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Analysis of Students' Mathematical Critical Thinking Skills in Solving Contextual Problems

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ABSTRACT

Mathematical critical thinking ability is an essential skill that students must possess in solving contextual problems. However, students' mathematical critical thinking ability is still considered low because students are more accustomed to solving problems procedurally rather than conducting analysis and evaluation. This study aims to analyze the mathematical critical thinking ability of vocational high school students based on Facione's indicators. The study employed a qualitative descriptive method involving 23 eleventh-grade students of SMK Budi Mandiri Tanjungsari as the research subjects. The research instruments consisted of a mathematical critical thinking ability test, interviews, and documentation. The results showed that 65% of students were in the low category and 17% were in the very low category. Students demonstrated fairly good ability in the indicators of interpretation and analysis; however, they were still weak in the indicators of evaluation and inference. Therefore, mathematics learning needs to emphasize evaluative and reflective thinking processes.

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1. INTRODUCTION

The rapid development of technology and the implementation of Education 5.0 have brought significant changes to 21st-century education. Students are not only required to master conceptual knowledge but also to possess higher-order thinking skills such as critical thinking, problem-solving, creativity, communication, and collaboration [1], [2]. Mathematics education plays a strategic role in developing higher-order thinking skills because mathematics trains students to think logically, systematically, and analytically [3]. In mathematics learning, critical thinking skills are highly important because students are required to interpret problems, analyze information, evaluate solution strategies, and draw logical conclusions [4]. Students who possess mathematical critical thinking skills can solve contextual problems effectively and apply mathematical concepts in everyday life [5].

Therefore, the development of mathematical critical thinking skills has become one of the primary goals of mathematics learning.

Critical thinking is defined as a reflective and rational thinking process focused on determining what to believe and what actions to take [6]. In the context of mathematics, critical thinking includes the ability to examine, analyze, evaluate, and systematically connect mathematical information to solve problems [7], [8], [9], [10], [11], [12], [13]. These studies state that as critical thinking skills develop, individuals tend to seek the truth, think openly and tolerate new ideas, analyze problems effectively, think systematically, possess intellectual curiosity, demonstrate maturity in thinking, and think independently and critically.

In this study, the indicators of critical thinking skills refer to those proposed by Peter A. Facione [14], namely: (1) interpretation, the ability to understand and explain the meaning of mathematical information such as data, symbols, graphs, and problem statements; (2) analysis, the ability to identify and describe important components of mathematical information by recognizing the relationships among these components; (3) evaluation, the ability to assess the quality of solution arguments or mathematical procedures based on logic and evidence; and (4) inference, the ability to draw logical conclusions based on available data or information.

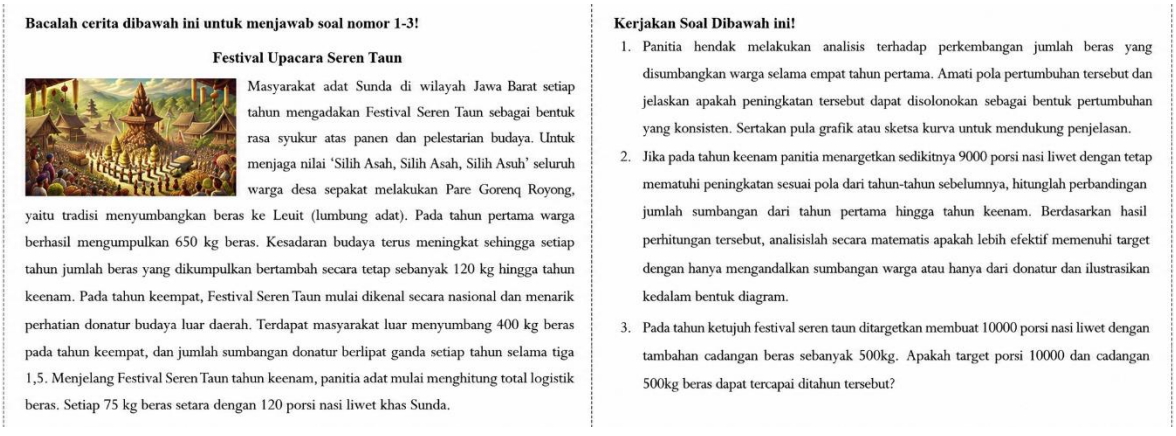
These indicators assess not only students' final answers but also the quality of their thinking processes. However, mathematics learning in schools still tends to be teacher-centered and procedural, causing students to become more accustomed to memorizing formulas rather than developing reasoning and reflective thinking skills [15], [16], [17], [18]. A literature review of previous studies conducted by [19], [20], [21], [22], [23] indicates that classroom learning processes are still dominated by teacher-centered instruction, resulting in students merely receiving information without actively constructing understanding. Several previous studies also revealed that students still experience difficulties in understanding contextual problems, determining appropriate solution strategies, and drawing logical conclusions [12], [24], [25].

