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Analysis of mathematical critical thinking skills on the Pythagorean theorem based on self-confidence and gender

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Abstract
This study aims to analyze and describe students' mathematical critical thinking skills in terms of self-confidence and gender. This research employed a qualitative descriptive approach. The study was conducted in class VIII-H of SMPN 17 Malang, involving a total of 31 students. From this class, 12 students were selected as research subjects based on gender to participate in a written test. The data collection techniques included questionnaires, written tests, interviews, and field notes. Data analysis was conducted based on the results of the self-confidence questionnaire, written test results, and interviews, which referred to critical thinking indicators. To ensure data validity, techniques such as prolonged engagement, triangulation, peer discussion, and member checking were employed. Based on the results and discussion, it can be concluded that: (1) the research subjects were better able to fulfill the evaluation indicators, (2) female students demonstrated higher self-confidence than male students, (3) higher levels of self-confidence, both in the high and low categories, were associated with higher written test results, and (4) female students tended to meet more critical thinking indicators.

Keywords: Critical thinking skills, Gender, Self-confidence

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Introduction

Learning is the process of teaching and learning activities involving students and teachers. In the learning process, especially in mathematics, teachers try to encourage students to construct their own knowledge through a process that goes beyond simply conveying information. Additionally, students interact with teachers and one another (Siregar & Andhany, 2021). This can lead to patterns of student activity emerging naturally. Furthermore, mathematics teaching involves the development of skills in addition to ideas and facts (Purba et al., 2022). There are many skills that must be possessed to support the learning process so that students can achieve maximum learning outcomes and support their intelligence (Ginting & Syahputra, 2024). By learning mathematics, students can apply skills, one of which is thinking skills, making it easier to understand a concept. Mathematical thinking is adopted as a comprehensive approach to developing the process of solving mathematical problems (Singh

et al., 2024). Additionally, mathematical problem-solving requires students to think more deeply and critically, as mathematics has varying levels of difficulty (Insani, 2020). Mathematics education is essential because it is driven to be part of solving real-world mathematical problems based on the needs of modern society (Popović et al., 2022). According to Simbolon et al. (2023), "most people consider this subject to be a guide for determining what success in life is.". Based on this, students must have critical thinking skills in solving problems.

Critical thinking is a skill that is embedded in a person that is cognitive, logical, and effective in gathering information to obtain valid decisions (Tohir et al., 2021). Critical thinking skills also enable one to answer mathematical problems (Wilujeng & Sudihartinih, 2021). Critical thinking skills in the implementation of mathematics involve the ability to analyze, evaluate, and apply appropriate problem-solving strategies (Safitri et al., 2024). Critical thinking skills should be honed and practiced during learning through interaction with teachers so that excellent education can be achieved. This ability is recommended because it can direct students' attention to problems, helping them identify and understand the underlying issues effectively. Inductive reasoning ability is necessary for critical thinking, and this ability includes the capacity to identify relationships, evaluate issues, establish cause and effect, draw conclusions, and provide context for relevant material (Hardika, 2020). To strengthen one's capacity for critical thinking, it is necessary to follow the guidelines outlined in Permendikbudristek No. 12 of 2024 concerning the Curriculum at the education level, which explains in detail the implementation of the Independent Curriculum for schools in Indonesia, including provisions for preserving the 2013 Curriculum within the Independent Curriculum. One curriculum that can provide stability and focus on core subjects is the Independent Curriculum or Merdeka Curriculum. In this curriculum, critical thinking is one of the skills that should be developed by students with a Pancasila-based personality.

Based on the researcher's observations in the field, the researcher found several contradictions demonstrated by students in terms of their mathematical critical thinking skills. One of these was questioning the origin of a mathematical formula in a particular subject. However, only one or two students thought critically and questioned the formula. On the other hand, many students simply accepted what the teacher said without questioning its origin. Currently, students' critical thinking skills have not yet reached their full potential. This can be seen from their learning patterns, where many students apply a formula memorization pattern and are still accustomed to using the same problem-solving methods as those provided by educators. Critical thinking is not something that happens unexpectedly. It is very important to hone this thinking skill from elementary school onwards. On the other hand, students' critical thinking skills are influenced by several surrounding factors.

