Panicgogy International Journal

Publication details, including instructions for authors and subscription information:
https://nakiscience.com/index.php/pij

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To cite this article:
Sulasti, S., Alsulami, N.M., Isnawan, M.G., Santosa, F.H., Olivero-Acuña, R.R., & Silgado-Tuñón, D.A. (2026). Exploring senior high school students' mathematical critical thinking barriers and self-generated solutions: A hermeneutic phenomenological study. *Panicgogy International Journal, 4*(1), 16 – 31.
To link to this article:
https://nakiscience.com/index.php/pij/
Published by:
Nashir Al-Kutub Indonesia
Residential Street Kila Rengganis, Block I, Number 11, Labuapi, Indonesia, 83361

Panicgogy International Journal, 4(1), 16 – 31, 2026
https://nakiscience.com/index.php/pij

Original Article

Exploring senior high school students' mathematical critical thinking barriers and self-generated solutions: A hermeneutic phenomenological study

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Abstract
Critical thinking is a foundational competency for mathematical problem-solving, yet Indonesian students continue to perform below international benchmarks such as PISA and TIMSS. Although prior studies have examined factors associated with weak mathematical critical thinking, few have explored the phenomenon directly through students' own lived experiences using a hermeneutic phenomenological design, and fewer still have paired thematic analysis with generative artificial-intelligence assistance such as ChatGPT to support systematic coding. This study aimed to identify the factors underlying students' low critical thinking skills in mathematics learning and to uncover the solutions students themselves proposed to overcome these barriers. A qualitative hermeneutic phenomenological approach was employed, using ChatGPT-assisted thematic analysis across six analytic tables covering factor codes, solution codes, categories, and themes. Participants were ten Grade XII students (nine female, one male; aged 16–17 years) at a public senior high school in West Lombok Regency, Indonesia, selected through purposive sampling because they had been identified as experiencing persistent difficulty with mathematical critical thinking. Data were collected through an open-ended questionnaire and analyzed following six phases of thematic analysis. The findings revealed four major factor themes: difficulty memorizing and understanding formulas, weak habits of critical thinking and information-seeking, suboptimal use of technology, and low internal motivation. Correspondingly, students proposed four solution themes centered on active learning strategies, contextual and reflective learning, educational use of technology, and cultivation of internal motivation. These findings suggest that mathematics teachers should adopt active, contextual, and technology-integrated pedagogies, supported by ongoing professional development, so that critical thinking is nurtured as a core learning outcome rather than a byproduct of content mastery.
Keywords: mathematical critical thinking; hermeneutic phenomenology; thematic analysis; learning motivation; educational technology

1. Introduction
Critical thinking is an essential skill that every student needs, particularly in mathematics learning. This ability helps students understand problems, analyze information, and make decisions logically (Widana, 2018). In mathematics lessons, critical thinking is especially important because students are not only asked to arrive at answers but are also required to

understand the problem-solving process and the reasoning behind each step of a solution (Suryawan et al., 2023). This ability makes students more careful in analyzing information and in determining the right strategy for answering questions.

According to Facione (2015), critical thinking plays a very important role in educational and professional contexts and has implications for participation in global society. Students who possess critical thinking skills are more adaptable to professional environments and engage with the global community as curious and innovative individuals (Nashori et al., 2023). Critical thinking is also not a fixed trait but a disposition and set of skills that can be deliberately cultivated across the curriculum through appropriately designed instruction (Ennis, 2016). This aligns with broader educational literature linking critical thinking and intrinsic motivation as jointly cultivable dispositions from an early age (Suprihatin, 2024). Providing constructive feedback and engaging students in activities that encourage analytical and evaluative thinking are therefore essential to support the development of critical thinking, especially for students who struggle in this area.

