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The Relationship Between Math Anxiety and Cognitive Flexibility on Students' Mathematical Critical Thinking Ability

Halil Arianto[1], Wayan Rumite[2]

[1,2]Department of Mathematics Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Makassar, Indonesia

Corresponding Author: halil.arianto@unm.ac.id

Abstract

Mathematical critical thinking is an essential skill that supports students in solving complex problems and making logical decisions in learning mathematics. However, students' ability to think critically is often influenced by both emotional and cognitive factors. This study aims to examine the relationship between math anxiety and cognitive flexibility on students' mathematical critical thinking ability. This research employed a quantitative approach with a correlational design involving junior high school students selected through purposive sampling. Data were collected using a math anxiety questionnaire, a cognitive flexibility scale, and a mathematical critical thinking test. The data were analyzed using descriptive statistics, Pearson correlation, and multiple regression analysis. The results show that students' math anxiety is at a moderate level (M = 68.45; SD = 8.72), cognitive flexibility is at a moderate–high level (M = 74.12; SD = 7.95), and mathematical critical thinking ability is at a moderate level (M = 70.36; SD = 9.10). Furthermore, math anxiety has a significant negative correlation with mathematical critical thinking ability (r = -0.52, p < 0.05), while cognitive flexibility has a significant positive correlation (r = 0.61, p < 0.05). The results of multiple regression analysis indicate that math anxiety (β = -0.41, p < 0.05) and cognitive flexibility (β = 0.48, p < 0.05) simultaneously influence students' mathematical critical thinking ability. These findings suggest that students with lower levels of anxiety and higher cognitive flexibility tend to demonstrate better critical thinking skills in mathematics. Therefore, improving students' mathematical critical thinking requires both reducing math anxiety and enhancing cognitive flexibility through appropriate instructional strategies.

Keyword: Math Anxiety, Cognitive Flexibility, Mathematical Critical Thinking.

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INTRODUCTION

Mathematics plays a pivotal role in shaping students' logical reasoning, problem-solving abilities, and higher-order thinking skills, which are essential competencies in the 21st century. In modern educational discourse, the emphasis has shifted from mere procedural fluency toward the development of critical thinking skills that enable students to analyze, evaluate, and construct mathematical arguments. Mathematical critical thinking is not only fundamental for academic success but also serves as a cornerstone for informed decision-making in everyday life (Sachdeva & Eggen, 2021; Sappaile et al., 2024; Zheng et al., 2026). However, despite its importance, many students continue to experience significant challenges in developing strong critical thinking abilities in mathematics, particularly in contexts that require deep conceptual understanding and flexible reasoning.

One of the persistent issues influencing students' performance in mathematics is the presence of negative emotional factors, among which math anxiety has received considerable attention. Math anxiety is commonly defined as a feeling of tension, apprehension, or fear that interferes with mathematical performance (Ika & Anita, 2014; Marzuki et al., 2024). This emotional response can manifest in various forms, such as avoidance of mathematical tasks, decreased confidence, and impaired working memory capacity during problem-solving processes. Students experiencing high levels of math anxiety often struggle to engage effectively with mathematical problems, especially those that require critical analysis and reasoning. Consequently, math anxiety has been identified as a significant barrier to the development of higher-order thinking skills in mathematics (Atabek et al., 2022; Gökçe & Güner, 2024; Jiang et al., 2021).

The impact of math anxiety extends beyond emotional discomfort, as it also affects cognitive functioning. Research suggests that anxiety consumes cognitive resources, particularly working memory, which is crucial for processing complex information and performing multi-step problem-solving tasks. When students are overwhelmed by anxiety, their ability to organize information, evaluate alternative solutions, and justify reasoning becomes compromised. This condition directly hinders the development of mathematical critical thinking, which relies heavily on the ability to analyze problems systematically and construct logical arguments. Therefore, understanding the role of math anxiety in shaping students' cognitive performance is essential for addressing learning difficulties in mathematics (Horowitz-Kraus et al., 2026; Ika & Anita, 2014; Jiang et al., 2021).

In addition to emotional factors, cognitive aspects such as cognitive flexibility play a crucial role in determining students' success in mathematical thinking. Cognitive flexibility refers

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to the ability to adapt thinking strategies, shift perspectives, and consider multiple solutions when faced with complex or unfamiliar problems. It is a key component of executive function that enables individuals to respond effectively to changing demands and to approach problems from different angles (Jarutkamolpong & Kwangmuang, 2025; Wang et al., 2025). In the context of mathematics, cognitive flexibility allows students to move beyond rigid procedures and explore alternative methods for solving problems, thereby fostering deeper understanding and critical thinking.