There is no doubt that internal and environmental influences affect a person's capacity for mathematical critical thinking. Internal elements that can have an impact include internal factors such as self-confidence. Self-confidence is a factor where an individual can believe in themselves and their ability to succeed (Lintuman & Wijaya, 2020). It is very important for people to develop self-confidence, especially for children learning mathematics (Rahmah et al., 2024). When working on problems, confident students can overcome obstacles and are not afraid to make mistakes in their solutions. According to Khoirunnisa & Malasari (2021), students' critical thinking skills improve as their self-confidence grows. However, it is not only

self-confidence that influences the improvement of cognitive abilities related to learning, but also gender. Several variables that can influence low critical thinking skills in mathematics are gender (Sari et al., 2022). According to Ismiati et al. (2021), "gender factors also influence mathematical critical thinking skills." Kusharyadi & Juandi (2023) stated in a survey conducted on secondary data regarding the results of basic research on the mathematical abilities of students of different genders. This statement is reinforced by Riyanto & Ishartono (2022), who stated that there are differences in mathematics learning when viewed from the perspective of gender. Meanwhile, in terms of solving mathematical problems, women and men are very different. According to Hadi et al. (2020), in Indonesia, lessons that incorporate critical thinking skills are still scarce. This also results in students not being accustomed to and struggling with critical-thinking problems, as they are not taught from elementary school.

In line with the final results of several previous studies, existing research on mathematical critical thinking skills has only focused on the aspect of self-confidence. This study is novel in terms of the indicators used, namely critical thinking indicators (Facione, 2015). On the other hand, this study also has a novelty in terms of gender. The advantage of this study is to determine how gender gaps appear in relation to core mathematical competence. Based on the above issues, the purpose of this study is to examine and explain critical thinking in solving problems in Pythagorean questions in terms of self-confidence and gender.

Methods

The research methodology used in this study is descriptive qualitative. Qualitative research is a method that provides qualitative data to aid in the analysis and interpretation of social phenomena. Meanwhile, descriptive research seeks to characterize a population, situation, or phenomenon accurately and methodically before analysis and conclusion-drawing (Sugiyono, 2019). The purpose of this study is to analyze and categorize students' critical thinking skills in terms of self-confidence and gender. This research study was conducted at SMPN 17 Malang. Data sources were obtained from students in class VIII-H. The criteria for selecting this school as the research site were based on survey results and interviews with several mathematics teachers in Malang City, indicating that SMPN 17 Malang is one of the schools that meets the conditions of the issues raised in the title. Some of these issues related to critical thinking include students tending to memorize formulas and materials rather than understanding concepts, as well as gender differences influencing the understanding of these concepts.

The data in this study were collected using a self-confidence questionnaire from 31 students in the research class. The questionnaire in this study was adapted from Bandura et al. (1999) and included the following aspects: (1) believing in oneself; (2) demonstrating independence in decision-making; (3) demonstrating optimism, calmness, and never giving up; and (4) demonstrating the ability to adapt and socialize. The questionnaire results were then grouped into three categories: low, moderate, and high. Two females and two males were selected from each category to serve as research subjects for the tests and interviews.

Based on the above categorization of subjects, 12 research subjects were selected to take a critical thinking written test, and the test results will be reinforced with interviews. The subjects above were selected based on the highest and lowest scores of 2 females and 2 males

in each category. In this study, the researcher used a written test instrument for critical thinking questions, consisting of 3 questions for the 12 subjects selected in the questionnaire. However, in this article, the researcher only selected one student from one question to describe each critical thinking indicator. The indicators outlined by Facione (2015) in Table 1 were used as guidelines for the written critical thinking test in this study. The written test questions are presented in Table 2.

Table 1. Mathematical Critical Thinking Indicators

Indicators	Indicators Description
Interpretation	Students are able to determine concepts in solving problems by writing down what is known and what is asked.
Analysis	Students are able to formulate solutions to problems by writing down mathematical models.
Inference	Students are able to identify and conclude the appropriate formulas/strategies used.
Evaluation	Students are able to solve problems using formulas/strategies and calculate accurately, and can correctly conclude the final answer.
Self regulation	Students are able to accurately recheck their work and answers to questions.