Despite this importance, students' critical thinking in learning activities in Indonesian schools generally remains relatively low. A lack of motivation and interest results in low levels of involvement and participation in the learning process, and in many classrooms, students are not consistently encouraged to use critical thinking skills when solving problems (Ichsan et al., 2023). Even at the junior secondary level, students frequently fail to identify appropriate strategies when confronted with mathematical critical-thinking problems, indicating that this difficulty begins well before senior high school (Mellawaty et al., 2023). Cross-national assessments corroborate this pattern: results from the Trends in International Mathematics and Science Study (TIMSS) indicate that Indonesian students' critical and higher-order thinking skills in mathematics still require substantial improvement (Fenanlampir et al., 2019), and the 2018 Programme for International Student Assessment (PISA) showed that the majority of 15-year-old Indonesian students remained below proficiency Level 2, while countries such as Australia, Finland, Hong Kong, and Japan reached Levels 5 and 6 (OECD, 2019). Based on the OECD (2010) framework, Level 2 represents only basic mathematics skills, in which students begin to use mathematics functionally in everyday life; many Indonesian students merely follow procedural steps without grasping the underlying meaning of the questions given (Najiyah & Mahmudah, 2025), which signals that their critical thinking remains underdeveloped.

A body of prior research has examined mathematical critical thinking from complementary angles. Yulianto et al. (2024) reported that students' critical thinking development is closely tied to problem-solving that can be applied across social, technological, economic, and mathematical contexts, and that contextual mathematics instruction eases the cultivation of critical thinking. A systematic review by Suryawan et al. (2023) similarly concluded that critical thinking in mathematical problem-solving is shaped by an interaction of cognitive strategies and classroom practices, while Arsyad et al. (2023) linked quantitative literacy to critical thinking among pre-service teachers. At a broader instructional level, meta-analytic evidence shows that problem-based learning interventions produce a small-to-moderate positive effect on critical thinking in higher education (Liu & Pásztor, 2022), and realistic mathematics education approaches have been shown to improve junior high school students' critical thinking ability (Samura et al., 2022). Taken together, these studies establish that critical thinking is malleable through instructional design, yet they rely predominantly on quasi-experimental or literature-review designs that describe what improves critical thinking rather than how students themselves experience and make sense of their own difficulties.

Although many studies have discussed critical thinking in mathematics learning, comparatively few have explored students' experiences directly through a hermeneutic phenomenological design. This design is well suited to uncovering deeper meaning in students' lived learning experiences and is particularly relevant for studying difficult-to-observe phenomena in education, including students' subjective struggles with critical thinking (Dangal & Joshi, 2020). In addition, thematic analysis (Braun & Clarke, 2006), although a well-established qualitative method, has not been used optimally in studies of this kind, especially in combination with technological assistance such as ChatGPT. Emerging methodological literature indicates that large language models can support the coding, categorizing, and theme-development stages of thematic analysis while leaving interpretive authority with the human researcher (Jalali & Akhavan, 2024; Morgan, 2023), making data grouping, initial coding, category and theme determination, theme review, and conclusion drawing more systematic and efficient.

The novelty of this study lies in its combination of a hermeneutic phenomenological design, which foregrounds students' first-person accounts of the barriers they face in developing mathematical critical thinking, with ChatGPT-assisted thematic analysis (Braun & Clarke, 2006; Morgan, 2023), an analytic pairing that has rarely been applied within Indonesian secondary mathematics education research. This combination allows the study to generate not only a phenomenological understanding of why students struggle to think critically in mathematics, but also a systematically coded, transparent map of the solutions students themselves are able to propose. Therefore, this study aims to determine the factors that cause students' low mathematical critical thinking skills and to identify solutions that can help improve these abilities. The research questions guiding this study are as follows:
(1) What factors cause students' low mathematical critical thinking skills?
(2) What solutions do students propose to overcome or optimize their critical thinking skills?

2. Method

2.1 Research Design

This study employed a hermeneutic phenomenological design. This design was chosen because phenomenology focuses on exploring a phenomenon as it is lived and experienced, in this case, the phenomenon of students' low critical thinking skills in mathematics learning at school. The purpose of adopting this design was to explore in depth the factors that contribute to students' low mathematical critical thinking, as well as to identify possible solutions based on the experiences students themselves expressed through open-ended questions. The hermeneutic dimension of the design allowed the researchers to interpret the meaning of students' experiences contextually, in relation to the specific problem under investigation, rather than merely describing those experiences at face value (Neubauer et al., 2019).