Research on mathematical critical thinking skills generally focuses on junior high school students, the implementation of problem-based learning models, and mathematics learning outcomes [7], [13], [21]. However, studies specifically analyzing vocational high school students' mathematical critical thinking skills in solving contextual problems based on each of Facione's indicators remain limited. In addition, previous studies generally focused only on written test results without strengthening the findings through interview data. Unlike previous studies, this research provides a more comprehensive analysis by examining students' mathematical critical thinking skills based on each of Facione's indicators and reinforcing the findings through student interviews. Furthermore, this study specifically focuses on vocational high school students in solving contextual problems on sequences and series material. Therefore, this study is expected to provide a deeper understanding of students' mathematical critical thinking processes and serve as an evaluation material for developing more effective mathematics learning strategies. Based on this background, this study aims to analyze vocational high school students' mathematical critical thinking skills in solving contextual mathematics problems based on Facione's

indicators. The novelty of this study lies in the comprehensive analysis of vocational high school students' mathematical critical thinking skills based on each of Facione's indicators and strengthened through interview triangulation on contextual problems of sequences and series.

2. METHOD

This study employed a qualitative descriptive method. Qualitative descriptive research aims to describe phenomena systematically and comprehensively based on data obtained from the field [26]. The study was conducted at SMK Budi Mandiri Tanjungsari with 23 eleventh-grade students of the TKRO 2 class as the research subjects. The subjects were selected using purposive sampling because the chosen class was considered to represent students with diverse mathematical abilities. Most previous studies focused on junior high school students and problem-based learning implementation, while studies specifically investigating vocational high school students' mathematical critical thinking skills on sequences and series topics remain limited. The research instruments consisted of a mathematical critical thinking skills test, interviews, and documentation. The mathematical critical thinking skills test was developed based on Peter A. Facione's critical thinking indicators, namely interpretation, analysis, evaluation, and inference. The test instrument consisted of contextual problems on sequences and series material. Before being administered, the instrument was validated by mathematics education lecturers to ensure the suitability of the indicators, materials, and test items. Data collection was conducted in three stages. First, students were given a test of mathematical critical thinking skills. Second, interviews were conducted with several students representing different ability categories to strengthen the interpretation of the written test results. Third, students' answer sheets were documented as supporting research data. The test instruments are presented in Figure 1.



Bacalah cerita dibawah ini untuk menjawab soal nomor 1-3!

Festival Upacara Seren Taun

Masyarakat adat Sunda di wilayah Jawa Barat setiap tahun mengadakan Festival Seren Taun sebagai bentuk rasa syukur atas panen dan pelestarian budaya. Untuk menjaga nilai 'Silih Asah, Silih Asah, Silih Asuh' seluruh warga desa sepakat melakukan Pare Gorenq Royong, yaitu tradisi menyumbangkan beras ke Leuit (lumbung adat). Pada tahun pertama warga berhasil mengumpulkan 650 kg beras. Kesadaran budaya terus meningkat sehingga setiap tahun jumlah beras yang dikumpulkan bertambah secara tetap sebanyak 120 kg hingga tahun keenam. Pada tahun keempat, Festival Seren Taun mulai dikenal secara nasional dan menarik perhatian donatur budaya luar daerah. Terdapat masyarakat luar menyumbang 400 kg beras pada tahun keempat, dan jumlah sumbangan donatur berlipat ganda setiap tahun selama tiga 1,5. Menjelang Festival Seren Taun tahun keenam, panitia adat mulai menghitung total logistik beras. Setiap 75 kg beras setara dengan 120 porsi nasi liwet khas Sunda.

