Rezeki & Amelia, 2025). Field-independent learners with high self-efficacy also demonstrate better critical thinking outcomes in numeracy tasks (Yustitia et al., 2025), and learning environments such as mobile apps, AI platforms, and game-based tools improve mathematical reasoning across style categories (Al-Barakat et al., 2025; Egara & Mosimege, 2024; Feng, 2024; Piquer-Martinez et al., 2024; Türkoğlu & Yalçınalp, 2024). Studies have also highlighted how textbook design, gender factors, and national curricula affect the learning style–performance relationship (Alibraheim, 2025; Umar et al., 2025; D. Walter et al., 2025). Cultural and contextual influences are particularly relevant in Southeast Asian settings, where integrating local approaches into AI-enhanced learning creates new opportunities for differentiated instruction (Ayob & Hamada, 2024; Payadnya et al., 2025). Further, learning preferences also relate to how students perceive numeracy, risk, and diagnostic reasoning, especially in interdisciplinary and higher education contexts (Demirkaya et al., 2025; Fallon et al., 2024; Ruiz-Ledesma et al., 2025). Although these studies have expanded the theoretical and practical understanding of learning styles in math education, few have directly mapped how each style affects core indicators of critical thinking such as interpretation, evaluation, analysis, and inference—indicating a gap that this study aims to address.

While the connection between learning styles and student achievement in mathematics has been widely discussed, most existing research tends to generalize outcomes without examining how specific cognitive processes—like critical thinking—are influenced by different learning preferences. Studies often emphasize test performance or engagement, but rarely explore how visual, auditory, or kinesthetic styles interact with core thinking skills such as interpretation, evaluation, analysis, and inference. Moreover, the majority of investigations do not directly address how these relationships manifest in junior high school learners, a stage where foundational reasoning skills begin to develop significantly. As such, there remains a lack of empirical evidence on how learning preferences support or hinder the growth of mathematical critical thinking. This oversight could lead to missed opportunities in designing instruction that supports cognitive diversity in the classroom. Furthermore, although digital tools and educational reforms have been introduced to personalize instruction, their alignment with students' mental processing modes has not been fully explored from a critical thinking standpoint. These limitations highlight the need for a focused analysis that links learning styles to cognitive indicators in mathematics. Addressing this gap will contribute to more inclusive teaching models and provide better instructional guidance based on actual learner characteristics.

This study is designed to explore the extent to which learning styles—categorized as visual, auditory, and kinesthetic—impact the development of mathematical critical thinking among junior high school students. The research seeks to identify whether and how each learning preference corresponds with specific components of critical thinking, including the abilities to interpret problems, analyze information, evaluate solutions, and draw logical conclusions. By focusing on these dimensions, the study aims to offer insight into how cognitive styles influence students' reasoning in mathematical contexts. The results are expected to assist educators in adapting instructional methods that better align with learners' processing tendencies. In addition to contributing to the practice of differentiated instruction, the study also aspires to fill a gap in theoretical understanding about how thinking skills emerge differently across learning styles. Based on this objective, the research proposes a hypothesis that students' dominant learning style significantly affects their critical thinking performance in solving mathematics problems. This hypothesis provides a framework for further investigation into the interaction between instructional strategies and cognitive characteristics. Ultimately, the study aims to support more responsive and evidence-based mathematics education.

METHOD

Research Design

This study was conducted using a descriptive qualitative approach aimed at exploring how students' dominant learning styles influence their critical thinking skills in mathematics. The design allowed the researcher to examine students' reasoning patterns without manipulating any variables, focusing on the natural processes by which learners engage with mathematical problems. The qualitative orientation also supported the use of rich, contextual data drawn from student responses and behaviors during task completion. A case study model was integrated to focus on selected individuals who represent different learning modalities. The stages of the research included participant identification, classification of learning styles, critical thinking task completion, and thematic analysis of responses. The choice of this design was driven by the need to obtain in-depth, detailed insights into how cognitive preferences manifest in real learning scenarios. This structure also enabled the documentation of qualitative variations in mathematical thinking. The research emphasized authentic interaction with mathematical content through tasks requiring interpretation, analysis, evaluation, and inference.

Participants

The participants were selected from junior high school students through purposive sampling, aimed at capturing learners who strongly represent the three major learning styles: visual, auditory, and kinesthetic. The classification of students was based on the results of a structured learning style inventory. Six students were chosen, comprising two from each learning style category, based on the clarity of their profile and their agreement to participate. Selection also considered consistent academic attendance, teacher recommendation, and parental consent. The participants engaged in mathematical tasks that required higher-order thinking. This small, focused group was intended to provide depth over breadth in exploring how thinking patterns differ across learning preferences. The diversity in styles ensured that cognitive variation could be meaningfully observed and compared. The ethical aspects of participation were addressed through informed consent and anonymity protocols.