Operationally, the hermeneutic phenomenological process in this study moved through an interpretive circle: the researchers first engaged with each student's written responses as a whole, then moved back and forth between individual statements and the developing set of codes, categories, and themes so that the meaning of each part was continually checked against the meaning of the whole data set. Before analysis began, the researchers explicitly reflected on their own assumptions as mathematics educators regarding why students struggle with critical thinking, so that these assumptions could be bracketed rather than imposed on the data. Thematic analysis

(Braun & Clarke, 2006) was then layered onto this phenomenological design as the concrete analytic technique used to move from raw statements to codes, categories, and themes, with ChatGPT employed as an assistive tool during the coding stages, consistent with recent methodological guidance on human–AI collaboration in qualitative analysis (Morgan, 2023).

2.2 Research Participants

The participants in this study were 10 Grade XII students at a public senior high school in West Lombok Regency, Indonesia. Of the 10 students, 9 were female and 1 was male, with an age range of 16–17 years. The school was selected because several students had been identified by their mathematics teachers as showing persistently low critical thinking skills, particularly in mathematics. Grade XII was chosen as the research subject because students at this level had already experienced three years of senior high school mathematics instruction, from Grade X to Grade XII, thereby providing them with broader insight into, and a deeper understanding of, the learning process, including the challenges and development of their own critical thinking skills. Grade XII students had also already encountered the upper-level curriculum, making their experiences more relevant to the aims of the study.

Participants were recruited through purposive sampling, a technique appropriate for phenomenological research because it deliberately selects individuals who have direct experience of the phenomenon under investigation rather than aiming for statistical representativeness. The inclusion criteria were: (a) currently enrolled in Grade XII mathematics; (b) identified by the class mathematics teacher as having experienced ongoing difficulty with critical thinking in mathematics learning; and (c) willing to complete the questionnaire and provide detailed written reflections. Students who met these criteria were approached by their teacher, briefed on the purpose of the study, and invited to participate voluntarily. The resulting sample was small and predominantly female, which is a common feature of purposive, experience-based qualitative sampling but also a limitation that is addressed further in the Discussion and Conclusion sections.

2.3 Data Collection

The instrument used in this study was a questionnaire on students' mathematical critical thinking skills, consisting of 10 closed-ended questions and 2 open-ended questions designed to explore in depth students' views and experiences regarding their critical thinking in the context of mathematics learning. The questionnaire was distributed online and could be completed at the participants' own pace; completion took approximately 20–30 minutes per student. The open-ended questions allowed students the freedom to describe their experiences and provide detailed responses related to their critical thinking skills in mathematics, which formed the primary data source for the phenomenological and thematic analysis reported in this article.

2.4 Data Analysis

The data in this study were analyzed using thematic analysis following the six-phase framework of Braun and Clarke (2006): (1) familiarizing with the data, (2) generating initial codes, (3) searching for/identifying categories, (4) reviewing and developing themes, (5) defining and naming themes, and (6) producing the final analytic account. This method was chosen for its systematic yet flexible approach, which made it easier to identify recurring patterns across students' open-ended responses and to move transparently from raw statements to abstract themes. To support the analysis, the researchers used ChatGPT as an assistive coding tool. During the familiarization phase, the researchers repeatedly read through students' written responses to gain a thorough understanding of the content and underlying meaning of each statement; ChatGPT was then used to help propose and organize initial codes and candidate categories, which the researchers subsequently reviewed, refined, and finalized by hand. Every code, category, and theme reported in this article therefore reflects the researchers' own interpretive judgment, with ChatGPT functioning only as an efficiency-oriented assistant rather than as an independent analyst, consistent with recommendations in the qualitative methodology literature on generative AI use (Jalali & Akhavan, 2024; Morgan, 2023).

2.5 Ethical Clearance

This study adhered to the ethical principles governing educational research involving human participants. Prior to data collection, the researchers obtained permission from the school principal to conduct the study, and informed participating students of the study's purpose, procedures, and voluntary nature. Written informed consent was obtained from each participating student; because all participants were minors, additional consent was also obtained from a parent or legal guardian. Participants were assured that their involvement would not affect their academic assessment in any way, that they were free to withdraw from the study at any time without consequence, and that their identities would remain strictly confidential. All responses were anonymized and reported using factor and solution codes (KF1–KF10 and KS1–KS10) rather than personal identifiers, and raw questionnaire data were stored securely and accessible only to the research team.