Kerjakan Soal Dibawah ini!

1. Panitia hendak melakukan analisis terhadap perkembangan jumlah beras yang disumbangkan warga selama empat tahun pertama. Amati pola pertumbuhan tersebut dan jelaskan apakah peningkatan tersebut dapat disolonokan sebagai bentuk pertumbuhan yang konsisten. Sertakan pula grafik atau sketsa kurva untuk mendukung penjelasan.
2. Jika pada tahun keenam panitia menargetkan sedikitnya 9000 porsi nasi liwet dengan tetap mematuhi peningkatan sesuai pola dari tahun-tahun sebelumnya, hitunglah perbandingan jumlah sumbangan dari tahun pertama hingga tahun keenam. Berdasarkan hasil perhitungan tersebut, analisislah secara matematis apakah lebih efektif memenuhi target dengan hanya mengandalkan sumbangan warga atau hanya dari donatur dan ilustrasikan kedalam bentuk diagram.
3. Pada tahun ketujuh festival seren taun ditargetkan membuat 10000 porsi nasi liwet dengan tambahan cadangan beras sebanyak 500kg. Apakah target porsi 10000 dan cadangan 500kg beras dapat tercapai ditahun tersebut?

Figure 1. Test Items for Mathematical Critical Thinking Ability

3. RESULTS AND DISCUSSION

3.1 Statistical Analysis of Mathematical Critical Thinking Skills

Based on the results of the mathematical critical thinking skills test administered to the students, score data were obtained for each test item, indicating variations in students' abilities to solve mathematical problems.

Table 1. Statistical Analysis of Test Results

	Score
Total Students	23
Average	48,55
Standard Deviation	13,91

The recapitulation results presented in Table 1 indicate that the students' average test score was 48.55. This result shows that the students had not yet achieved the minimum mastery criterion established by the school, which was 75. This condition indicates that most students still experienced difficulties in interpreting problems and connecting mathematical concepts, and there were considerable differences in students' levels of understanding. Consequently, students' higher-order thinking skills had not developed optimally. The interpretation of students' mathematical critical thinking skill categories according to Ponna et al. [27] is presented as follows.

Table 2. Categories of Students' Mathematical Critical Thinking Ability

Interpretation	**Categories**
$81{,}25 < x \leq 100$	Very High
$71{,}25 < x \leq 81{,}5$	High
$62{,}5 < x \leq 71{,}25$	Moderate
$43{,}75 < x \leq 62{,}5$	Low
$0 < x \leq 43{,}75$	Very Low

Based on the categories of the mathematical critical thinking skills test results, where x represents the test score, the percentages of students' mathematical critical thinking skills in the moderate, low, and very low categories are presented as follows.

Table 3. Results of Students' Mathematical Critical Thinking Ability Test

Categories	**Percentage**
Very High	0%
High	0%
Moderate	17%
Low	65%
Very Low	17%

Based on Table 3, which presents the percentage distribution of the mathematical critical thinking skills test results of 23 students, it was found that the majority of students were in the low category, consisting of 15 students. This finding indicates that most students had not yet been able to develop their critical thinking skills optimally, particularly in aspects requiring in-depth analysis, evaluation of strategies, and drawing logical and systematic conclusions.

In addition, four students were categorized as very low, indicating that some students still experienced considerable difficulties in interpreting the given information, transforming problems into mathematical representations, and determining appropriate solution steps. Meanwhile, the remaining four students were in the moderate category, indicating that only a small proportion of students had been able to fulfill the critical thinking indicators at a better level, although these abilities had not yet developed optimally.

