MATHEMATICAL CRITICAL THINKING SKILLS IN TERMS OF GENDER: A SYSTEMATIC LITERATURE REVIEW

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Abstract. *Critical thinking has become one of the essential skills needed in the era of globalization, especially in the context of education. This study aims to examine the trends, differences in mathematical critical thinking* skills *based on gender, and the factors influencing these differences through a systematic literature review (SLR) approach. The method follows the PRISMA guidelines, analyzing 31 articles from an initial 699 references published between 2014 and 2024. The findings indicate that female students excel in evaluation, detailed analysis, and reflection, while male students are more efficient and excel in interpretation and spatial visualization. These differences are influenced by cognitive styles, socio-cultural factors, and pedagogical approaches. The study also identifies regional and temporal trends. It concludes that gender-responsive teaching approaches can help reduce this gap and recommends evidence-based pedagogical interventions to optimize the development of students' critical thinking skills.*

Keywords: *Critical Mathematical Skills, Gender, Systematic Literature Review*

1. INTRODUCTION

The era of globalization and digital transformation has introduced complex challenges, requiring individuals to possess critical thinking skills as an essential competency. The (World Economic Forum, 2023) ranks critical thinking as one of the top three most essential skills, projecting that 87% of global companies will prioritize this skills in employee recruitment by 2025. This urgency is further emphasized by (UNESCO, 2023), which highlights that although gender parity in access to education has improved, significant gaps remain in learning outcomes, particularly in higher-order thinking skills.

The Program for International Student Assessment (PISA) 2022 reveals a substantial gender gap in complex problem-solving skills, with an average score difference of 18 points across OECD countries. These findings align with a meta-analysis by (Martinez & Singh, 2023), covering 45 studies from 2018 to 2023, which identified that 60% of research shows significant differences in critical thinking patterns based on gender. Longitudinal research by (Brown & Johnson, 2021) further demonstrated that gender-responsive pedagogical interventions could reduce critical thinking gaps by up to 40%.

In Indonesia, the dynamics of gender and critical thinking skills reveal unique complexities. Data from the Ministry of Education, Culture, Research, and Technology indicate that among 4.5 million university students, gender parity has been achieved, with 51% female and 49% male students. However, a comprehensive study by the Center for Educational Assessment (2023) involving 150,000 high school/vocational students across 34 provinces uncovered intriguing patterns: females excelled in analysis and evaluation aspects (average score 75.3 out of 100), while males outperformed in practical problem-solving (average score 73.8 out of 100).

Despite these findings, the results of individual studies do not conclusively demonstrate that mathematical critical thinking skills differ consistently across genders. There is heterogeneity among the study outcomes, with some studies potentially affected by bias. A comprehensive review appears necessary to portray mathematical critical thinking skills in terms of gender. Hence, this study employs a systematic

literature review (SLR) method to address these issues. SLR is a research method designed to comprehensively search and synthesize studies addressing specific questions, using organized, transparent, and replicable procedures at every stage. A robust SLR minimizes errors and biases, which is crucial in research synthesis since biases can emerge from original studies, publication processes, dissemination, and reviews, leading to cumulative effects. Consistent bias may overestimate or underestimate effects, resulting in incorrect conclusions. Like any well-conducted study, a systematic review follows a protocol (a detailed plan) that establishes the goals, concepts, and primary methods. Each step and decision is meticulously documented to enable readers to follow and evaluate the review's methodology.

The primary goal of this study is to analyze mathematical critical thinking skills from a gender perspective, focusing on research trends, differences in mathematical critical thinking skills across genders, and the contributing factors. An essential stage of the SLR is data collection, comprising experimental research findings on mathematical critical thinking skills based on gender. By synthesizing the results of relevant studies, this systematic review seeks to provide a clear and evidence-based understanding of gender-related differences in mathematical critical thinking skills and the factors influencing these differences.