3. Results and Discussion

3.1 Results

This study set out to determine the factors that cause students to experience low mathematical critical thinking skills and to identify the solutions students themselves proposed to improve these skills. Analysis of students' open-ended responses proceeded through six sequential analytic stages, each summarized in a corresponding table: initial factor codes (Table 1), initial solution codes (Table 2), factor categories (Table 3), solution categories (Table 4), factor themes (Table 5), and solution themes (Table 6). The following subsections present and interpret each stage in turn.

Table 1
Initial Factor Codes

No	Description of Factors	Origin Code
1	Lack of memorization of mathematical formulas	KF1
2	Lack of habit of reading and seeking information	KF2
3	The use of technology is not utilized properly	KF3
4	Mood affects learning motivation	KF4
5	Being absent-minded or daydreaming interferes with thinking	KF5
6	Lack of support and quick-thinking exercises	KF6
7	Lack of critical thinking because of being used to accepting things as they are	KF7
8	Too many formulas are confusing	KF8

No	Description of Factors	Origin Code
9	Lazy habit of thinking	KF9
10	Memorizing formulas makes you dizzy	KF10

As shown in Table 1, ten initial factors emerged as obstacles in students' mathematics learning process, coded KF1 through KF10. The most frequently recurring factors were difficulty memorizing formulas (KF1), a lack of reading habits (KF2), unproductive use of technology (KF3), mood fluctuations affecting learning enthusiasm (KF4), and a generally lazy disposition toward thinking (KF9). These initial codes indicate that students' learning obstacles are multidimensional, spanning cognitive difficulties (e.g., memorization and comprehension), behavioral habits (e.g., reading and information-seeking), environmental factors (e.g., technology use), and affective states (e.g., mood and motivation). Notably, several codes, such as KF5 (being absent-minded or daydreaming) and KF10 (memorizing formulas causing dizziness), point to an emotional or even mildly aversive relationship that some students have developed toward formula-based mathematics content, which is worth attending to independently of purely cognitive remediation.

Table 2

Initial Solution Codes

No	Solution Description	Origin Code
1	Answering math questions repeatedly so as not to forget them easily	KS1
2	Changing learning methods to be more varied	KS2
3	Utilizing technology as a learning medium	KS3
4	Cultivating intention and motivation	KS4
5	Increasing the number of practice questions and repeating previous lessons	KS5
6	Relating lessons to everyday life	KS6
7	Giving students space to think critically	KS7
8	Building self-confidence and opening minds to the benefits of mathematics	KS8
9	Motivating oneself by thinking of school fees to be more enthusiastic	KS9
10	Cultivating curiosity about mathematics to be more interested	KS10

Table 2 presents the ten initial solutions students proposed in response to the difficulties they described, coded KS1 through KS10. The most frequently proposed solutions were increasing the number of practice questions (KS1 and KS5), changing learning methods to be more varied and interesting (KS2), using technology for learning purposes (KS3), and cultivating learning motivation from within (KS4 and KS9). Read alongside Table 1, this pattern shows that students' proposed solutions map closely onto the difficulties they reported: students who cited memorization difficulty tended to propose repetition-based solutions, while students who cited passive or unproductive technology use tended to propose more purposeful technology use. This close correspondence between factors and solutions suggests that students possess considerable metacognitive awareness of their own learning obstacles, even though this awareness has not yet translated into changed classroom practice.