(Facione, 2015)

Table 2. Critical Thinking Test Questions

No	Questions
1	Nadya leaves her house and rides her bike to school. She rides her bike westward for x km until she reaches a T-junction. After the T-junction, Nadya must turn south for 5.6 km to reach her school. If the shortest distance between Nadya's house and her school is 10.6 km, how far is Nadya's house from the T-junction?
2	Andre saw a ladder leaning against a wall. The top and bottom ends of the ladder are A and B, respectively. It is known that A is 160 cm from the wall and the length of the ladder is 200 cm. How high is the wall in meters?
3	My uncle has a diamond-shaped corn field with diagonals measuring 42 meters and 56 meters. The field is surrounded by wire fencing five times around the perimeter. If the price of 1 meter of wire is Rp. 7,500.00, calculate the total amount of wire and the cost required by my uncle!

Data analysis in this study includes data reduction, data presentation, and conclusion drawing. In data reduction, the author summarized the students' self-confidence data from the questionnaire results and then categorized them. After categorization, the author selected students to be subjects in the study to take tests and answer interviews.

The second analysis is data presentation. In this stage, the author presents the test results that will be used as reference material for the interviews and presents the interview results. Next is the drawing of conclusions, which involves reviewing and checking the validity of the data to draw conclusions. The researcher then presents the criteria for the questionnaire scoring results in Table 3 and the criteria for the critical thinking test scores in Table 4, which are used as a reference for selecting research subjects.

Table 3. Criteria for Self-Confidence Questionnaire Score Results

Number	Questionnaire Score	Category
1	$60 < x \leq 80$	High
2	$40 < x \leq 60$	Medium
3	$20 < x \leq 40$	Low

Adapted from research by Ramadani et al. (2023)

Table 4. Criteria for Critical Thinking Test Scores

Number	Test Scores	Category
1	$40 < x \leq 60$	High
2	$20 < x \leq 40$	Medium
3	$0 < x \leq 20$	Low

Adapted from research by Rosliani & Munandar (2022)

The next step in data analysis after reduction is to present the data obtained, which will then be analyzed again to draw conclusions in the form of findings that can answer the research questions. The researcher can then summarize and describe the conclusions related to gender and self-confidence in critical mathematical ability. Data validity checks in this study include: increasing rigor, triangulation, peer discussion, and member checking. In the rigor enhancement stage, the researcher consistently reviews various book references and related research findings. In the triangulation stage, the researcher used triangulation techniques, namely tests, interviews, and field notes to obtain the same data, but the triangulation results were linked to the questionnaire results. In the peer discussion stage, the researcher discussed the research process and results with fellow researchers. In the member check stage, the researcher individually checks with data providers to verify the validity and consistency of the written data with the actual data through gradual and ongoing interviews.

Result

The results of the questionnaire will be used as a reference for selecting research subjects. These results will be classified into three categories: high, medium, and low, and two females and two males will be selected from each category. The purpose of administering the self-confidence questionnaire is to measure the level of self-confidence of each student. The researchers present the questionnaire results for each category in Table 5.

Table 5. Self-Confidence Survey Results for Each Category

Questionnaire Score	Category	Student Codes	Number of students
$60 < x \leq 80$	High	006P, 027P, 017P, 031L, 018L, 012P	6 students
$40 < x \leq 60$	Medium	020L, 024P, 011L, 010P, 022L, 014L, 008P, 003P, 015P, 001L, 016L, 002L, 029L, 021P, 013L,028L, 023L, 004P, 005L	19 students
$20 < x \leq 40$	Low	030P, 009L, 026P, 025L, 019L	5 students

Based on the results of the questionnaire in Table 5, research subjects will be selected. Research subjects will be selected based on the highest and lowest questionnaire scores in each category, viewed from the perspective of gender. The research subjects in this article include: high category subjects (006P, 017L, 018L, 012P), medium category subjects (020L, 024P, 023L, 004P), and low category subjects (030P, 009L, 026P, 019L).

After obtaining the research subjects, the researcher gave a written test on mathematical critical thinking to 12 research subjects. The purpose of this written test was to measure and analyze the level of critical thinking of students in solving Pythagorean problems. This written critical thinking test was based on Facione (2015) indicators, which include interpretation, analysis, inference, evaluation, and self-regulation. Subsequently, interviews were conducted

with each research subject to reinforce the results of the test questions that had been completed. The type of interview used was semi-structured, with interview guidelines serving as a reference during the interviews. These interviews were based on Facione's critical thinking indicators. Based on the data obtained, the researcher analyzed the five critical thinking indicators in solving Pythagorean problems, considering self-confidence and gender, as follows.