2. LITERATURE REVIEW

2.1 Systematic Literature Review (SLR)

Systematic Literature Review (SLR) is a research method that emphasizes an explicit search process, allowing it to be replicated by other researchers. This ensures transparency by detailing the steps taken in the process. The main goal of SLR is to make literature reviews, which are often subjective, more objective to minimize researcher bias (Snyder, 2019). The purpose of conducting a review using the SLR model is to identify, examine, assess, and define each existing study related to an interesting problem theme and specific research questions (Triandini dkk., 2019) In addition to focusing on the search methodology, SLR allows for various types of data analysis, including statistical analysis, often referred to as meta-analysis. However, meta-analysis has its limitations as it can only be conducted on prior research with quantitative statistical data. Consequently, qualitative studies are often excluded from such analyses. As an alternative, qualitative analysis can be conducted through an approach known as qualitative SLR (Snyder, 2019).

2.2 Mathematics critical thinking skills

Critical thinking is an essential skill in education that supports cognitive development and improves students' academic performance (Changwong dkk., 2018). It involves proving, analyzing, evaluating, and synthesizing information to make rational decisions (Ennis, 1985; Facione, 2015). In mathematics, mathematical critical thinking is used to understand, formulate, and solve problems through logic and reasoning (Abdullah, 2013). Its indicators include interpretation, analysis, evaluation, and inference (Facione, 2015). This skill trains students to analyze, draw conclusions, and better understand concepts, making it easier to solve complex problems and improve learning outcomes (Kintoko dkk., 2022; Sulistiani & Masrukan, 2017).

2.3 Gender

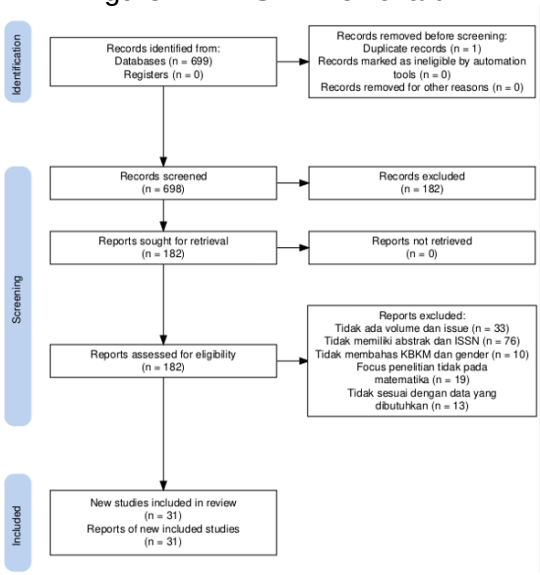
Gender, derived from *genus* (type or kind), refers to the roles, traits, and behaviors of men and women shaped by social and cultural processes (Nurjannah, 2022; Rosdiana dkk., 2023). It focuses on societal constructs rather than biological differences (Arbain, 2015; Nur A, 2020).In mathematics, gender differences influence learning styles. Girls often excel in language and precision, while boys tend to outperform in spatial reasoning and logical inference (Widyawati dkk., 2024). Despite this, girls can surpass boys in many mathematics-related fields. Boys typically

approach problem-solving with flexibility and logic, whereas girls emphasize accuracy and effective communication (Anita & Firmansyah, 2022). However, individual abilities vary, and gender should not generalize learning experiences.

3. RESEARCH METHODS

This study is a systematic literature review (SLR) aimed at synthesizing information in the field of students' mathematical critical thinking skills from a gender perspective. The research follows the PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses), which are widely adopted and developed in 2005 (Mother dkk., 2009). The PRISMA statement consists of four steps: identification, screening, eligibility, and inclusion criteria as shown in figure 1.

Figure 1. PRISMA flowchart



The data collected originates from primary research published in national and international journal articles, sourced from registered electronic databases indexed by Google Scholar, Semantic Scholar, ERIC, and direct URLs of national journals. Subsequently, all retrieved articles are extracted, and only relevant articles that meet the inclusion criteria are analyzed (Jesson dkk., 2011; Juandi & Tamur, 2022).