Table 3

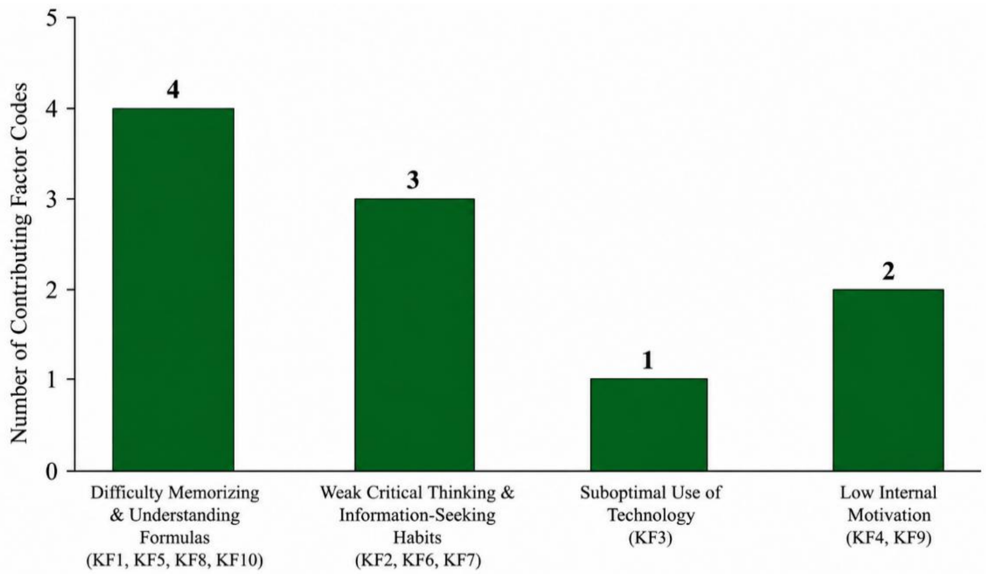
Factor Categories

Initial Code	Factor Category	Category Origin
KF1, KF5, KF8, KF10	Problems in Memorizing Formulas and Understanding Material	KF1: Lack of memorization; KF5: Careless/daydreaming; KF8: Confusing formulas; KF10: Memorization causes dizziness
KF2, KF6, KF7	Lack of Critical Thinking and Information-Seeking Habits	KF2: Lack of reading habit; KF6: Lack of quick-thinking exercise; KF7: Passive acceptance of information
KF3	Suboptimal Use of Technology	KF3: Technology not used optimally (e.g., for gaming)
KF4, KF9	Motivation and Intention in Learning	KF4: Mood affects motivation; KF9: Lazy thinking habit

Table 3 organizes the ten initial factor codes into four broader categories: (1) problems in memorizing formulas and understanding material (KF1, KF5, KF8, KF10), which was the largest category with four contributing codes; (2) lack of critical thinking and information-seeking habits (KF2, KF6, KF7); (3) suboptimal use of technology (KF3); and (4) low motivation and intention to learn (KF4, KF9). This categorization clarifies that the single most substantial obstacle category concerns memorization and comprehension of mathematical material, while the remaining three categories point respectively to habitual, environmental, and motivational barriers. Figure 1 visualizes the relative weight of each category based on the number of contributing factor codes.

Figure 1

Thematic Map of Factors Underlying Students' Low Mathematical Critical Thinking Skills



As Figure 1 illustrates, the memorization-and-comprehension category accounts for the largest share of contributing codes (four of ten), followed by the critical-thinking-and-information-seeking-habits category (three codes), the motivation category (two codes), and the technology-use category (one code). This distribution reinforces the interpretation that, from the students' own perspective, the most pressing barrier to mathematical critical thinking is not a single dramatic cause but a cluster of interrelated difficulties in retaining and making sense of mathematical content.

Table 4

Solution Categories

Initial Code	Solution Category	Category Description
KS1, KS5, KS8, KS10	Solutions for Memorization and Understanding	Focus on practice questions, repetition, and meaning-making in learning mathematics
KS2, KS6, KS7	Critical and Meaningful Learning	Encourages active and contextual learning
KS3	Educational Use of Technology	Demonstrates solutions using technology for learning
KS4, KS9	Building Motivation and Learning Awareness	Refers to students' internal motivation

In Table 4, the solutions students proposed are grouped into four categories that mirror the factor categories in Table 3: (1) solutions for memorization and understanding (KS1, KS5, KS8, KS10); (2) critical and meaningful learning (KS2, KS6, KS7); (3) educational use of technology (KS3); and (4) building motivation and learning awareness (KS4, KS9). This parallel structure between Tables 3 and 4 demonstrates that students did not merely list surface-level fixes but articulated solution categories that directly target the categories of difficulty they themselves identified, touching on technical aspects (such as practice questions) as well as psychological aspects and broader learning strategies.

Table 5

Factor Themes

No	Factor Theme	Origin Code	Theme Description
1	The need for effective learning strategies to memorize and understand the material	KF1, KF5, KF8, KF10	Brings together issues about the difficulty of understanding and memorizing mathematical material
2	The need to get used to thinking critically and seeking information independently	KF2, KF6, KF7	Reflects weak reflection and analysis skills
3	The importance of using technology positively for learning	KF3	Emphasizes the need for transformation of technology use into a learning tool
4	The need to grow motivation and intention to learn internally	KF4, KF9	Focuses on the internal aspects of students in fostering a spirit of learning

Table 5 synthesizes the four factor categories into four broader themes: (1) the need for effective learning strategies to memorize and understand mathematical material; (2) the need to cultivate critical thinking and independent information-seeking habits; (3) the importance of using technology positively for learning; and (4) the need to grow internal motivation and intention to learn. These themes represent the researchers' interpretive synthesis of the categories in Table 3 and provide the conceptual basis for the discussion of instructional implications that follows in Section 3.2.