Students with high cognitive flexibility tend to demonstrate greater adaptability in problem-solving situations. They are more capable of recognizing patterns, restructuring information, and integrating prior knowledge with new concepts. This adaptability is particularly important in tasks that require critical thinking, as such tasks often involve evaluating the validity of arguments, identifying assumptions, and drawing logical conclusions. Conversely, students with low cognitive flexibility may rely heavily on memorized procedures and struggle when confronted with non-routine problems that demand innovative thinking. As a result, cognitive flexibility is considered a vital factor in the development of mathematical critical thinking abilities (Dawson et al., 2025; Jin & Cutumisu, 2024).

The interaction between emotional and cognitive factors in learning mathematics presents a complex dynamic that warrants further investigation. While math anxiety can inhibit cognitive processes, cognitive flexibility may serve as a protective factor that helps students navigate challenging mathematical tasks. For instance, students with high cognitive flexibility might be better equipped to manage anxiety by employing adaptive strategies, such as reframing problems or exploring alternative solution paths. On the other hand, students with low cognitive flexibility may be more vulnerable to the negative effects of anxiety, as they lack the ability to adjust their thinking when faced with difficulties. This interplay suggests that both math anxiety and cognitive flexibility contribute significantly to students' mathematical performance, particularly in relation to critical thinking.

Previous studies have explored the individual effects of math anxiety and cognitive flexibility on various aspects of mathematical achievement. Research on math anxiety consistently indicates a negative correlation between anxiety levels and mathematical performance, including problem-solving and reasoning abilities. Meanwhile, studies on cognitive flexibility highlight its positive association with academic achievement and higher-order thinking skills. However, much of the existing literature tends to examine these variables in isolation, without considering their combined influence on mathematical critical thinking (Sachdeva & Eggen, 2021; Sappaile, Dhaksietsatsura, et al., 2025; Sappaile, Wahyudin, et al., 2025). This gap

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in the literature limits our understanding of how emotional and cognitive factors interact to shape students' learning outcomes. Furthermore, there is a growing recognition of the need to integrate psychological constructs into mathematics education research. Traditional approaches to teaching mathematics often focus primarily on content delivery and procedural practice, overlooking the psychological dimensions that influence learning. As educational paradigms evolve toward more holistic approaches, it becomes increasingly important to consider how factors such as anxiety and cognitive flexibility affect students' engagement and performance. By examining these factors simultaneously, educators and researchers can gain a more comprehensive understanding of the challenges faced by students in developing critical thinking skills.

Another important consideration is the context in which students learn mathematics. Differences in educational environments, instructional strategies, and cultural factors may influence the levels of math anxiety and cognitive flexibility among students. For example, highly competitive classroom settings may exacerbate anxiety, while student-centered approaches that encourage exploration and discussion may enhance cognitive flexibility. These contextual factors highlight the importance of designing learning environments that support both emotional well-being and cognitive development. In this regard, investigating the relationship between math anxiety, cognitive flexibility, and critical thinking can provide valuable insights for improving instructional practices (Homayouni et al., 2024; Suherman & Vidákovich, 2024). In the context of secondary education, the development of mathematical critical thinking is particularly crucial, as students are expected to engage with increasingly complex concepts and problem-solving tasks. At this level, students are required not only to apply mathematical procedures but also to justify their reasoning and evaluate the validity of solutions. However, many students struggle to meet these expectations due to a combination of emotional and cognitive challenges. Identifying the factors that influence their performance can help educators design targeted interventions to enhance learning outcomes.

Despite the growing body of research on math anxiety and cognitive flexibility, there remains a lack of empirical studies that examine their simultaneous effects on mathematical critical thinking, particularly within specific educational contexts. This gap underscores the need for further investigation to determine how these variables interact and to what extent they influence students' ability to think critically in mathematics. Understanding these relationships can contribute to the development of more effective teaching strategies that address both the emotional and cognitive needs of students. Given the importance of fostering critical thinking skills in mathematics, it is essential to explore the factors that facilitate or hinder their

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development. By examining the relationship between math anxiety and cognitive flexibility, this study aims to provide a more nuanced understanding of how these variables influence students' mathematical critical thinking ability. Such insights can inform the design of instructional approaches that not only enhance cognitive skills but also mitigate the negative effects of anxiety, ultimately leading to improved learning outcomes. In summary, mathematics education today demands a balanced approach that considers both cognitive and emotional dimensions of learning. Math anxiety and cognitive flexibility represent two critical factors that shape students' engagement and performance in mathematics. While anxiety can act as a barrier to effective learning, cognitive flexibility offers a pathway for overcoming challenges and enhancing critical thinking. Investigating the relationship between these variables is therefore essential for advancing our understanding of mathematical learning processes and for developing strategies that support students in achieving their full potential.