The research began with a literature search using *Publish or Perish 8* with keywords "Critical Mathematical Thinking," "critical mathematic," and "gender," covering articles in both Indonesian and English published between 2014-2024, yielding 699 references. After screening titles, abstracts, and full texts, 486 references were excluded for not meeting the inclusion criteria, such as being irrelevant, not indexed, or published in non-accredited journals. Of the 182 references examined further, 151 articles were excluded due to issues with methodology and content, leaving 31 articles. These articles were thematically analyzed to explore gender-based differences in mathematical critical thinking across educational levels, including factors influencing these differences.

4. RESULTS AND DISCUSSION

The research data included in this review consist of the analysis and summary of studies related to Mathematical Critical Thinking Skills in Terms of Gender from 2014 to 2024. The following are the findings on Mathematical Critical Thinking skills in Terms of Gender:

RQ1. What are the trends in mathematical critical thinking skills in terms of gender?

The main characteristics of the 31 studies on mathematical critical thinking skills in terms of gender, included in this systematic literature review, as shown in table 1:

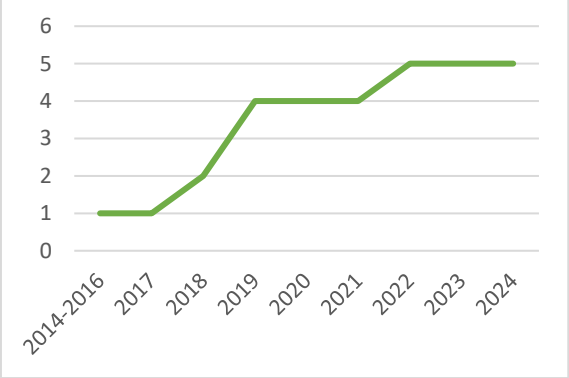
Table 1. Overview of Research Characteristics

Characteristics	Variance	Result
Year of Research	2016	1
	2017	1
	2018	2
	2019	4
	2020	4
	2021	4
	2022	5
	2023	5
	2024	5
Research Demographics	Palembang	1
	Riau	1
	Jawa barat	3
	Jawa Tengah	8
	Jawa Timur	5
	Jakarta	3
	Maluku	2
	Sulawesi Tengah	1
	Sulawesi Selatan	2
	NTT	3
	NTB	2
Education Level	Elementary School	1
	Junior High School	13
	Senior High School	7
	Vocational High School University	2
		8
Mathematics Topic	Fractions	1
	Social Arithmetic	3
	Geometry	10
	Algebra	10
	Calculus	3
	Functions	2
	Trigonometry	2

Based from the table 1, here are 31 studies that meet the inclusion criteria and will be analyzed. The results of the review are as follows:

1. Based on Publication Year

Figure 2. Data Based on Year of Research



Based on Figure 2, research on mathematical critical thinking skills shows a consistent upward trend from 2016 to 2024. In 2016 and 2017, there was only 1 study in each year, accounting for 3.2% of the total studies. The number of studies increased to 2 studies (6.5%) in 2018. From 2019 to 2021, the number of studies grew significantly, with 4 studies (12.9% per year) in each year. The peak number of studies occurred in the last three years, 2022, 2023, and 2024, each contributing 5 studies (16.1% per year). This trend reflects the growing attention to mathematical critical thinking skills in academic research, indicating an increasing focus on this topic over time.