Table 6

Solution Themes

No	Solution Theme	Origin Code	Theme Explanation
1	Implementation of active learning strategies to overcome memorization and comprehension difficulties	KS1, KS5, KS8, KS10	A solution to memorization difficulties through an applicable and meaningful approach
2	Building engaging, contextual, and critical learning	KS2, KS6, KS7	Answers the challenges of passive learning with active and reflective methods
3	Use of technology as a positive learning tool	KS3	Encourages the use of gadgets and technology in a wise and educational manner
4	Cultivating motivation and internal awareness in learning	KS4, KS9	Ignites the spirit of learning from within students for long-term results

Finally, Table 6 presents the solution themes derived from the previously categorized solution groups: (1) implementation of active learning strategies to overcome memorization and comprehension difficulties; (2) building engaging, contextual, and critical learning; (3) use of technology as a positive learning tool; and (4) cultivating motivation and internal awareness in learning. Read together, Tables 5 and 6 show a clear one-to-one correspondence between the barriers students experience and the solutions they are able to articulate, which is the central empirical finding of this study and the foundation for the interpretation developed in the following Discussion section.

3.2 Discussion

The most dominant factor identified in this study was students' difficulty in memorizing formulas and understanding mathematical material, reflected in codes KF1, KF5, KF8, and KF10. This difficulty caused students to feel confused, to forget material easily, and even to feel dizzy when confronting mathematics lessons. A systematic and repetitive learning strategy therefore appears necessary to improve students' critical thinking skills; in response, students themselves proposed increasing practice questions, repeating previous material, and implementing active learning strategies (KS1, KS5, KS8, and KS10). This finding is consistent with Yulianto et al. (2024), who found that students often study mathematics simply by imitating the solution methods demonstrated by the teacher and by memorizing formulas without necessarily understanding them, a habit that prevents critical thinking skills from developing optimally because students are not accustomed to analyzing or reflecting on their own thinking processes. This mirrors the compounding cognitive, affective, and linguistic barriers found among Indonesian junior high school students with low conceptual understanding in solving mathematical story problems (Rauhun et al., 2025). This pattern also aligns with Ennis's (2016) broader argument that critical thinking dispositions must be deliberately cultivated across the curriculum; without such deliberate cultivation, procedural memorization tends to substitute for genuine understanding.

The second theme showed that students' critical thinking skills were still relatively low, as reflected in codes KF2, KF6, and KF7. Several students admitted that they rarely read, were unaccustomed to thinking quickly, and tended to receive information passively without questioning it further. This condition indicates that the learning approaches used so far have not fully encouraged active student involvement. In response, students suggested that learning be made more varied, contextual, and provide greater space for thinking (KS2, KS6, and KS7). This finding is consistent with Anwar and Muti'ah (2022), who found that students' low critical thinking is associated with a lack of habits of reflecting on their own thinking process and a lack of learning activities that encourage exploration. Complementing this, Häusler et al. (2024) found that insufficient teacher wait time after posing questions — often less than three seconds — significantly hinders students' ability to reason through problem-solving tasks, thereby limiting the development of critical thinking. This is further reinforced by Darcie et al. (2024), who emphasized that a classroom culture that does not support exploration and reflection can inhibit the formation of critical thinking dispositions even among students who have the underlying potential for it. Meta-analytic evidence from problem-based learning research similarly shows that structured opportunities for exploration and reflection are among the most reliable levers for improving critical thinking (Liu & Pásztor, 2022), which strengthens the interpretation that the second theme in this study is primarily a matter of insufficient opportunity rather than insufficient student capability. This is corroborated by classroom-level evidence that combining concrete teaching aids with problem-based learning significantly enhances students' engagement and higher-order thinking, particularly critical thinking (Safira & Darmawan, 2025).

