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Meta-Synthesis: The Influence of Mathematical Anxiety on Critical Mathematical Thinking

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ABSTRACT

The purpose of this research is to describe the influence of mathematics anxiety on students' mathematical critical thinking abilities. The research method used in this study was meta-synthesis, a qualitative systematic review that analyzed four relevant articles with the research title. The steps involved formulating the research problem, followed by searching for previous relevant research with the same title and then analyzing it in depth. The data collection technique used non-tests by examining previous research with similar problems to obtain results and conclusions. The study surveyed 4 articles, consisting of 3 national journal articles and one international journal article. The analysis of the four related articles resulted in the conclusion that math anxiety has a negative impact on students' mathematical critical thinking abilities.

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INTRODUCTION

Education plays a crucial role in life. The evolution of education is characterized by changes in the education system, alterations in learning and teaching methods, curriculum modifications, student development, learning styles, educational tools, facilities, and the competencies of graduates throughout time (Risdianto, 2019). Mathematics is one way to develop student's abilities and skills (Suhendra, 2017). Therefore, mathematics is one of the subjects that plays a vital role at every level of education. Based on Permendikbud Number 22 of 2016, one of the objectives of mathematics learning is to solve mathematical problems, including the ability to understand issues, devise models, solve models, and provide accurate solutions. Mathematics learning aims to focus on developing attitudes and skills, not only on developing mathematical knowledge. The "Merdeka Belajar" program is for the Minister of

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Education and Culture. One of the Programs, "Merdeka Belajar," is the National Examination (UN) is replaced with the Minimum Competency Assessment (AKM) and Character Survey (Nurhikmah, Hidayah & Kadarwati, 2021).

The Minimum Competency Assessment prepares students to face the challenges of the 21st century in attaining various skills (Rafiqoh, 2020). These skills refer to four competencies abbreviated as 4C, which include critical thinking and problem-solving (students can engage in critical thinking and solve problems), creativity (students demonstrate creativity), communication skills (students possess communication abilities), and the ability to collaborate effectively (students can work together) (Anton & Trisoni, 2022; Rahmania et al., 2023). Critical thinking skills are highlighted as a crucial competency that supports the Minimum Competency Assessment (AKM). By 21st-century learning, students will be required to acquire competencies in critical thinking, creative thinking, communication, and collaboration (Tohir *et al*., 2018).

Critical mathematical thinking is among the essential abilities to be acquired while learning mathematics (Sutini et al., 2017). The skill of critical thinking is an attempt to gain more profound and more complex knowledge that applies to each individual (Septiana *et al*., 2019). Critical thinking also provides skills to prepare students to be competitive in the 21st century (Dewanthikumala et al., 2021; Ismail et al., 2018; Putri et al., 2020). However, students' critical thinking abilities are still low and moderate (Agoestanto et al., 2016; Dewanthikumala et al., 2021; Rochmad et al., 2018). The essential indicators of thinking used in this research are from Perkins & Murphy (2006): clarification, assessment, inference, and strategies.

Based on the results of a test on mathematical critical thinking skills conducted by researchers, it was found that 68.97% of students in class VII A have difficulty solving problems that require critical thinking. The lack of mathematical critical thinking skills among students can be demonstrated by the fact that they attempt to write down the solution directly to the strategic stage but are unable to clarify, assess, and conclude, resulting in incorrect answers. Some students have written down the clarification stage but must be moved to the strategic stage, resulting in incorrect answers. Therefore, most students still need to meet the indicators of clarification, assessment, conclusion, and strategy. Based on the results of interviews and preliminary studies at SMP Negeri 39 Semarang, it was also found that students' mathematical critical thinking skills are relatively low. Hence, the essential mathematical skills of thinking require significant attention in education. Critical thinking

skills as cognitive abilities are also related to affective abilities.

One of the affective abilities that triggers students' low critical mathematical thinking abilities is high mathematics anxiety. Mathematics anxiety is a person's feelings in the form of fear, tension, or anxiety when facing mathematics problems or when learning mathematics, which causes various symptoms (Hadi et al., 2020). The findings of Rohmah & Mashuri (2021) state that mathematics anxiety affects students' critical thinking. Students who are less interested in mathematics are not aware of their mathematics skills and consider mathematics a complex and challenging subject, which causes anxiety (Justicia-Galiano et al., 2017). Students experiencing math anxiety tend to have low perceptions of their mathematical skills and perform poorly in mathematical reasoning tasks, processing numerical information, and evaluative situations related to mathematics (M. H. Ashcraft & Moore, 2009; Paechter et al., 2017; Shi & Liu, 2016). The math anxiety indicators in this study are from Cooke et al. (2011), namely Somatic, Cognitive, Attitude, and Mathematical knowledge/understanding. According to the observations made, it was noted that the level of math-related anxiety among students at SMP Negeri 39 Semarang remained quite elevated. This was evident when students were given the chance to solve problems on the blackboard in front of the class, as they displayed signs of restlessness and nervousness while approaching the task.