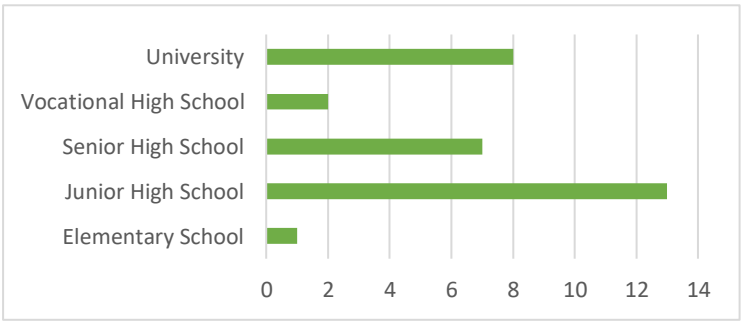
2. Based on Research Location

Figure 3. Data Based on Research Demographics

Based on Figure 3, the majority of the studies were conducted in the Java Island region, with Central Java contributing 8 studies (25.8%), East Java with 5 studies (16.1%), and West Java and Jakarta each with 3 studies (9.7%). Overall, Java Island dominates with a total of 19 studies, or 61.3% of the total studies. Other regions, such as Sumatra, including Palembang and Riau, contributed only 2 studies (6.5%). Meanwhile, the Eastern Indonesia regions, such as Maluku, NTT, NTB, and Central Sulawesi, accounted for a total of 10 studies (32.2%). This distribution indicates that research is more concentrated on Java Island, possibly reflecting the availability of better educational and research resources. However, Eastern Indonesia and Sumatra are underrepresented and require more attention to ensure greater diversity in research data.

3. Based on Education Level

Figure 4. Data Based on Education Level

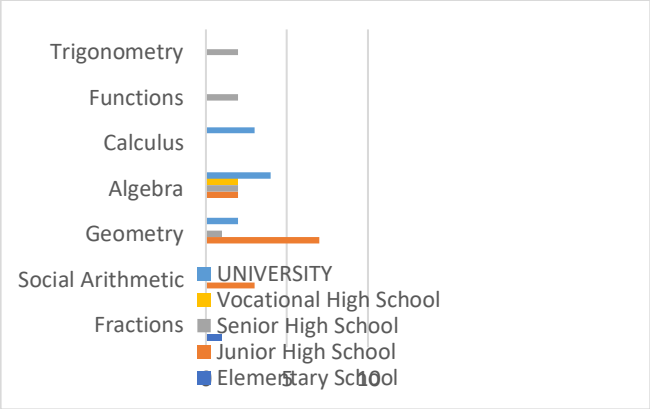


Based on Figure 4, research on mathematical critical thinking skills was most commonly conducted at the Junior High School (SMP) level, with 13 studies or 41.9% of the total studies. The University level ranked second with 8 studies (25.8%), followed by Senior High School (SMA) with 7 studies (22.6%). The Vocational High School (SMK) level contributed 2 studies (6.5%), and the Elementary School (SD) level had the fewest studies, with only 1 study (3.2%). Research focused on the SMP and University levels indicates a primary focus on adolescence and young adulthood, which are considered critical periods in the development of critical thinking skills. In the context of gender,

these levels may serve as key areas to explore potential differences in skills between males and females.

4. Based On Mathematics Topic

Figure 5. Data Based On Mathematics Topic



Based on Figure 5, the majority of research focused on Geometry and Algebra, with 10 studies each, accounting for 32.3% of the total studies. Social Arithmetic contributed 3 studies (9.7%), while Calculus, Functions, and Trigonometry each had 2 studies (6.5%). Fractions were the least studied, with only 1 study (3.2%). The dominance of Geometry and Algebra can be understood, as these subjects require visual analysis and logical thinking, which are considered relevant for evaluating critical thinking skills. In the context of gender, these subjects can also serve as a focal point for exploring whether there are performance differences between males and females in mathematical critical thinking skills.

RQ2. How do mathematical critical thinking skills differ between male and female students?

Gender differences are often a significant factor influencing how male and female students approach the critical thinking process, whether in terms of methods, priorities, or outcomes. Based on the analysis of various journals, these differences are seen in tendencies in thinking styles, the skills to meet critical thinking indicators, and how each gender faces and solves mathematical problems effectively.

1. Mathematical Critical Thinking Skills in Male Students

Male students have unique characteristics in their mathematical critical thinking Skills, which reflect a practical and efficient approach to solving problems. Male students tend to excel in certain indicators, such as problem-solving speed, logical Skills, and alternative strategies. However, they often lack attention to indicators that require deep focus on details and reflection, such as evaluation and self-regulation. Looking at the critical thinking Skills indicators, the following can be observed:

a. Interpretation

Interpretation involves the skills to understand, identify, and formulate mathematical problems. Male students tend to be quicker in identifying the key elements of a problem, but often overlook details that are deemed less relevant. Their approach is more practical and gets to the heart of the issue, making their interpretation more efficient, although sometimes less in-depth compared to female students, especially when dealing with problems that require a more complex contextual analysis.