In the third theme, the results showed that technology has not been used optimally to support learning activities. Based on code KF3, many students still use gadgets for purposes unrelated to their lessons, such as playing games or other entertainment, even though, in the digital era, technology should ideally serve as an effective learning tool — for example, by watching instructional videos, completing practice questions through applications, or searching for supplementary material online. Some students in this study suggested that technology be used more deliberately to support the learning process, such as through educational applications, instructional videos, or online quizzes (KS3), so that learning becomes more engaging rather than a source of distraction. This is supported by Kravchenko et al. (2023), who found that the use of technology in education has been shown to be effective in improving critical thinking skills and contributes positively to students' academic performance. Similarly, Harandi (2015) found that technology-based learning (e-learning) can increase students' learning motivation because it is more flexible and engaging. A hermeneutic phenomenological study of Indonesian secondary students similarly found that technology plays a paradoxical role, enhancing conceptual understanding while also introducing digital distractions and equity gaps (Anisa et al., 2025). Realistic mathematics education approaches that deliberately integrate contextual, technology-supported problems have likewise been shown to strengthen critical thinking among secondary students (Samura et al., 2022), suggesting that the direction students proposed in this study, purposeful, learning-oriented technology use, is well aligned with the broader research evidence.

Motivation and intention to learn were also important highlights of this study. Based on codes KF4 and KF9, poor mood and laziness frequently emerged as major obstacles in students' learning process; if left unaddressed, these conditions can contribute to declining achievement and diminished overall enthusiasm for learning. Family and home-environment factors have similarly been shown to depress Indonesian elementary students' learning motivation (Wulandari et al., 2023), suggesting that motivational barriers such as KF4 and KF9 may also have roots outside the classroom. To address this, students suggested cultivating motivation from within, for example, by remembering their learning goals, thinking about the future, and recognizing their parents' sacrifices (KS4 and KS9). This finding is supported by Self-Determination Theory (Ryan & Deci, 2000), which posits that intrinsic motivation, the drive that originates from within a person, strongly influences learning engagement and success, and by Steinmayr et al. (2019), whose findings similarly emphasize the central role of student motivation in academic achievement. Peer learning and self-regulatory strategies have also been shown to strengthen mathematics interest and performance (Michael et al., 2025), suggesting that students' proposed solution of relating lessons to peers and everyday contexts (KS6) has empirical support beyond intrinsic motivation alone. Taken together, these two strands of evidence suggest that interventions aimed at improving mathematical critical thinking cannot rely solely on cognitive strategies such as repeated practice; they must also nurture the underlying motivational conditions that make sustained engagement with difficult material possible in the first place.

Overall, the results of this study indicate that students are, in fact, reasonably aware of the various learning obstacles they experience, ranging from difficulty understanding material and low motivation to inappropriate technology use and a lack of critical thinking habits. Interestingly, students also proposed a range of concrete solutions, from increasing practice and learning through instructional videos to cultivating motivation from within themselves. This self-awareness and desire for change represent important capital for the learning process, particularly for efforts aimed at developing critical thinking skills. Critical thinking itself is important precisely because it enables students to analyze, evaluate, and solve problems logically (Arslan et al., 2014). As explained by Widana (2018), critical thinking is not merely about answering questions correctly but also about how students reflect on their own understanding and make decisions through deeper thinking; Espina (2022) similarly emphasizes that critical thinking involves the courage to ask questions, to evaluate information, and to avoid accepting claims at face value. This is consistent with evidence that students' mathematical creative thinking is closely linked to their self-confidence (Efwan et al., 2024), reinforcing why solutions such as KS8 (building self-confidence) emerged alongside cognitive strategies.

Given these findings, the role of teachers becomes central to shaping a learning process that supports critical thinking. Teachers are not only responsible for explaining material but must also guide students to think actively, discuss, evaluate, and draw conclusions independently. As Geng (2021) argues, active and contextual learning strongly supports the growth of critical thinking skills because students become directly involved in the learning process rather than merely listening and taking notes; teachers act as guides rather than sole conveyors of material. In a related vein, Susanti and Sari (2021) found that implementing the Contextual Teaching and Learning (CTL) model within Lesson Study activities successfully enhanced students' critical thinking by encouraging the identification of relevant problems and by promoting collaborative classroom discussion. Considered alongside the meta-analytic evidence on problem-based and realistic mathematics education (Liu & Pásztor, 2022; Samura et al., 2022), these findings collectively point toward a coherent set of instructional recommendations: active, contextual, technology-integrated, and motivationally supportive pedagogy, sustained through ongoing teacher professional development, rather than isolated or one-off interventions.