Instruments

Two core instruments were employed in this study. The first was a learning style questionnaire adapted from the VAK (Visual, Auditory, Kinesthetic) model, designed to determine students' preferred mode of information processing. It consisted of multiple-choice items covering daily learning habits and tendencies. The second instrument was a mathematics task set designed to elicit critical thinking across four domains: interpreting problems, analyzing data, evaluating reasoning, and drawing logical conclusions. These tasks were created with reference to Bloom's taxonomy and aligned with topics familiar to junior high school students. Additionally, an observation guide and interview framework were used to collect supporting qualitative data. The instruments underwent expert validation to ensure that they accurately targeted the skills and cognitive processes under investigation. Together, these tools provided both classification of learner types and insight into their cognitive performance in mathematics.

Data Analysis

The collected data were examined using a thematic analysis technique, which involved categorizing student responses based on critical thinking indicators. The process began with coding transcripts from task responses, observations, and interviews. Patterns were identified and grouped according to the dimensions of critical thinking: interpretation, analysis, evaluation, and inference. Coding reliability was enhanced by involving two independent reviewers. A triangulation process, combining task outcomes with observational and interview data, was used to improve validity. The analytical stages followed the model of data reduction, data display, and drawing conclusions. These steps allowed for systematic condensation and organization of findings before interpretation. This process ultimately supported the development of conclusions about the connection between learning preferences and critical thinking behavior in mathematics. To clarify the flow of the research method, here is a visualization of the process in the form of a flowchart:

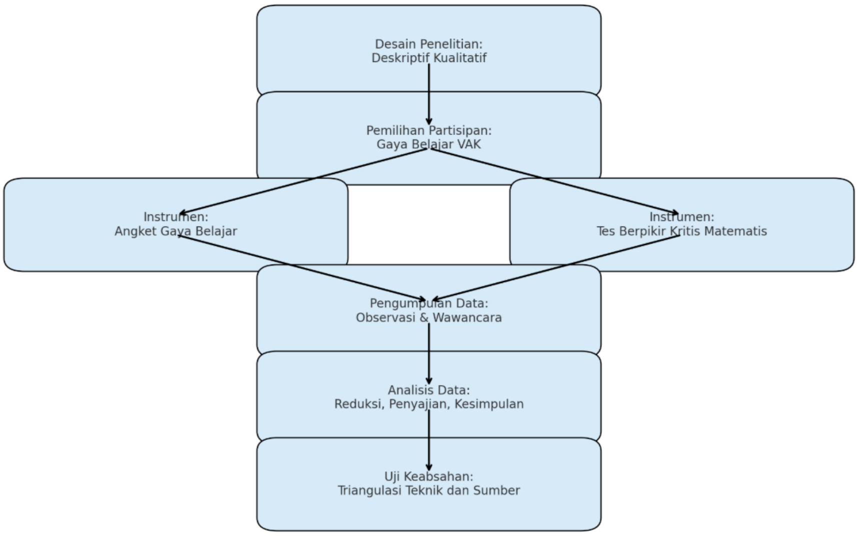

Figure 1. Flowchart of Method

RESULTS AND DISCUSSION

Results

The analysis of student responses revealed that each learning style group—visual, auditory, and kinesthetic—exhibited distinct tendencies in demonstrating critical thinking skills during mathematics problem-solving. Students with a visual learning style showed notable strengths in interpreting visual information and performing analytical tasks, particularly when supported by diagrams or structured layouts. Those identified as auditory learners were more proficient in articulating their reasoning and evaluating mathematical arguments during verbal discussions. On the other hand, kinesthetic learners excelled in inference-based tasks, especially those that involved physical or contextual exploration.

Despite these unique strengths, the evaluation aspect of critical thinking appeared to be underdeveloped across all learning styles. For instance, although visual learners could interpret and analyze data well, they often lacked the ability to critically judge the validity of arguments. Similarly, kinesthetic learners demonstrated inferential understanding but struggled when asked to justify solutions through critical examination. These patterns were evident from the triangulated data, which included students' task responses, observation notes, and interview transcripts.