3.2 Analysis of Students' Answers Based on Categories

Overall, this condition demonstrates that students' critical thinking abilities are still predominantly in the low category, highlighting the need to implement instructional strategies that are more oriented toward the development of critical thinking skills, such as problem-based learning or approaches that encourage students to actively analyze, evaluate, and independently draw conclusions from problems. In this study, the analysis of students' mathematical critical thinking abilities in solving mathematical critical thinking test items employed a structured and objective assessment instrument capable of comprehensively describing students' achievement. The scoring rubric used in this research was adapted from Facione's framework by Karim and Normaya [20].

The following section presents sample student responses from MY, SA, and FA, along with their analyses based on the low category, as this category dominates students' critical thinking ability and includes the majority of the research subjects. In addition, to strengthen the analysis, interviews were also conducted with several students to confirm their reasoning and approaches in solving the problems. The integration of written response analysis and interview findings allows for a more accurate interpretation of students' mathematical critical thinking abilities.

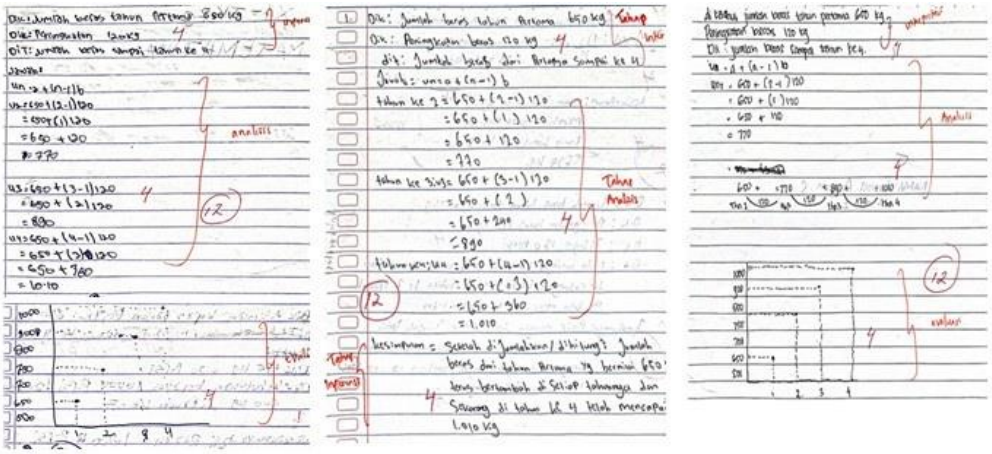


Figure 2. Students' Responses to Question 1

Based on Figure 2, the analysis of students' responses indicates that students' mathematical critical thinking abilities vary across test items. For Question 1, students MY, SA, and RA were able to correctly identify the given and the required information, indicating that their initial ability to understand the problem was well developed. The students were also able to transform verbally presented information into mathematical models and represent it graphically. However, in SA's response, the analysis was not presented as a graph, although SA was able to draw a conclusion based on the obtained solution. In contrast to SA, students MY and RA presented graphs as representations of their analyses but were unable to draw appropriate final conclusions based on the relationships between variables shown in the graphs. To further explore these findings, interviews were conducted with the respective students. The interview results revealed that when understanding word problems, students did not directly express the information in numerical or mathematical symbolic form; instead, they first rewrote it in sentence form to facilitate comprehension of the

problem. In addition, students explained that selecting data for problem solving involved identifying information that was appropriate and relevant to the formulas or solution strategies to be applied. However, SA stated that a graph was not presented because they forgot the steps involved in constructing a graph. Students also reported that writing conclusions was not always performed for every answer.

Based on data triangulation between the written test results and the interview findings, it can be concluded that students tend to focus more on computational processes and procedural problem-solving. However, students have not fully connected these solution results with the formulation of logical and meaningful conclusions. This finding is consistent with the results of studies by [28], [29], [30], which report that students are generally able to solve problems procedurally but are still not accustomed to making inferences and drawing conclusions, and tend to be more oriented toward final answers rather than toward interpreting the meaning of the obtained results.

