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CRITICAL THINKING PROCESSES OF VOCATIONAL SCHOOL STUDENTS IN SOLVING TRIGONOMETRY PROBLEMS FROM A GENDER PERSPECTIVE

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Abstract
Critical thinking is an essential competency in 21st-century learning and the implementation of the Merdeka Curriculum, particularly for Vocational High School (SMK) students to face the complexities of the workforce. This study aims to describe the critical thinking processes of female and male vocational students in solving trigonometry problems. This study employed a descriptive qualitative approach. The research subjects consisted of one female student and one male student with high mathematical ability. Data were collected through trigonometry problem-solving tasks and task-based semi-structured interviews. The data were analyzed in-depth using Facione's (2016) theoretical framework of critical thinking, which encompasses six processes: interpretation, analysis, inference, evaluation, explanation, and self-regulation. The results indicated distinct characteristics in the thinking processes between the two subjects. The female student's critical thinking process was characterized by being systematic and reflective; she was able to perform accurate interpretation and analysis, utilized inference based on supporting data, and demonstrated strong evaluation and self-regulation during the verification of the solution against the problem's conditions. In contrast, the male student's critical thinking process was characterized by being impulsive and intuitive; he encountered misconceptions during the analysis stage and exhibited weak evaluation and self-regulation processes, resulting in an illogical final outcome. This study concludes that there are variations in critical thinking process characteristics between female and male vocational students regarding the depth of evaluation and self-regulation when solving trigonometry problems.

Keywords: critical thinking, problem solving, trigonometry, gender

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INTRODUCTION

Education in the 21st century faces complex challenges, requiring each individual to possess a number of essential skills in order to participate effectively in an ever-evolving global society. Experts have emphasized the need to develop four 21st-century skills, namely critical thinking, communication, collaboration, and creativity and innovation (As'ari, 2016). Among these skills, critical thinking is often considered one of the most essential competencies (Miller & Topple, 2020). This ability is also a fundamental goal in education (Maria, 2018).

The importance of critical thinking is also reinforced in national education policy. Through Decree No. 56/M/2022, the Ministry of Education, Culture, Research, and

Technology officially implemented the Merdeka Curriculum, with the vital element of the Pancasila Student Profile Strengthening Project (P5). The Pancasila Student Profile itself covers six dimensions, with critical thinking being the fifth dimension. This indicates that this skill is very much needed by students in the implementation of the new curriculum (Anton & Trisoni, 2022).

Critical thinking itself is defined as the ability to systematically analyze and evaluate information, uncover assumptions, and then form strong and accurate inferences (Paul & Elder, 2020). Facione (2016) reveals that critical thinking involves a series of complex cognitive processes, including interpretation, analysis, inference, evaluation, explanation, and self-regulation. Meanwhile, Ennis (2000) defines it as reasonable and reflective thinking focused on decisions about what to believe or do, involving careful analysis, evaluation, and judgement.

In the context of mathematics learning, critical thinking skills play a very significant role. Mathematics as a subject that emphasizes logical reasoning and complex problem solving inherently requires good critical thinking skills (Syukriani, 2018). Problem solving requires critical thinking in order to gain a deep understanding of the conditions and design effective solutions. Students with good critical thinking skills are generally better able to understand mathematical concepts in depth and evaluate the correctness of the solutions they obtain (Wahyuningtyas et al., 2018).

One mathematical topic that plays an important role in various applications, especially for vocational high school (SMK) students, is trigonometry. This topic covers the relationship between angles and sides in triangles, which has vital applications in vocational majors such as Machining Engineering and Visual Communication Design. However, solving problems in trigonometry is often considered difficult for SMK students because the subject matter is considered abstract (Ulfa and Pratiwi, 2022), challenging students' critical thinking skills in solving non-routine problems.

This challenge becomes increasingly urgent given the context of vocational school graduates. Based on data from Statistics Indonesia, vocational school graduates contribute the most to total unemployment compared to other education levels (Akbar et al., 2022). Therefore, equipping students with essential skills such as critical thinking is very important in order to face the complexity and challenges of the workforce in the Industry 4.0 era, which demands adaptation and new skills (Dewanto et al., 2018).

Students' critical thinking skills in solving mathematical problems can be influenced by a number of aspects, including gender. Previous studies indicate performance differences between male and female students. For example, females generally have good verbal skills, while males have good spatial skills (Santrock, 2017).