b. Analysis

Analysis includes the skills to break down information into essential elements and identify relationships between those elements. Male students are more dominant in fast, logic-based analysis, especially for problems involving visualization or numbers. However, they tend to overlook small details that may be relevant to understanding the whole problem. Their approach is more direct and efficient, but it is less comprehensive compared to females, particularly in problems requiring in-depth analysis.

c. Evaluation

Evaluation involves the skills to assess the solution that has been reached, both in terms of accuracy and relevance to the problem. Male students are more focused on the final outcome and often neglect to evaluate the process. They tend to trust their first solution without revising it thoroughly. This approach is time-efficient but lacks the depth of evaluation conducted by females.

d. Inference

Inference involves drawing conclusions based on existing data or information. Male students are typically quicker at drawing conclusions but often do so without providing adequate explanations or supporting reasons. They tend to take a single approach to a problem without exploring alternative solutions. This suggests that males focus on efficiency in decision-making, although their approach is less exploratory compared to females.

e. Explanation

Explanation involves the skills to explain the solutions or steps taken. Male students tend to provide shorter, more direct explanations, focusing on key points. Their explanations are efficient but often lack the detail that could clarify the solution further. This approach works well for simpler problems, but is insufficient for more complex issues that require a deeper explanation.

f. Self-Regulation

Self-regulation reflects the skills to reflect on and control the problem-solving process. Male students tend to be less reflective in self-regulation. They rely more on intuition and focus on quick steps to solve problems. Revisions of their work are often minimized in favor of time efficiency, which can increase the risk of mistakes. Male students' self-regulation is less developed compared to females, especially in problems requiring a more thorough review.

Male students excel in interpretation and inference indicators. They understand problems quickly and draw logical conclusions, as found by (Cahyono dkk., 2019), where male students were more effective in utilizing mathematical data to solve problems. This was reinforced by (Yuwono dkk., 2019), who noted that male students often provide alternative solutions, albeit less thoroughly. However, in analysis, males tend to focus on efficiency without delving into all the details. They often skip important steps when checking solutions (Hidayanti dkk., 2020). Research by (Firdaus, 2024) also found that male students are faster but less meticulous in analyzing problems.

In evaluation, males are able to determine solutions but lack reflection. (Riyanto & Ishartono, 2022) noted that they excel in tactical steps but rarely evaluate the final solution. Other research by (Sartika Putri & Alyani, 2023) mentioned that male students make quick decisions but their evaluations are superficial. In explanation, males prefer visualization over verbal elaboration. (Setyawati dkk., 2020) observed that males often give brief explanations without much detail. (Hidayanti dkk., 2020) showed that they are more focused on results than steps taken. Self-regulation is a strength for male students in the high- skills category. Research by (Benyamin dkk., 2021) indicated that males dominate in fast problem-solving strategies. (Pebianto dkk., 2018) also found that they

are more confident in solving problems, even if they are less reflective about the steps taken.

2. Mathematical Critical Thinking skills in Female Students

Female students demonstrate significant advantages in mathematical critical thinking skills compared to male students on several key indicators, although these results vary based on skills levels and learning contexts. Based on the analysis of critical thinking skills indicators, the following can be observed:

a. Interpretation

On the interpretation indicator, female students excel in understanding and identifying information from mathematical problems with precision. They are able to formulate problems well and often use their own words to explain the context of the problems. This skills demonstrates that females read problems more thoroughly and understand the important elements, giving them a strong foundation for moving to the next problem-solving stages.

b. Analysis

In analysis, female students have a more structured and logical skills. They are able to identify the important elements of a problem and understand the relationships between those elements. Their approach is systematic, ensuring that all relevant steps are considered before moving to the next stage of solving the problem. This advantage makes females more detailed in evaluating information and developing problem-solving strategies.