This study adds to previous research on the relationship between mathematical critical thinking abilities and mathematics anxiety. The focus of meta-synthesis is answering why and how questions and relating to humans and their behavior (Chrastina, 2018). The research question examined in this study describes the influence of mathematics anxiety on students' mathematical critical thinking abilities. This research aims to explain how mathematics anxiety impacts students' abilities in mathematical critical thinking. Previous explanations highlight the importance of conducting a comprehensive meta-synthesis regarding the influence of mathematics anxiety on students' mathematical critical thinking abilities. This is necessary for evaluating implementation and gaining a clearer understanding of overall trends.

RESEARCH METHOD

The method employed in this research is meta-synthesis. Meta-synthesis can be defined as a qualitative systematic review method. Meta-synthesis has two approaches: meta-aggregation and meta-ethnography (Lewin, 2008). In this study, the approach used is meta-

aggregation, which involves summarizing various validated research findings that have been conducted previously (Walsh D, 2005). Meta-aggregation divides research topics into specific themes to create an analytical framework (conceptual framework). Relevant research articles on this topic were sought, evaluated, and summarized. In the meta-aggregation approach, the synthesis outcomes comprise various research findings aligned with pertinent themes (Siswanto, 2010). Meta-synthesis can be an effort to understand multiple advances in research that are increasingly developing rapidly (Krisnawwati et al., 2022). In other words, meta-synthesis aims to summarize various research results found previously.

The first thing to do is choose a planned topic. Then, the topic is elaborated on into specific themes, followed by looking for articles relevant to the desired theme and comparing and summarizing one article with another. The synthesized outcomes in this study encompass collections of diverse research findings categorized by pertinent themes. The study that the researcher will conduct aims to explore how mathematics anxiety influences students' mathematical critical thinking abilities. Research data was obtained from scientific journal searches on Google Scholar and Scopus using the keywords "Mathematics Anxiety" and "Critical Thinking Ability" and qualitative research methods. In this study, four articles that were relevant to the research title were analyzed. After obtaining several pertinent journals related to the research title, these journals were analyzed by seeking essential sections, namely the significance of critical thinking skills, the correlation between mathematics anxiety and critical mathematical thinking abilities, and the obtained research results.

This research produces a qualitative analysis, which is described according to the important components in the meta-synthesis. According to (Francis & Baldesari., 2006), the steps for meta-synthesis are as follows.

1. Formulate the research question (formulating the review equation); determining the research question involves understanding the description of how mathematics anxiety influences mathematical critical thinking abilities.
2. Develop a protocol (conducting systematic literature research), looking for articles related to mathematics anxiety and critical thinking skills from 2018-2023.
3. Screening and selecting appropriate research articles (screening and selecting appropriate research articles): the articles that have been obtained are chosen by considering the content of the articles using qualitative methods, including mathematical critical thinking skills and mathematical anxiety.

4. We are analyzing and synthesizing qualitative findings, analyzing and synthesizing previously selected articles.
5. Implementing quality control (maintaining quality control), ensuring that the articles produced meet the requirements to be considered articles using the qualitative meta-synthesis method.
6. I am summarizing and making conclusions from the results and discussions that have been prepared.

RESULTS AND DISCUSSION

The analysis of the four selected articles will be described individually according to the components to be analyzed in each journal. The essential components that will be analyzed in each journal are the research objectives, methods used, and results obtained. Journal data is processed according to meta-synthesis steps. The following is data from 4 articles that have been analyzed.