METHOD

The steps carried out in this study are systematically organized to examine the relationship between math anxiety, cognitive flexibility, and students' mathematical critical thinking ability. The research design, data collection procedures, instruments, and data analysis techniques are described in detail to ensure the validity and reliability of the findings. This study employed a quantitative approach using a correlational research design. The purpose of this design is to identify and analyze the degree of relationship between independent variables, namely math anxiety and cognitive flexibility, and the dependent variable, namely mathematical critical thinking ability. A correlational approach is considered appropriate because it allows the researcher to examine the interaction among variables without manipulating them, thereby reflecting real conditions in the learning environment.

The population of this study consisted of junior high school students. The sample was selected using a purposive sampling technique, considering specific criteria such as students who had received mathematics instruction on relevant topics and were actively engaged in classroom learning. The total number of participants involved in this study was determined based on the adequacy for statistical analysis to ensure meaningful interpretation of results. The research procedure was carried out through several stages, starting from preparation to data analysis. The overall process of the study is illustrated in Figure 1 below.

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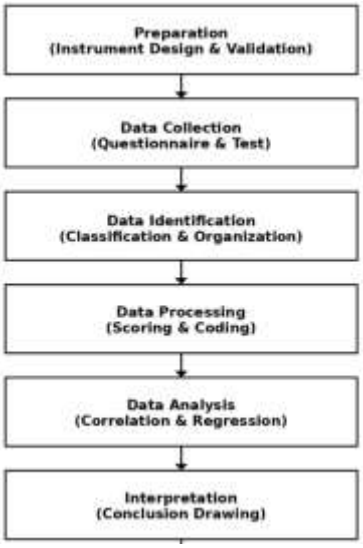


Figure 1. Research Flowchart

To provide a clearer overview, the implementation stages of this study are summarized in Table 1 below.

Table 1. Research Implementation Stages

No	Stage	Description
1	Preparation	Designing instruments, validating content, and conducting pilot testing
2	Data Collection	Administering math anxiety questionnaire, cognitive flexibility scale, and critical thinking test
3	Data Identification	Classifying and organizing collected data
4	Data Processing	Scoring, tabulating, and coding data
5	Data Analysis	Applying statistical tests (correlation and regression analysis)
6	Interpretation	Interpreting findings and drawing conclusions

Research Instruments

The instruments used in this study consisted of three main components, each designed to measure a specific variable:

1. Math Anxiety Questionnaire : This instrument was used to measure students' level of anxiety in mathematics. It was developed based on established indicators such as feelings of tension, worry, and fear when dealing with mathematical tasks. The questionnaire used a Likert scale ranging from strongly disagree to strongly agree (Ika & Anita, 2014; Jiang et al., 2021).

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2. Cognitive Flexibility Scale : This instrument aimed to assess students' ability to adapt their thinking, shift strategies, and consider alternative solutions. The scale included statements that reflect flexibility in problem-solving and openness to new approaches (Marzuki et al., 2024).
3. Mathematical Critical Thinking Test : This test was designed to measure students' critical thinking skills in mathematics, including abilities to analyze problems, evaluate arguments, and draw logical conclusions. The test consisted of open-ended questions that require reasoning and justification (Fadli et al., 2022; Sachdeva & Eggen, 2021).

All instruments were validated by experts to ensure content validity. In addition, a reliability test was conducted using Cronbach's Alpha to ensure internal consistency.

Data Collection Technique

Data collection was conducted by administering the instruments directly to students during scheduled learning sessions. The math anxiety questionnaire and cognitive flexibility scale were distributed first, followed by the mathematical critical thinking test. Students were given clear instructions and sufficient time to complete each instrument to ensure the accuracy of responses.

Data Analysis Technique

The data obtained from the instruments were analyzed using statistical techniques. The analysis process included several steps:

1. Descriptive Analysis : This analysis was conducted to describe the general characteristics of each variable, including mean, standard deviation, and distribution of scores.
2. Assumption Testing : Before conducting inferential analysis, prerequisite tests were performed, including normality and linearity tests, to ensure that the data met the assumptions required for parametric analysis.
3. Correlation Analysis : Pearson correlation analysis was used to determine the strength and direction of the relationship between math anxiety and mathematical critical thinking, as well as between cognitive flexibility and mathematical critical thinking.
4. Multiple Regression Analysis : Multiple regression analysis was applied to examine the simultaneous effect of math anxiety and cognitive flexibility on students' mathematical critical thinking ability.