Interpretation

Students' ability to interpret is 61%. This interpretation indicator is in line with the stages of recognizing and defining problems according to John Dewey's theory (Abdullah et al., 2022). It explains that students can write down what is known and what is asked in the question. In this study, students were required to interpret math questions on the Pythagorean theorem, but some students did not write down the known and unknown parts. Figure 1 shows students' work on question number 1 of the critical thinking written test on the Pythagorean theorem, specifically on moderate self-confidence.

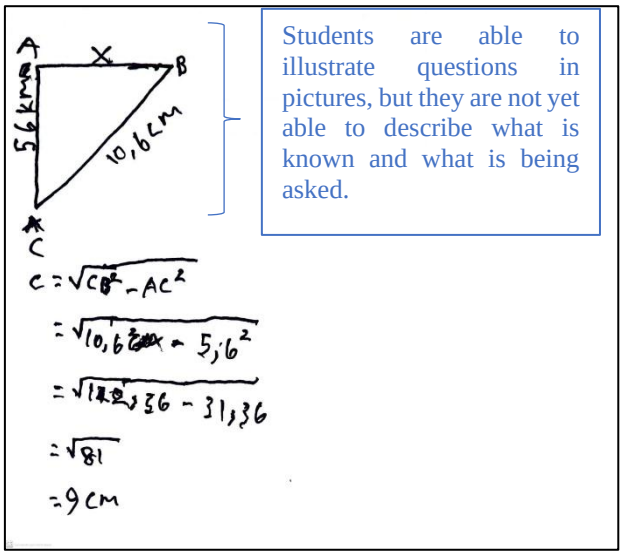

Figure 1. Excerpt from the response of a male subject with moderate self-confidence 020L

In the answers (Figure 1), students were unable to interpret the questions into answers by writing down what was known and what was asked. Students are not accustomed to first identifying what is known and what is asked, which is why problem-solving and critical thinking processes have not yet been applied.

Analysis

Students' ability to analyze in solving this problem resulted in a percentage of 67%. Critical thinking skills in this analysis indicator require students to be able to model mathematical problems, but they fail to write symbols at each point drawn and do not illustrate known aspects of the problem through drawings. The research students who did not write symbols on the diagram and their examples are male subjects with high self-confidence 018L, male subjects with moderate self-confidence 023L, and female subjects with low self-confidence 030P and

026P. The researcher presents excerpts from the answers of students with low self-confidence in Figure 2.

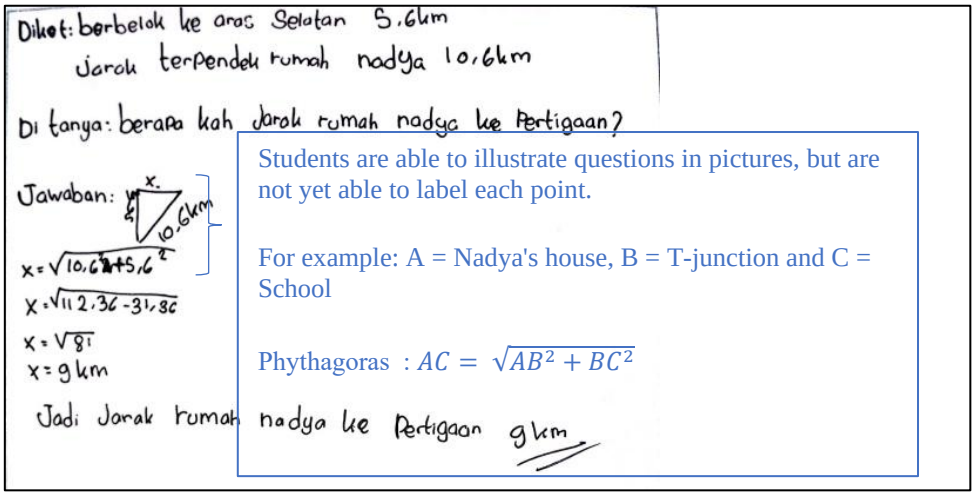

Figure 2. Excerpt from the response of a female subject with low self-confidence 030P

Based on the answers in Figure 2, student 030P can only analyze in the form of mathematical models in the form of illustrations. Student 030P is not less capable of writing symbols at each point and is unable to illustrate the known aspects in the question through pictures. This results in the student being less able to formulate formulas, because the formulas are taken from the symbols in the pictures. The student's inability to analyze is due to their confusion in solving the Pythagorean theorem problem and can only draw it without any symbols or other elements.