Table 1. Details of the Articles Analyzed

No	Title	Author, Year	Journal/Proceedings
1	Berpikir Kritis Dalam Pemecahan Masalah Open-Ended Ditinjau dari Kecemasan Matematika	(Jannah et al., 2020)	Transformasi : Jurnal Pendidikan Matematika dan Matematika
2	Profil Berpikir Kritis Siswa dalam Menyelesaikan Soal Higher Order Thinking Skills Ditinjau dari Tingkat Kecemasan Matematika	(Makrufah, 2022)	MATHEdunesa : Jurnal Ilmiah Pendidikan Matematika
3	Profil Kemampuan Berpikir Kritis Ditinjau dari Kecemasan Matematika Siswa SMK	(Alvariz & Miatun, 2023)	Jurnal Penelitian dan Pembelajaran Matematika
4	Analysis of critical thinking ability of VII grade students based on the mathematical anxiety level through learning cycle 7E model	(Widyaningsih et al., 2018)	Journal of Physics: Conference Series

The first journal "Berpikir Kritis Dalam Pemecahan Masalah Open-Ended Ditinjau dari Kecemasan Matematika". The open-ended mathematical problem-solving test instrument takes the form of descriptions related to the volume of cubes and blocks. The data analysis process commences with examining the mathematics anxiety questionnaire responses, followed by the analysis of test data related to solving open-ended mathematical problems, which serves as a guide in formulating interview questions. The final data analysis involves the interview outcomes, encompassing data reduction, data presentation, and data drawing or verification. Here is a summary of the research findings that have been analyzed based on critical thinking criteria in the context of mathematics anxiety.

Table 2. Problem-Solving Results Based on Critical Thinking Criteria

No	Critical Thinking Criteria	Critical Thinking Indicators	High Mathematics Anxiety Subjects	Moderate Mathematics Anxiety Subjects	Low Mathematics Anxiety Subjects
1	Interpretation	Categorization	✓	✓	✓
		Decode	✓	✓	✓
		Clarification	✓	✓	✓
2	Analysis	Identify Arguments	✓	✓	✓
		Argument Analysis	✓	✓	✓
	Evaluation	Argument Assessment	✓	✓	✓
	Inference	Alternative Thinking	-	-	✓
		Drawing Conclusions	-	-	✓
		Problem-solving	-	-	✓
3	Explanation	Problem Description	✓	✓	✓
		Justification of Procedures	✓	✓	✓
		Argument Articulation	✓	✓	✓
4	Self Regulation	Self-assessment	-	✓	✓
		Self-Correcting	-	✓	✓

The second journal "Profil Berpikir Kritis Siswa dalam Menyelesaikan Soal Higher Order Thinking Skills Ditinjau dari Tingkat Kecemasan Matematika". The research findings indicate that students with low mathematics anxiety demonstrate a critical thinking profile when solving HOTS problems at the analyzing (C4), evaluating (C5), and creating (C6) levels by focusing on what they know and what is asked in the problem using their language. Conversely, students with high mathematics anxiety exhibit a critical thinking profile when solving HOTS problems at the analyzing (C4) level by focusing on what they know and what is asked in the problem using their language. For students with high mathematics anxiety solving HOTS problems at the evaluating (C5) level, they focus on what is known and what is asked in the problem using language adopted from the question.

The third journal "Profil Kemampuan Berpikir Kritis Ditinjau dari Kecemasan Matematika Siswa SMK". The research data includes the outcomes of critical thinking ability tests and interview records. Subject interview data was transcribed and presented to assess the student's critical thinking abilities. Low levels of anxiety can solve problems effectively so that when given a mathematics problem, students are still able to analyze the answer to draw conclusions that are not correct and can clarify wrong answers. To solve mathematics problems in the moderate anxiety category, they are still able to explain a statement correctly/accurately; however, they are less able to make conclusions using the strategy that has been chosen; in terms of critical thinking abilities to solve problems, those categorized with high anxiety levels may struggle to contemplate other aspects or elements. So, when given a math problem, students cannot solve the problem.

The fourth journal, "Analysis of critical thinking ability of VII grade students based on the mathematical anxiety level through learning cycle 7E model". The qualitative findings reveal the progression of students' critical thinking phases corresponding to their levels of mathematics anxiety. At the clarification stage, subjects with high, moderate, and low levels of mathematics anxiety could state the known information about the problem and identify the requested information concerning the issue. Subjects with lower levels of mathematics anxiety could mention related details. In the assessment stage, subjects with lower mathematics anxiety could mention concepts and ideas for problem-solving, connect problem information with concepts and ideas for resolution, and evaluate the produced information. In the inference stage, subjects across different levels of mathematics anxiety could mention problem-solving concepts and ideas. Lower levels of mathematics anxiety were linked to subjects effectively connecting problem information with concepts and ideas for solving problems and evaluating the produced information. In the strategy phase, lower levels of mathematics anxiety were associated with subjects effectively explaining sequential and accurate problem-solving based on the mentioned steps.