This study is not without limitations. The sample was small (n = 10), drawn from a single school, and predominantly female, which limits the transferability of the findings and means the results should be interpreted as an in-depth account of a particular group of students' experiences rather than a population-level estimate. The use of ChatGPT as an analytic assistant, while methodologically documented (Jalali & Akhavan, 2024; Morgan, 2023), also introduces a dependency on a proprietary tool whose outputs the researchers necessarily had to verify and adjust by hand. Future research could extend this study by employing a larger and more gender-balanced sample, by triangulating questionnaire data with classroom observation or semi-structured interviews, and by testing the instructional recommendations identified here through a quasi-experimental design that measures change in students' mathematical critical thinking over time.

4. Conclusion

Based on the results of this research and the discussion presented above, it can be concluded that senior high school students' critical thinking skills in mathematics learning remain relatively low. This condition is caused by several interrelated factors: difficulty memorizing formulas and understanding material, a lack of reading habits and reflective thinking, less-than-optimal use of technology, and weak motivation and intention to learn.

Interestingly, students are not only aware of the obstacles they face but are also able to propose a range of active and independent solutions, including increasing the number of practice questions, repeating material, using technology in an educational manner, and cultivating motivation from within. This self-awareness constitutes an important asset for building a more meaningful learning process, and it is precisely this asset, combined with the hermeneutic phenomenological and ChatGPT-assisted thematic analysis employed in this study, that constitutes the study's main contribution: a transparent, student-grounded account of both the barriers to, and the pathways toward, stronger mathematical critical thinking.

Critical thinking skills are of central importance in learning because they enable students to analyze, evaluate, and solve problems logically and independently. However, these skills cannot develop optimally if learning remains passive and continues to emphasize memorization alone. The role of teachers is therefore vital: teachers must act as facilitators who cultivate an active, contextual, and reflective learning atmosphere, directing students not only to follow procedures but also to ask questions, discuss, and evaluate information in depth.

Contextual learning, encouragement of exploration, and the provision of space for students to think deeply have all been shown to support the development of critical thinking skills, and teachers play an essential role in creating a learning environment where this can be achieved. With the support of appropriate methods and approaches, and with attention to the motivational and technological dimensions highlighted in this study, students' potential for critical thinking can develop more fully. Future studies with larger, more diverse samples and mixed-methods or quasi-experimental designs are recommended to validate and extend these findings across broader educational contexts.

Acknowledgment
The authors would like to express their sincere gratitude to the principal, mathematics teachers, and students of the participating senior high school in West Lombok Regency, Indonesia, for their cooperation and willingness to take part in this study. The authors also thank Universitas Nahdlatul Wathan Mataram for the institutional support provided throughout the research and manuscript preparation process. Appreciation is further extended to colleagues and peer reviewers whose constructive feedback helped improve the quality of this manuscript.

Declarations

Author Contribution : Susi Sulasti: Conceptualization, Writing – Original Draft, Methodology, Data Collection, Formal Analysis, and Investigation.
Naif Mastoor Alsulami: Review and Editing
Muhamad Galang Isnawan: Supervision, Writing – Review and Editing.
Farah Heniati Santosa: Supervision, Writing – Review and Editing.
Ronaldo Rafael Olivero-Acuña: Review and Editing
Denilsón Andrés Silgado-Tuñón: Review and Editing

Funding Statement : This research received no external funding from public, commercial, or not-for-profit funding agencies.

Conflict of Interest : The authors declare no conflict of interest.

AI Declaration : Generative artificial intelligence (ChatGPT) was used as an assistive tool during the thematic-analysis coding stages, as described in Section 2.4; all codes, categories, and themes were reviewed, verified, and finalized by the authors. AI tools were additionally used for grammar checking and language polishing during manuscript preparation. All intellectual content, data collection, analysis, and interpretation were performed by the authors.

Data Availability : The data supporting the findings of this study are available from the corresponding author upon reasonable request, in accordance with the confidentiality and ethical-clearance terms described in Section 2.5.

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