Other studies reinforce that academic achievement and emotional intelligence are also influenced by gender differences (Nasir et al., 2025). These cognitive differences can affect critical thinking ability profiles. This is supported by findings of differences in critical thinking abilities between male and female students in a study focusing on prospective biology teachers (Andayani et al., 2019).

However, studies that specifically examine the description of vocational high school students' critical thinking processes in solving trigonometry problems while considering gender aspects are still limited. This gap needs to be closed to provide an in-depth picture of how critical thinking processes take place in vocational student groups.

Therefore, this study aims to provide a deeper understanding of the critical thinking processes of female and male Vocational High School students when confronted with the challenge of solving trigonometry problems.

RESEARCH METHOD

This study utilized a qualitative approach with a case study design. The research was conducted at SMK Negeri 13 Surabaya, involving 11th-grade students from the Visual Communication Design (DKV) program who had previously learned trigonometry. The specific class (XI DKV 2) was selected based on teacher recommendations regarding student activity levels. Data were collected using two instruments: a Mathematics Ability Test (TKM) covering 10th-grade topics and a Trigonometry Problem Solving Assignment. Both instruments were validated by mathematics education lecturers and practitioners. The subjects were selected using purposive sampling based on two criteria: (1) gender differences (one male and one female) and (2) equivalent high mathematical abilities. The selection was determined based on the highest TKM scores, as detailed in Table 1.

Table 1.
List of Research Subjects

No.	Initial	Label	Gender	TKM Score	Mathematics Ability Category
1	ARSP	SP	Female	94	High
2	NAU	SL	Male	94	High

Source: Gender Data and TKM Scores

Notes:
SP : First research subject with female gender and high mathematical ability
SL : Second research subject with male gender and high mathematical ability

After determining the research subjects, the researcher gave them an assignment, namely the Trigonometry Problem Solving Task/TPMT and a task-based semi-structured interview to explore the students' critical mathematical thinking processes.

Suatu tim sedang memasang panel surya sepanjang 2 meter di atas atap horizontal, di mana panel tersebut harus dipasang dengan sudut kemiringan (θ) yang merupakan salah satu dari sudut istimewa $30°, 45°, 60°$. Pemasangan ini memiliki dua kendala utama:

1. Ketinggian vertikal (t) dari ujung atas panel ke atap tidak boleh melebihi 1,5 meter,
2. Sudut yang dipilih adalah sudut istimewa yang menghasilkan proyeksi horizontal (x) terpanjang demi stabilitas struktural kerangka penyangga.

Dengan menggunakan pemahaman Anda tentang perbandingan trigonometri sudut istimewa, hitung sudut kemiringan (θ) yang paling tepat agar proyeksi horizontal maksimum dan jelaskan setiap langkah Anda!

Source: TPMT Instrument
Figure 1.

Meanwhile, the TPMT and task-based interview data obtained were then analyzed using critical thinking indicators.

Table 2.
Critical Thinking Indicators

No.	Indicator	Sub-Indicator
1	Interpretation	a. Identifying sections that contain known information and information to be found. b. Understanding the relationship between existing information. c. Paraphrasing or reformulating the problem in your own words.
2	Analysis	a. Connecting relevant ideas or concepts to the problem. b. Determining appropriate strategies or methods for resolution.
3	Inference	a. Proposing several alternative strategies if necessary. b. Gathering additional data or information as needed. c. Drawing conclusions or results from each calculation step.
4	Evaluation	a. Implementing the planned steps accurately. b. Ensuring that all steps taken are in accordance with the plan.
5	Explanation	a. Writing down the results of each step of the solution. b. Explaining why that solution step was chosen. c. Presenting arguments for each step of the solution.
6	Self-Regulation	a. Monitoring the thinking process and results. b. Correcting the thinking process and results.