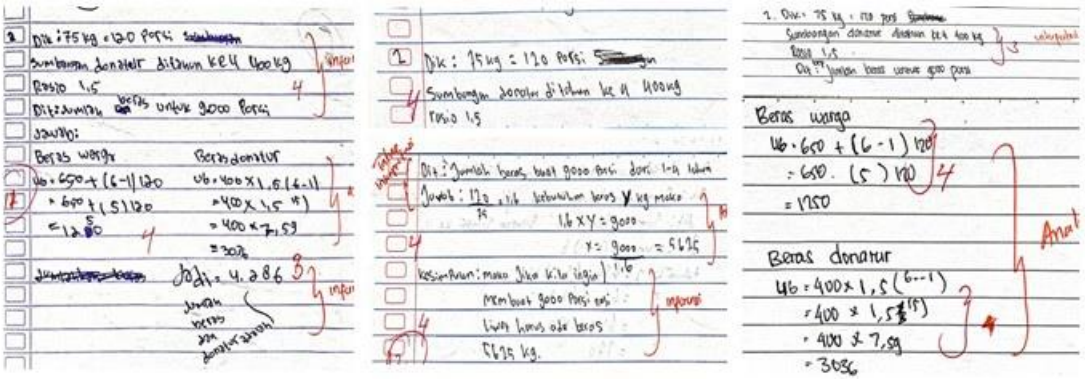


Figure 3. Students' Responses to Question 2

Based on Figure 3, the students' responses to Question 2 indicate that students were able to carry out basic computational procedures fairly well and understood the initial steps of the problem-solving process. However, the students did not fully meet the demands of the question, as several steps were not completed thoroughly. In contrast, RA's response was not accompanied by an explanation when concluding. Meanwhile, MY and SA provided final conclusions based on the processes they had undertaken, although not all solution steps were completed. These findings are supported by the interview results, in which students stated that when solving word problems, data selection was conducted by identifying information required by the formulas used. In addition, students explained that conclusions were formulated based on the answers or calculation results obtained previously. However, RA did not provide a final conclusion because he did not know how to draw one. The interview results also showed consistency with the students' written responses, indicating that students were able to reflect on their work, even though their computational processes were not yet entirely accurate and systematic. Triangulation between test results and interview findings suggests that students possess the ability to reflect on their thinking processes, particularly at the stages of interpretation and analysis. However, the failure to complete solution steps and provide adequate mathematical explanations was a factor affecting the accuracy of the final answers. These findings are consistent with studies by

[31], [32] which state that inaccuracies or incompleteness in solution steps can lead to final answers that do not meet the demands of the problem, even when students can conclude the problem-solving process.

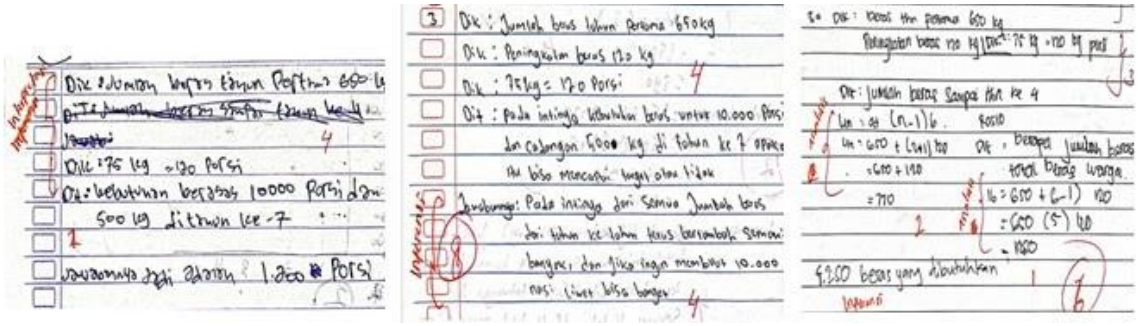


Figure 4. Students' Responses to Question 3

For Question 3, student RA provided a brief solution at the analysis stage by transforming the available information into a mathematical model. This initial step indicates that RA understood how to model the given problem and was able to draw an initial conclusion based on the results of the analysis, albeit in a concise manner. In contrast to RA, students MY and SA did not carry out the analysis stage; instead, they merely wrote down the given information and drew a direct conclusion without continuing the problem-solving process to the evaluation stage. Consequently, no appropriate computational strategies, such as algebraic manipulation or other mathematical solution techniques, were applied, resulting in the problem not being solved comprehensively.