Inference

The students' ability to infer in this study resulted in a percentage of 45%. Students were able to infer correctly in this study, as shown by their ability to give symbols to the images they had created and then implement them into the Pythagorean formula. However, there were some who were unable to infer in the questions, including male subjects with high self-confidence (018L), male subjects with moderate self-confidence (023L), and all research subjects in the low self-confidence category. The researcher presents the answers of research subjects with moderate self-confidence in Figure 3. Based on the answers in Figure 3, student 023L is unable to analyze the question properly, resulting in an inability to formulate a formula or solution strategy. Student 023L incorrectly placed the symbols for the sides in the triangle diagram. If the right angle is marked with the symbol A, then the hypotenuse of the triangle should be side a, and the other sides should follow the location of the angle in front of it. This resulted in student 023L incorrectly formulating the formula, even though the method of solving the problem was correct. The student is unable to infer the problem because they rushed to solve the core part of the problem and lacks mastery of the Pythagorean theorem.

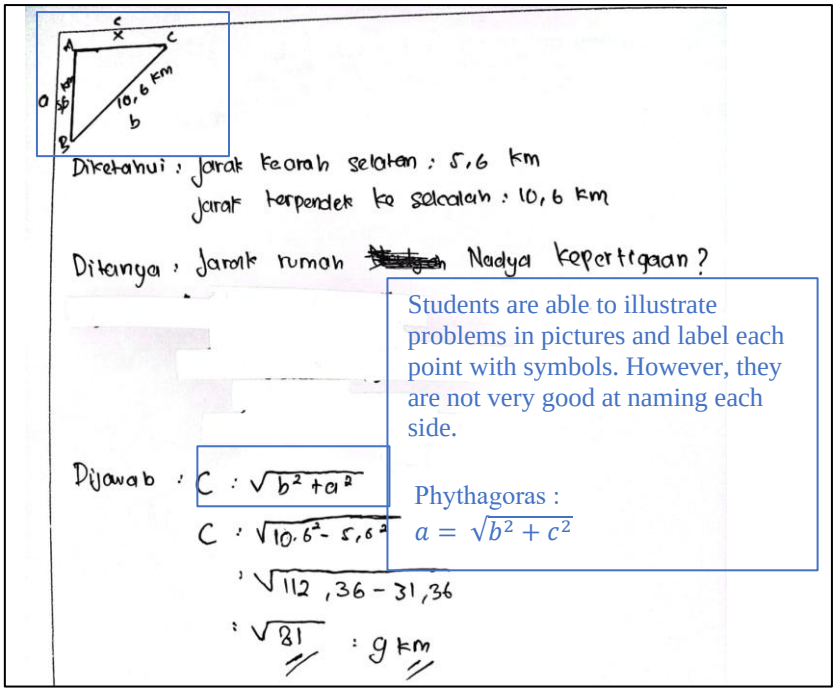

Figure 3. Responses of Research Subjects with Moderate Self-Confidence 023L

Evaluation

Students' ability to evaluate this indicator resulted in a percentage score of 68%. This indicator had the highest percentage score. Students were able to evaluate the questions accurately in this study, as demonstrated by their ability to use formulas and calculations correctly. However, in the interview results, some research participants were able to apply the formulas but lacked certain methods and calculations, particularly among male subjects with low self-confidence, namely 009L and 019L. The researcher presents the answers of students with low self-confidence in question 3 in Figure 4.