Based on the findings from the four articles, several similarities and differences can be identified, offering potential discoveries. Firstly, a common aspect across all articles is the discussion of critical thinking abilities and mathematics anxiety. The results from these articles collectively indicate that mathematics anxiety influences vital thinking skills. Hence, the following description can be deduced regarding the impact of mathematics anxiety on critical thinking abilities.

Description of High Mathematics Anxiety on Mathematical Critical Thinking Ability

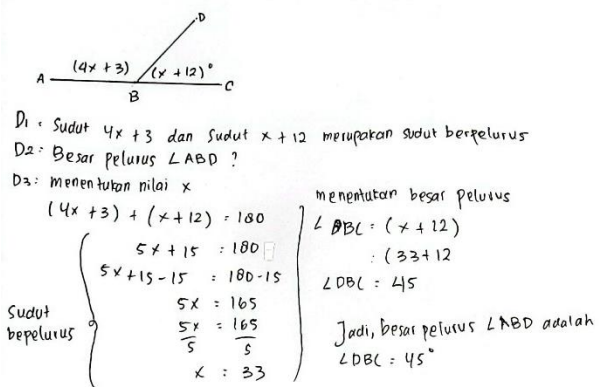

Figure 1. Students Work of High Mathematics Anxiety

At the clarification stage, subjects experiencing high levels of anxiety can state the known information and mention the information required concerning the presented

mathematical problem. However, they need help to mention any other related information. In the assessment phase, subjects tend to articulate concepts and ideas for problem-solving but haven't connected problem information with concepts and ideas for resolution nor evaluated the generated data. Moving to the conclusion stage, subjects have yet to identify the source of concepts and ideas for problem-solving, recognize their connections, or specify a sequential problem-solving procedure. Lastly, in the strategy stage, subjects need to be capable of sequentially and accurately explaining the problem-solving process based on the provided steps.

Description of Moderate Mathematics Anxiety on Mathematical Critical Thinking Ability

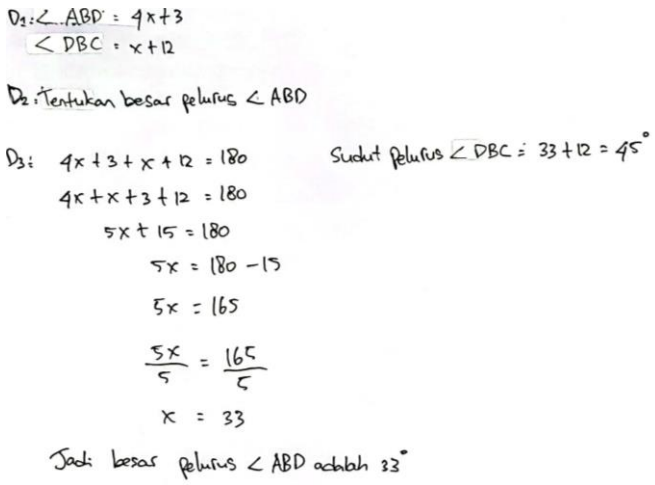

Figure 2. Students Work of Moderate Mathematics Anxiety

At the clarification stage, subjects experiencing moderate anxiety are capable of stating the known information, identifying the information required, and mentioning other related information. In the assessment stage, subjects tend to articulate concepts and ideas for problem-solving, connect problem information with concepts and ideas for resolution, and evaluate the generated data. At the conclusion stage, subjects can identify the origin of problem-solving concepts and ideas, recognize their connections, and specify a sequential problem-solving procedure. Lastly, subjects effectively explain the sequential and accurate problem-solving process based on the provided steps in the strategy phase.

Description of Low Mathematics Anxiety on Mathematical Critical Thinking Ability

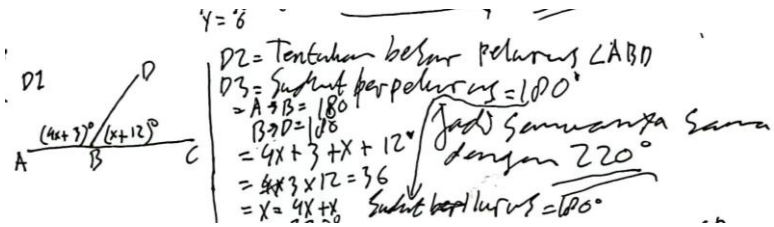

Figure 3. Students Work of Low Mathematics Anxiety

At the clarification stage, subjects with low anxiety levels are proficient in stating known information, identifying the required information, and mentioning other relevant information. In the assessment phase, these subjects can cite concepts and ideas for problem-solving, connect problem information with concepts and ideas for resolution, and evaluate the generated data. As for the conclusion stage, these subjects are adept at indicating the origin of problem-solving concepts and ideas, recognizing their connections, and specifying a sequential problem-solving procedure. Lastly, in the strategy phase, these subjects are proficient in sequentially and accurately explaining the problem-solving process based on the mentioned steps.