The interview results reinforce these findings. Students stated that in selecting data for word problems, they tended to look for information that corresponded to the formulas they intended to apply. RA expressed confidence in the strategy or formula used, as the material had been studied previously at the tenth-grade level. However, all three students reported that the solution process could not be completed fully due to time constraints and rushed working conditions, which led to incomplete problem-solving procedures.

Based on data triangulation between the written test results and interview findings, it can be concluded that students possess an initial understanding of concepts and problem-solving strategies. However, students still encounter difficulties in developing these strategies into more complex and systematic computational procedures. In addition, time constraints also affect the completeness of problem-solving processes. These findings are consistent with studies by Syafruddin et al. [33], which indicate that students continue to experience difficulties in developing solution strategies and accurately applying more complex mathematical computational procedures. To obtain a deeper understanding of students' mathematical critical thinking abilities, the students' test results were analyzed for each critical thinking indicator, as presented below.

Table 5. Indicators of Interpretation Skills in Mathematical Critical Thinking

	Indicators			
	1	**2**	**3**	**4**
Average	3,5	2,9	0,91	1,2
Percentage	84%	70%	21%	27%

Based on the results of the analysis of students' mathematical critical thinking abilities across each indicator, varying levels of achievement were identified, reflecting students' mastery at each stage of critical thinking. Indicator 1, namely the ability to interpret problems by accurately identifying the given and required information, achieved the highest percentage at 87%. This result indicates that almost all students were able to understand the given problems well, particularly in identifying the essential elements contained in the questions. This finding suggests that students' initial ability to comprehend the context and information of mathematical problems has developed very well. Furthermore, for Indicator 2, which refers to the ability to analyze problems by transforming the obtained information into appropriate mathematical representations or models, a percentage of 70% was obtained. This result shows that the majority of students were able to perform the analysis process fairly well, namely by converting verbal information into symbols, equations, or mathematical models.

Nevertheless, some students were not yet fully consistent and accurate in performing mathematical modeling, which subsequently affected the problem-solving process. In contrast to the previous two indicators, the achievement for Indicator 3, namely the ability to evaluate by selecting and applying appropriate strategies or formulas in problem solving and reviewing the analyses that had been conducted, was relatively low, at 21%. This finding indicates that most students experienced difficulties in determining and applying suitable solution strategies and were not yet accustomed to evaluating the steps they had taken. As a result, the solutions obtained were often inaccurate or not supported by strong mathematical reasoning. The lowest achievement was found in Indicator 4, namely the ability to draw logical and systematic conclusions based on the results of problem solving, with a percentage of 27%. The low achievement in this indicator suggests that students were not yet able to formulate final conclusions that were consistent with the processes and results of their solutions. The conclusions provided tended to be incomplete, inaccurate, or misaligned with the problem context.

Overall, these results indicate that students' mathematical critical thinking abilities are relatively strong at the stages of interpretation and initial analysis but remain weak at the stages of evaluation and conclusion drawing. This finding highlights the need to implement instructional strategies that place greater emphasis on developing students' evaluative and reflective abilities, so that mathematical critical thinking processes can develop more comprehensively.

4. CONCLUSION

This study shows that vocational high school students' mathematical critical thinking skills in solving contextual problems are still predominantly in the low category. Students

demonstrated fairly good abilities in interpreting and analyzing mathematical information; however, they still experienced difficulties in evaluating solution strategies and drawing logical conclusions. The findings indicate that students are still more accustomed to solving problems procedurally rather than engaging in reflective and evaluative thinking processes.

The results of this study imply that mathematics learning needs to place greater emphasis on activities that encourage students to analyze, evaluate, and reflect on their thinking processes. Teachers are expected to implement learning models such as Problem-Based Learning and contextual learning to facilitate the development of students' mathematical critical thinking skills. This study was limited to one vocational high school and focused only on sequences and series material. Therefore, future studies are recommended to involve broader research subjects and examine the implementation of innovative learning models in improving students' mathematical critical thinking skills.

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