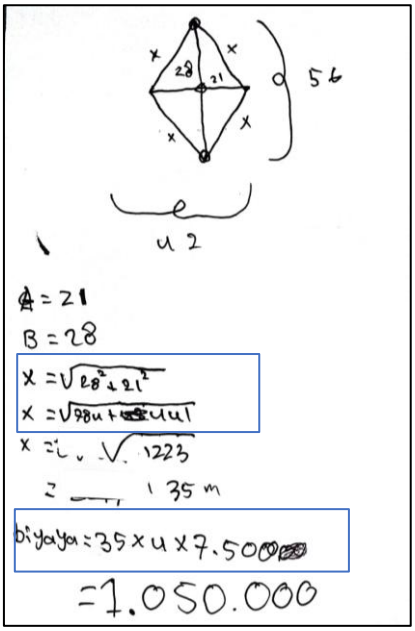

Figure 4. Answer to Question Number 3 Subject Male Low Self-Confidence 019L

Question 3 states that Uncle has a diamond-shaped corn field with diagonals measuring 42 meters and 56 meters. The field is fenced with wire 5 times around the perimeter. If the price of 1 meter of wire is Rp. 7,500.00, calculate the total amount of wire and the cost required by Uncle! Student 019L can solve the problem using the given formula, but the answer is incomplete. The correct answer should be $\sqrt{(784+441)}=\sqrt{1225}$, but student 009L mentioned $\sqrt{1223}$. The steps taken are correct, but student 019L failed to read the question carefully, resulting in missing steps and calculations. Student 019L only multiplied the outer perimeter of the garden, which is $35 \times 4 \times 7{,}500$. Student 019L failed to multiply by 5. However, it is clear that the question states, "wire is installed five times around the perimeter of the garden." This caused Student 019L to incorrectly write the final answer.

Self Regulation

The students' ability to regulate themselves on this test resulted in a percentage of 8%. In the self-regulation section, students were required to be able to double-check their work and results. However, many did not double-check their answers because they were in a hurry to finish, afraid of running out of time, and not accustomed to checking their answers. Data collection supporting self-regulation outcomes was conducted through direct observation by the researcher, supplemented by interviews. Interview results indicated that students unable to regulate themselves included all research participants except the high self-confidence female subject 012P and the high self-confidence male subject 018L.

The researchers present the findings of this study based on Facione (2015) indicators, which are described more briefly in the bar chart in Figure 5 as follows.

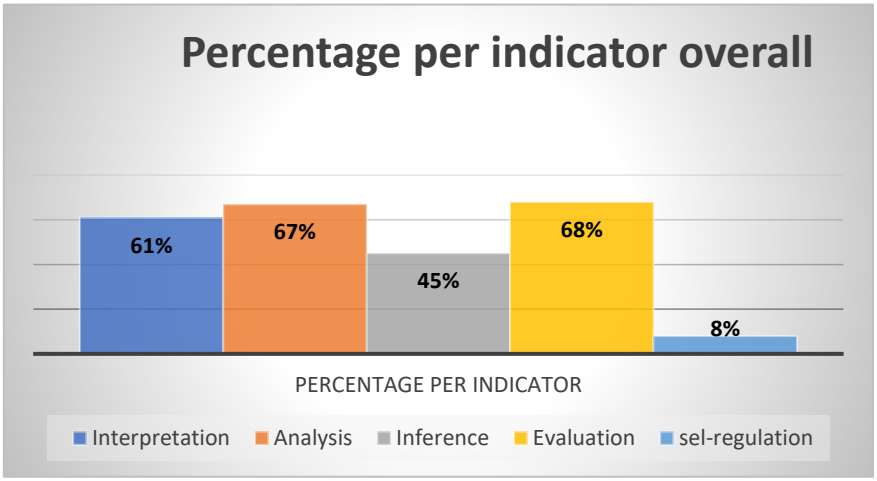

Figure 5. Results of Critical Thinking Written Test Scores per Indicator

Based on the results of the written test scores above, the researcher can conclude that students are more capable of meeting the evaluation indicators, because these indicators produced the highest percentage score of 68% with a total score of 98. This is because most students are only accustomed to focusing on the essence of solving mathematics problems. In this study, the researcher only included descriptions of questions 1 and 3 because many students answered these questions incorrectly, while many were able to answer question 2 correctly.

Discussion

From the results of the test on male subjects with high self-confidence 018L, who were then interviewed to reinforce their answers based on critical thinking indicators, it was found that students who did not take notes were identified and questioned because they were not yet accustomed to using this problem-solving method. This interpretation indicator is in line with Ennis' indicator, which focuses on questions. In this indicator, there is a component of formulating problems by identifying problems in questions (Hardika, 2020). In this study, many students were able to understand the problems in the questions, as evidenced by the third highest score out of the five critical thinking indicators being in the interpretation indicator. Parameswari & Kurniyati (2020) state that students' ability to understand problems facilitates their identification or interpretation of important information in the question. This is supported by the research of Subali et al. (2015), who state that critical thinking interpretation skills and the evaluation of interactions, research, and other data sources.