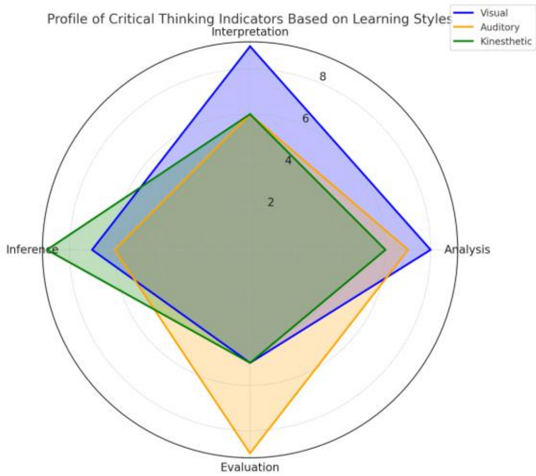

Figure 2. Radar Chart of Critical Thinking Indicators Based on Learning Styles

Discussion

This study highlights the close connection between students' learning styles and their ability to engage in critical thinking within mathematics. Visual learners often find it easier to interpret symbols, diagrams, or spatial representations, which in turn enhances their analytical performance (Nuari et al., 2025; Emylia & Setyaningsih, 2025). In contrast, students with an auditory preference tend to perform better when reasoning is expressed verbally, especially during discussions or explanations (Putri et al., 2024). Kinesthetic learners show greater capacity in drawing conclusions when they can interact with materials physically or situationally (Yustitia et al., 2025). These patterns suggest that each learning style corresponds with certain strengths in thinking processes. Educators who understand this variation can better design instructions to support diverse learners. If teaching does not accommodate these differences, opportunities for critical engagement may be reduced. Therefore, learning environments should be structured to reflect cognitive diversity.

Despite these differences, many schools still rely on conventional teaching styles that focus primarily on visual and verbal input. Such methods may not offer sufficient support for kinesthetic learners who require more active or experiential modes of learning (Pramuditya & Masduki, 2025). When learning preferences are overlooked, students may struggle to connect with content and underperform in complex tasks. For instance, a student may be capable of critical reasoning but unable to express it effectively in a mismatched format. Differentiated learning strategies are necessary to make thinking skills more accessible to all students. When instruction varies in format and delivery, students can respond using their natural strengths (Cao, 2025). Inclusive teaching not only improves understanding but also strengthens reasoning. This flexibility must be a standard part of lesson planning.

An important issue that emerged from this study was the limited ability of students to evaluate mathematical reasoning. Although learners could often interpret and analyze problems, they found it difficult to justify or critique their solutions (Yustitia et al., 2025). This suggests that evaluation, as a thinking skill, is not emphasized strongly enough in daily instruction. Mathematics classrooms often center on arriving at the correct answer, rather than questioning how or why that answer was reached (Alibraheim, 2025). As a result, students may develop accuracy without reflection. To address this, tasks should ask students to assess reasoning, compare strategies, or reflect on alternatives. Evaluation must become a visible part of how mathematical thinking is taught. Building metacognition requires more than solving problems—it requires asking students to think about their thinking.

Allowing students to express ideas in varied ways can help them process and clarify their reasoning. Auditory learners showed improvement when explaining solutions aloud, reinforcing their understanding through verbal explanation (Putri et al., 2024). Visual learners benefited from drawing their reasoning in the form of diagrams or concept maps. Meanwhile, kinesthetic learners gained clarity when physically engaging with the learning environment or modeling concepts (Türkoğlu & Yalçınalp, 2024). A one-size-fits-all method for expression can obscure students' true abilities. By using multimodal instruction and assessment, educators can observe how students think more clearly. Multiple forms of expression allow for more personalized feedback and greater inclusion. These strategies also help bridge the gap between surface-level understanding and deeper reasoning.

Effective mathematics teaching must prioritize adaptability to meet learners' cognitive needs. When instruction is overly rigid or standardized, it may hinder students from connecting meaningfully with mathematical content (Ayob & Hamada, 2024). Instructional variation not only enhances engagement but also supports the development of high-level thinking. For example, using stories or discussions may support auditory learners, while games or manipulation tools may help kinesthetic learners. Visual learners can be challenged with data interpretation through graphs or visual aids. By combining multiple strategies, teachers can ensure all students are challenged appropriately (Cao, 2025). This kind of responsive instruction supports not just learning, but deeper, self-regulated thinking. Educators should strive to move beyond routine instruction and into cognitively stimulating practice.

It is important to note that students rarely fit entirely within one learning style. Many students shift preferences depending on the task, context, or subject (Demirkaya et al., 2025). In this study, several students exhibited mixed behaviors, switching between visual and auditory approaches as needed. These overlaps suggest that learning preferences should be viewed as dynamic and context sensitive. Teachers must be attentive to these shifts and avoid assigning students to fixed categories. A flexible mindset allows instruction to evolve alongside student needs (Feng, 2024). Responding to how students learn in real time helps promote independence and deeper thinking. Ultimately, teaching should encourage students to explore and develop strategies that suit them best.