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RESULTS AND DISCUSSION

RESULTS

This study aims to examine the relationship between math anxiety, cognitive flexibility, and students' mathematical critical thinking ability. The data obtained from the research instruments were analyzed using descriptive statistics, assumption testing, correlation analysis, and multiple regression analysis. The descriptive analysis was conducted to describe the general characteristics of each variable. The results indicate that students' math anxiety is at a moderate level, suggesting that most students experience a certain degree of tension and concern when dealing with mathematical tasks. Cognitive flexibility, on the other hand, is categorized as moderate to high, indicating that students demonstrate relatively good adaptability in thinking and problem-solving. Meanwhile, students' mathematical critical thinking ability is also at a moderate level, reflecting that students possess basic analytical skills but still require improvement in reasoning and evaluation. The results of the descriptive statistics are presented in Table 2.

Table 2. Descriptive Statistics of Research Variables

Variable	Mean	Std. Deviation	Category
Math Anxiety	68.45	8.72	Moderate
Cognitive Flexibility	74.12	7.95	Moderate–High
Mathematical Critical Thinking	70.36	9.10	Moderate

Before conducting inferential analysis, assumption testing was carried out to ensure that the data met the requirements for parametric analysis. The results of the normality test show that all variables are normally distributed, as indicated by significance values greater than 0.05. In addition, the linearity test indicates that the relationship between the independent variables and the dependent variable is linear. Therefore, the data meet the prerequisites for further statistical analysis. Furthermore, Pearson correlation analysis was conducted to determine the relationship between variables. The results indicate a negative relationship between math anxiety and mathematical critical thinking ability, meaning that higher levels of anxiety are associated with lower levels of critical thinking. In contrast, cognitive flexibility shows a positive relationship with mathematical critical thinking ability, indicating that higher cognitive flexibility is associated with better critical thinking performance. The results of the correlation analysis are presented in Table 3.

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Table 3. Correlation Analysis Results

Variables	Correlation Coefficient (r)	Significance (p)
Math Anxiety – Critical Thinking	-0.52	0.000
Cognitive Flexibility – Critical Thinking	0.61	0.000

The results show that both relationships are statistically significant. The negative coefficient between math anxiety and critical thinking indicates an inverse relationship, while the positive coefficient between cognitive flexibility and critical thinking indicates a direct relationship. To further examine the simultaneous effect of math anxiety and cognitive flexibility, multiple regression analysis was conducted. The results indicate that both variables significantly influence students' mathematical critical thinking ability. Math anxiety has a negative regression coefficient, while cognitive flexibility has a positive regression coefficient. The results of the regression analysis are presented in Table 4.

Table 4. Multiple Regression Analysis Results

Variable	Beta (β)	t-value	Significance (p)
Math Anxiety	-0.41	-4.85	0.000
Cognitive Flexibility	0.48	5.72	0.000

These results indicate that math anxiety and cognitive flexibility simultaneously contribute to students' mathematical critical thinking ability. The model shows that both variables are significant predictors, with cognitive flexibility having a stronger positive influence compared to the negative effect of math anxiety.

DISCUSSION

The findings of this study demonstrate that both math anxiety and cognitive flexibility are significant factors influencing students' mathematical critical thinking ability. The negative relationship between math anxiety and critical thinking suggests that emotional factors play a critical role in hindering students' cognitive performance (Lim & Darvin, 2026; Marzuki et al., 2024; Weigelt et al., 2026). This result aligns with theoretical perspectives that emphasize the impact of anxiety on cognitive processes, particularly working memory and attention. When students experience anxiety, their cognitive resources are divided between managing emotional responses and solving mathematical problems, which reduces their ability to think critically

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(Adawiya & Csíkos, 2026; Atabek et al., 2022; Sappaile, 2025). This finding is consistent with previous studies indicating that math anxiety negatively affects students' ability to engage in higher-order thinking processes. Students with high levels of anxiety tend to avoid complex problems, rely on procedural strategies, and demonstrate limited reasoning ability. Such conditions prevent them from developing critical thinking skills, which require deep analysis, evaluation, and logical reasoning. Therefore, reducing math anxiety is essential to improving students' performance in mathematics (Ika & Anita, 2014).

On the other hand, the positive relationship between cognitive flexibility and mathematical critical thinking highlights the importance of adaptive thinking in problem-solving. Cognitive flexibility enables students to approach problems from different perspectives, shift strategies when necessary, and explore alternative solutions. This adaptability is crucial in mathematics, where problems often require more than one approach and involve complex reasoning.