c. Evaluation

In terms of evaluation, female students demonstrate high consistency in assessing the solutions they adopt. They carefully evaluate the problem-solving process to ensure the accuracy of the results and make revisions to steps that are deemed incorrect. This reflective approach makes females more reliable in rechecking the final results.

d. Inference

On the inference indicator, female students excel at drawing conclusions supported by data and logical reasoning. They tend to consider various alternative solutions before making a final decision. Additionally, females are more systematic in constructing arguments that support their conclusions, resulting in more comprehensive and justifiable answers.

e. Explanation

Female students excel at providing detailed, coherent, and logical explanations. They often explain the entire problem-solving process in detail, including small steps that might be overlooked. Their verbal approach, rich and structured, ensures that the solutions they present can be easily understood by others.

f. Self-Regulation

In terms of self-regulation, female students are more disciplined and consistent. They tend to review their work to ensure the accuracy and quality of their solutions. Females are also more organized in structuring their problem-solving steps, reducing the risk of errors in the final result. This self-regulation indicates deep reflection on their learning process.

Female students demonstrate significant advantages in mathematical critical thinking skills compared to male students on several key indicators, although results can vary based on skills and learning context. Female students excel in the indicators of analysis, evaluation, and explanation, demonstrating a more meticulous approach. Research by (Oktaviasari & Khotimah, 2023) notes that females are more careful in identifying key

information. (Aulia & Sutarni, 2024) show that females dominate in analysis in both high and medium categories. In evaluation, females often assess solutions more thoroughly. (Hidayanti dkk., 2020) note that females meet all the FRISCO evaluation criteria, including revisiting steps. Also found that females are more cautious in evaluating alternative solutions (Mulawakkan Firdaus, 2024).

In explanation, females provide more detailed explanations. (Setyawati dkk., 2020) found that they write every relevant piece of information from the problem. Research by (Cahyono dkk., 2019) also shows that females provide more comprehensive and structured descriptions. The interpretation indicator is also a strength for females, with the skills to understand information thoroughly. Research by (Yuwono dkk., 2019) shows that females are more careful in identifying the core of the problem. (Aulia & Sutarni, 2024) support this finding, where females excel in writing information accurately.

In inference, females draw conclusions more carefully. Research by (Benyamin dkk., 2021) states that females often review conclusions to ensure their accuracy. (Mulawakkan Firdaus, 2024) also mentions that they are more reflective than males. On the self-regulation indicator, females are consistent in reflection and rechecking. Note that females evaluate their strategies more often than males (Hidayanti dkk., 2020). Research by (Liunokas dkk., 2023) also found that they are more systematic in reviewing their steps.

RQ3. Factors Influencing the Gender Differences in Mathematical Critical Thinking Skills

The differences in mathematical critical thinking skills between male and female students are influenced by several interacting factors, including cognitive styles, biological and cognitive factors, self-confidence, motivation, socio-cultural norms, learning strategies, self-regulation, and external influences. Each of these factors contributes to distinct thinking patterns and approaches to solving mathematical problems.

1. Cognitive Style

Cognitive style significantly affects students' critical thinking skills in mathematics. (Widyastuti & Jusra, 2022) found that male students with an impulsive cognitive style tend to complete tasks faster but often overlook details. (Fadilah & Winarso, 2021) observed that female students with a reflective cognitive style are superior in fulfilling all critical thinking indicators. Added that females tend to be more systematic in understanding mathematical problems, supported by their more field-independent cognitive style (Sugiarti dkk., 2023). the reflective style of females better supports problem-solving based on in-depth analysis compared to males (Yuwono dkk., 2019).

2. Biological and Cognitive Factors

Biological and cognitive differences also influence critical thinking patterns in students. Female brains are more dominant in verbal skills, while male brains excel in visual-spatial skills (Wahyuningtiyas dkk., 2024). Females are better at verbal and systematic analysis compared to males, who tend to focus on final outcomes (Aulia & Sutarni, 2024). Males are quicker in understanding abstract concepts, while females are more meticulous in evaluating solutions (Sari dkk., 2021). Athifah & Khusna (2022) added that the meticulousness of females leads them to frequently fulfill the evaluation and analysis indicators.