According to Facione (2015), analysis is the process of identifying inferential relationships between statements, concepts, and representations to reveal specific information. Based on this analytical ability, in mathematics, students are required to be able to formulate problem-solving methods by writing mathematical models in the form of illustrations in pictures. Based on the results of the analysis of student 030P's written test, their work did not meet the analysis indicators. This was because student 030P did not explain the symbols in the illustrations they created and did not provide examples or explanations for the symbols. This aligns with the research by Simbolon et al. (2023), who stated that "students' errors in solving word problems stem from a lack of process skills, as learners are unable to transform the information in the problem into a mathematical model."

Inference indicators are in line with the problem-solving steps, namely the stage of selecting the appropriate strategy (Krulik & Rudnick, 1988). Therefore, it is important for teachers to emphasize the context of the concept represented in the formula, not just the calculation process (Mulyatna et al., 2023). In line with the research, where the subject demonstrates their ability to carefully examine the question and identify the information provided. Then, they proceed to create a plan to solve the existing problem (Yesieka et al., 2024). Therefore, based on Facione's indicators, it can be said that the subject can meet the inference indicators. In this indicator, students can create a plan to solve the given problem by formulating the correct formula. Students who can formulate the correct formula are those who can analyze the problem into a mathematical model or graphical illustration accompanied by symbols and their explanations.

The findings of this study are in line with professional assessments that determine that students are able to complete the critical thinking assessment stage when they are able to solve problems using logical formulations or techniques (Facione, 2015). This indicator has the highest percentage compared to other indicators. Based on this evaluation ability, students are required to be able to use formulas accurately when solving problems, ensuring that the steps and calculations are correct, and to be able to write the final conclusion.

Based on the results of the analysis of the self-regulation indicator test, many students did not meet this indicator. However, there were several students who were able to regulate themselves by checking their work process and results, one of whom was student 018P. Student

018P checked all of their answers from start to finish, as revealed in the interview results. This theory aligns with the stages of problem-solving, specifically the reflection and development stages (Krulik & Rudnick, 1988). At this stage, students are able to cross-check their answers and identify the answers they have written. This aspect is crucial as it serves as self-directed feedback in the form of evaluating completed work and assessing how individuals regulate themselves toward predetermined goals (Hasan et al., 2021). Based on this, self-regulation positively impacts an individual's capacity to solve mathematical problems (Ituga & Alman, 2023).

Conclusion

The conclusion from the above explanation is that (1) the research subjects were more capable of fulfilling the critical thinking indicators in the evaluation section. This is evidenced by the percentage per indicator, where the interpretation indicator achieved a score of 61%, the analysis indicator achieved a score of 6%, the inference indicator achieved a score of 45%, the evaluation indicator achieved a score of 68%, and the self-regulation indicator achieved a score of 8%. (2) Female subjects have higher self-confidence than male subjects, as evidenced by the top two rankings in the questionnaire scoring results being occupied by female subjects. Meanwhile, the bottom two rankings are occupied by male subjects. (3) The higher the self-confidence scores in the high and low categories among research subjects, the higher the critical thinking test scores. This is evident in the correlation between self-confidence questionnaire scores and critical thinking test scores. (4) Female subjects in each category tend to better meet the indicators of critical thinking, as seen in the researcher's data presentation and the fact that female subjects' critical thinking test scores are higher in each category.

The results of this study are expected to serve as a reference for further research on critical thinking skills and self-confidence. It is also recommended that other researchers further explore the area of self-confidence, as the current study did not provide a detailed description of self-confidence. The researchers only described self-confidence in general terms due to the limited duration of the study. Additionally, this research can serve as a reference for teachers in improving classroom instruction by guiding students to meet the indicators of critical thinking.

Declarations

Author Contribution : PSKD: Conceptualization, Methodology, Writing - Original Draft, and Editing.
IKS: Writing - Review & Editing, and Supervision.
NF: Writing - Review & Editing, and Supervision.
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