The results of this study are in line with previous research emphasizing that cognitive flexibility is a key component of executive function that supports higher-order thinking skills (Marzuki et al., 2024; Wang et al., 2025). Students with high cognitive flexibility are better able to regulate their thinking, integrate prior knowledge, and respond effectively to new challenges. As a result, they are more capable of demonstrating critical thinking in mathematical contexts. Furthermore, the results of the regression analysis indicate that math anxiety and cognitive flexibility simultaneously influence students' mathematical critical thinking ability. This suggests that emotional and cognitive factors interact in shaping students' learning outcomes (Atmojo et al., 2025). While math anxiety acts as a barrier, cognitive flexibility serves as a supporting factor that enhances students' ability to think critically. Students who are cognitively flexible may be able to cope with anxiety more effectively by adjusting their strategies and maintaining focus during problem-solving (Amalina & Vidákovich, 2023; Kolar & Hodnik, 2021).

This interaction highlights the need for a balanced approach in mathematics education that considers both emotional and cognitive aspects. Teachers should not only focus on delivering content but also create a learning environment that reduces anxiety and promotes flexible thinking. For example, the use of open-ended problems, collaborative learning, and multiple-solution approaches can encourage students to explore different strategies and develop confidence in their abilities. In addition, providing positive reinforcement and reducing pressure in the classroom can help minimize students' anxiety (Atabek et al., 2022; Jiang et al., 2021). When students feel safe and supported, they are more likely to engage actively in learning and take risks in problem-solving. This, in turn, can enhance their critical thinking ability.

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The findings of this study also have important implications for instructional design. Integrating teaching strategies that promote cognitive flexibility, such as problem-based learning and inquiry-based learning, can significantly improve students' critical thinking skills (Marzuki et al., 2024). These approaches encourage students to think independently, analyze problems deeply, and evaluate different solutions. Despite these contributions, this study has certain limitations. The correlational design does not allow for causal conclusions, and the sample is limited to a specific group of students. Future research should consider using experimental designs and involving a more diverse sample to provide a more comprehensive understanding of the relationships among variables.

Overall, this study confirms that math anxiety negatively affects students' mathematical critical thinking ability, while cognitive flexibility positively contributes to it. The combination of these factors provides a more complete understanding of students' learning processes in mathematics. Therefore, efforts to improve students' critical thinking should focus on reducing anxiety and enhancing cognitive flexibility simultaneously.

CONCLUSION

Based on the results of this study, it can be concluded that math anxiety and cognitive flexibility have significant relationships with students' mathematical critical thinking ability. Math anxiety shows a negative relationship, indicating that higher levels of anxiety tend to reduce students' ability to think critically in mathematics. In contrast, cognitive flexibility demonstrates a positive relationship, suggesting that students who are more adaptable in their thinking tend to have better critical thinking skills. Furthermore, the results of multiple regression analysis indicate that math anxiety and cognitive flexibility simultaneously contribute to students' mathematical critical thinking ability. This finding highlights that both emotional and cognitive factors play important roles in shaping students' performance in mathematics. Therefore, improving students' critical thinking ability requires not only enhancing cognitive skills but also addressing emotional aspects such as reducing anxiety. Overall, this study provides empirical evidence that fostering cognitive flexibility and minimizing math anxiety are essential strategies in improving students' mathematical critical thinking ability. However, this study is limited to a specific sample and research design, therefore future studies are recommended to involve broader participants and apply different research approaches to obtain more comprehensive results.

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LIMITATIONS

This study has several limitations that should be considered when interpreting the findings. First, the use of a correlational research design limits the ability to establish causal relationships among math anxiety, cognitive flexibility, and mathematical critical thinking ability. The results only indicate the strength and direction of relationships without confirming direct cause-and-effect interactions. Second, the sample of this study was limited to students from a specific educational context, which may affect the generalizability of the findings. Differences in learning environments, instructional practices, and student characteristics in other contexts may produce different results. Third, the data collection relied on self-reported instruments, particularly for measuring math anxiety and cognitive flexibility. Such instruments are potentially subject to response bias, where students may not fully reflect their actual conditions. Finally, this study focused only on two independent variables, namely math anxiety and cognitive flexibility, while other factors that may influence mathematical critical thinking ability such as motivation, self-efficacy, and teaching strategies were not examined. Therefore, future research is recommended to employ experimental or longitudinal designs, involve more diverse samples, and include additional variables to obtain a more comprehensive understanding of factors influencing students' mathematical critical thinking ability.

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