The results of these four articles indicate that math anxiety has a significant impact on students' critical thinking abilities, aligning with previous research. Earlier studies have shown that math anxiety can disrupt students' cognitive processes, reducing their ability to solve problems effectively and think critically. For instance, research by Mark H. Ashcraft & Kirk (2001) states that math anxiety can affect students' cognitive performance by reducing their working memory capacity, which is essential in critical thinking and problem-solving processes. Dowker *et al.* (2016) research also found that math anxiety can diminish students' ability to understand and apply more complex mathematical concepts. Therefore, the findings of this study, which show that students with low anxiety have better critical thinking skills compared to students with high anxiety, are consistent with the existing literature. However, there are some differences compared to previous research. This study found that students with moderate anxiety are still able to connect problem information with concepts and ideas for solutions and evaluate the resulting data. This contrasts with some studies that indicate even moderate levels of anxiety can disrupt cognitive processes. These differences may be due to variations in teaching methods, types of math tasks, or individual differences among the students studied.

The differences were subsequently identified after summarizing the similarities among the four articles. One article introduces a new variable, Higher Order Thinking Skills (HOTS). This research utilized HOTS questions as a reference to describe students' critical thinking processes. The HOTS questions consisted of analysis level (C4), evaluation level (C5), and creation level (C6). The findings revealed that students with low mathematics anxiety demonstrated all criteria for critical thinking indicators in solving analysis, evaluation, and creation-level HOTS questions. In contrast, students with high mathematics anxiety only

demonstrated all criteria in solving analysis-level HOTS questions. For other researchers and readers, particularly educators, it's advisable to design instructional practices that offer diverse HOTS exercises to further foster students' critical thinking skills.

One interesting aspect of this research is the introduction of a new variable, namely Higher Order Thinking Skills (HOTS). This study used HOTS questions as a reference to describe students' critical thinking processes, involving levels of analysis (C4), evaluation (C5), and creation (C6). The findings indicate that students with low math anxiety demonstrated all the criteria for critical thinking indicators in answering HOTS questions at the levels of analysis, evaluation, and creation. In contrast, students with high math anxiety only met all the criteria in answering HOTS questions at the analysis level. This research is also intriguing because it shows that students with moderate math anxiety have a fairly good critical thinking profile, although not as good as students with low anxiety. This suggests that there is potential for interventions to help students with moderate anxiety achieve higher critical thinking abilities. Moreover, the study highlights the importance of instructional design that includes HOTS exercises to develop students' critical thinking skills. By providing a variety of exercises in HOTS, educators can help students further develop their critical thinking abilities, regardless of their level of math anxiety. This is an important practical implication for educators in designing effective curricula and teaching strategies.

CONCLUSION AND SUGGESTION

Based on the explanations provided for the description of mathematics anxiety at different levels, the conclusion drawn is that mathematics anxiety has a detrimental impact on students' mathematical critical thinking abilities. At the clarification stage, subjects with high, medium, and low mathematics anxiety were able to state information that was known about the problem and were able to state information that was known to be the problem. Can you provide the information requested regarding the problem? The lower the level of mathematical anxiety, the more the subject can mention other related information. At the assessment stage, the lower the level of mathematical anxiety, the subject can mention concepts and ideas to solve problems, connect problem information with concepts and ideas to solve problems and assess the information created. At the inference stage, subjects with low, medium, and high levels of mathematical anxiety could name concepts and ideas to solve problems. The lower the level of mathematical anxiety, the more the subject can connect problem information with concepts and ideas to solve the problem and assess the

information created. In the strategy phase, the lower the level of mathematical anxiety, the more proficient the subjects are in systematically and accurately explaining the problem-solving process based on the mentioned steps.

This research recommends continuing to increase the number of articles analyzed. The more articles there will be, the more results will be analyzed. The more significant number of articles analyzed increases the possibility of obtaining new findings from analyzing all related articles. For researchers interested in the same variables as this research, it is recommended to add several variables related to critical thinking abilities and mathematics anxiety, such as other affective abilities, one of which is self-efficacy, or can be linked to cognitive psychology.

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