Thinking skills in mathematics are also shaped by the environment, not just the learner. The structure of the curriculum, the types of assessment used, and the goals emphasized by schools all influence how students think. When evaluation is not embedded into learning activities, students may develop a narrow view of mathematics (Walter et al., 2025). This study suggests that instructional practices must include space for reflective and evaluative tasks. Teachers should be encouraged and trained to design problems that invite explanation and reasoning (Egara & Mosimege, 2024). Supporting teachers in this process will lead to a shift from performance-oriented to thinking-oriented instruction. It is essential for the system to value critical thinking, not just correct answers. Changing mindsets about what matters in math learning is part of long-term educational reform.

In sum, this research demonstrates that students' learning styles contribute significantly to how they develop critical thinking in mathematics. While each style shows strengths in different cognitive areas, none performed strongly across all dimensions (Emylia & Setyaningsih, 2025; Yustitia et al., 2025). Evaluation was a common area of difficulty that deserves focused attention in instruction (Putri et al., 2024). Instruction should be guided by learning styles but not restricted by them. Teachers must stay flexible and responsive as students engage in tasks in different ways. The goal is not only to improve understanding but to build independent, self-aware thinkers. Effective instruction should support this transformation. Cultivating critical thinkers starts by acknowledging and valuing how students learn.

Implications

Although this study contributes useful insights, several limitations need to be acknowledged before generalizing the findings. The study involved only a small number of participants from a single school, which narrows the range of learning contexts represented. As a result, the conclusions drawn may not apply broadly across different educational settings or age groups. The identification of learning styles relied on self-reported responses, which can sometimes be inconsistent or oversimplified. The study also took place over a limited time, preventing observation of long-term changes in students' thinking development. Additionally, the influence of external factors such as classroom climate, teaching style, or student motivation was not examined in depth. While triangulation was used to ensure credibility, qualitative interpretation always carries some degree of subjectivity. These limitations serve as important considerations when applying this study's outcomes to wider practices or policies.

Limitations

Although this study offers meaningful insights, it is limited by several factors that must be acknowledged. The sample size was relatively small, consisting of only six students, which limits the generalizability of the results. All participants were drawn from a single school environment, reducing the potential diversity of learning contexts. Additionally, the classification of learning styles relied on self-report questionnaires, which may not fully capture the complexity of each student's cognitive profile. The study was also conducted within a short time frame, preventing the observation of long-term cognitive development. Other variables such as prior knowledge, motivation, and teaching quality were not deeply explored but may have influenced student performance. Despite efforts to ensure data validity through triangulation, qualitative interpretation remains subject to researcher bias. These limitations should be considered when applying the findings to broader educational settings.

Suggestions

Future researchers are encouraged to explore the relationship between learning styles and critical thinking using larger and more varied samples. Expanding the setting across different schools or regions can provide broader perspectives on how learning preferences influence problem-solving. A longer study duration could also reveal how these thinking skills evolve over time with consistent exposure to differentiated instruction. Combining qualitative insights with quantitative data from critical thinking assessments would help increase the reliability of the findings. Researchers might also study how digital tools interact with different learning preferences in the mathematics classroom. Exploring teacher practices that support evaluation and reasoning skills across styles would also be valuable. Further research should consider how to design adaptable instructional models that are easy to implement across levels. Ultimately, improving thinking skills in mathematics depends on continued effort to connect pedagogy with how students learn best.

CONCLUSION

This research highlights the significant impact of learning styles (visual, auditory, and kinesthetic) on students' critical thinking abilities in mathematics. Visual learners performed better in tasks involving analysis and evaluation, benefiting from visual aids like diagrams, while kinesthetic learners excelled in tasks that required physical engagement but faced challenges with abstract reasoning. Auditory learners demonstrated strength in verbal analysis but struggled with tasks that required hands-on or visual methods. The study underscores the importance of adapting teaching strategies to align with students' learning preferences, suggesting that personalized instruction can foster improved critical thinking skills. While the study is limited by its cross-sectional design and the scope of the critical thinking assessments, it provides valuable insights into how differentiated teaching approaches can enhance mathematical problem-solving and analytical thinking.

AUTHOR CONTRIBUTIONS STATEMENT

Endang Yuliani: Conceptualized the study, developed the research methodology, and conducted the data analysis. Contributed significantly to the interpretation of results and writing of the manuscript.
Iskandar: Assisted in the data collection process, particularly with the student surveys and tests, and contributed to the manuscript's editing and finalization.

Ummi Rosyidah: Reviewed and provided valuable input during the early stages of the research, especially regarding theoretical frameworks and literature review.
Irma Ayuwanti: Provided critical feedback on the research design and methodology, and contributed to the manuscript revisions, ensuring academic rigor and coherence.

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