3. Self-Confidence and Motivation

Self-confidence is a key factor in critical thinking skills. Athifah & Khusna (2022) found that females with high self-confidence tend to be more active in critical thinking. Yuwono et al.(2019) added that females' motivation to solve problems correctly is higher, even though it may take more time. Setyawati et al., (2020) noted that males with low self-

confidence often make mistakes during the critical thinking process. Firdaus (2024) observed that male students often neglect to reflect on their work due to overconfidence.

4. Socio-Cultural Environment

Gender socialization shapes students' approaches to critical thinking. Oktaviasari & Khotimah (2023) found that females are encouraged to be more meticulous, while males are taught to complete tasks quickly. Riyanto & Ishartono (2022) showed that the stereotype that females must be perfect creates pressure to solve problems deeply. Hidayanti et al (2020) noted that teacher biases in giving more attention to male students in technical tasks can reinforce gender differences. Sugiarti et al (2023) added that social expectations for males to excel in mathematics often influence their learning motivation.

5. Learning Strategies and Approaches

Learning methods also influence critical thinking skills based on gender. Firdaus (2024) observed that females respond better to structured learning, while males are more effective with exploration-based methods. Yuwono et al.(2019) found that collaborative approaches helped females improve their analytical skills. Setyawati et al (2020) pointed out that teachers often give more attention to males in logical aspects, which benefits them in problem-solving. Pebianto et al (2018) added that the procedural learning methods commonly used in schools do not fully support the development of critical thinking skills in females.

6. Role of Emotions and Self-Regulation

Females tend to be more skilled in self-regulation, which helps them evaluate solutions in more detail. Hidayanti et al (2020) found that females more often recheck their solutions, while males focus on the final result without deep reflection. On the other hand, male students are more responsive in high-stress situations, enabling them to solve problems quickly, although they often do so with less accuracy.

7. External Influences (Teachers and Teaching Methods)

Teachers play a crucial role in shaping critical thinking skills. Sugiarti et al (2023) mentioned that teachers tend to give more attention to males in logical aspects, while female students are encouraged to think more systematically. Additionally, Setyawati et al (2020) noted that more collaborative and discussion-based teaching methods tend to enhance female students' critical thinking skills.

In conclusion, gender differences in mathematical critical thinking are influenced by a combination of cognitive, biological, social, emotional, and educational factors. These factors interact to shape the distinct approaches that male and female students adopt in solving mathematical problems. Understanding these influences can help in designing more effective learning environments and strategies that cater to the needs of both genders.

CONCLUSION

This study successfully synthesizes important findings related to gender-based differences in mathematical critical thinking abilities. Female students demonstrate superiority in accuracy, evaluation, and self-regulation, while male students are faster and more efficient in solving problems but tend to overlook details and reflection. These differences are particularly evident in mathematical topics such as geometry and algebra, where male students rely more on spatial visualization, while female students use a more systematic procedural approach. Factors such as cognitive styles, social norms, and educational approaches have a significant impact on these differences. Females with a reflective learning style excel in analysis, while impulsive males are more

efficient but prone to errors. Social norms and gender stereotypes also influence motivation and learning patterns, creating differences in learning outcomes.

This study also reveals temporal and regional trends, with the majority of studies concentrated in Java, particularly in East and Central Java. Interest in this topic has significantly increased in recent years, with a focus on junior high school levels, as cognitive development at this age allows for clearer observation of gender differences. Topics such as geometry and algebra have been the main focus, reflecting the importance of these fields in exploring gender-based cognitive strategies. The results of this study have significant implications for educational practices. Emphasis on reflective practices could also help improve accuracy and critical evaluation for both gender groups. Educators need to pay attention to social norms and cognitive styles that influence students' critical thinking abilities and adjust teaching methods to encourage inclusivity. However, this study has limitations, including reliance on the quality and scope of previous studies and a lack of exploration of external factors such as family support or socio-economic conditions. Further research is needed to investigate additional factors influencing critical thinking abilities in various contexts, including interventions to address the identified gaps.

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