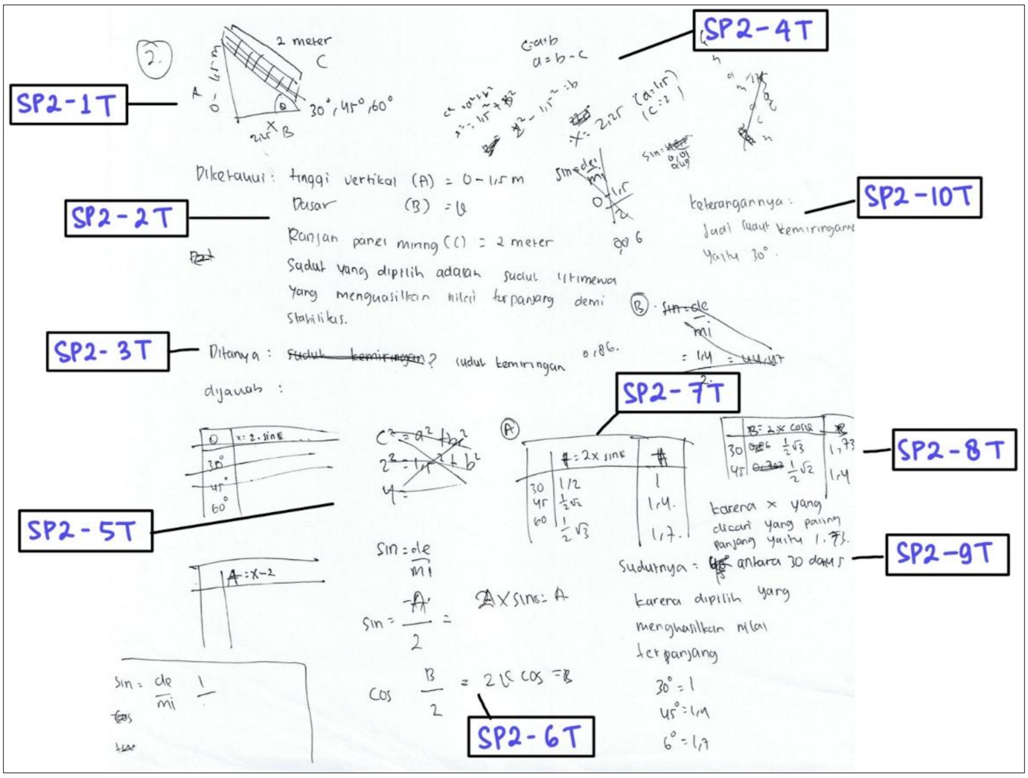
Adapted from Facione (2016)

RESEARCH RESULTS AND DISCUSSION

Results

This section describes the critical thinking processes of female students (SP) and male students (SL) in solving trigonometry problems related to solar panel installation. The description is based on six critical thinking indicators: interpretation, analysis, inference, evaluation, explanation, and self-regulation.

1. Critical Thinking Processes of Female Students (SP) in Solving Trigonometry Problems



Source: SP Subject Answer Sheet

Figure 2.

Interpretation

In the interpretation process, SP began by accurately identifying key information. On the answer sheet label [SP2-1T], SP draws a sketch of a right triangle representing the position of the solar panel, complete with special angles (30°, 45°, 60°). SP also identifies the information that is known and explicitly asked for on labels [SP2-2T] and [SP2-3T]. This was confirmed through an interview when the researcher asked about the table columns he had created:

[PP2-9]: "What is this column? Is it A or B?"

[SP2-9]: "This is T, the result, the height."

[PP2-10]: "What does A mean?"

[SP2-10]: "Yes, A."

This excerpt shows that SP's meaning-making process was going well, where he understood that the vertical side of the triangle (A) represented the height, which was the constraint in the question.

Analysis

In the analysis stage, SP connects the concept of trigonometry with the problem at hand. In label [SP2-4T], SP writes down the relationship between the sides of the triangle (c, a, b) and then in label [SP2-6T] identifies the basic sine and cosine formulas. Despite initial confusion in determining the order of the variables to be found, SP continues the analysis process by deciding on a new strategy:

[SP2-31]: "Eeeh, at first I was confused about whether to find X or the height first."

Despite the confusion, SP decided to use a table ([SP2-5T]) to compare the values of the three angles, an effective analysis strategy for discrete optimization problems.

Inference

SP's inference process can be seen from the way he draws conclusions based on the calculation data. In label [SP2-8T], SP presents a complete calculation table: for angles 30°, 45°, 60°, he calculates the values of X (horizontal) and vertical height. SP concludes the calculation results accurately:

[PP2-11]: "The tallest one?"

[SP2-11]: "Yes, the one with the sixty-degree angle."

SP understands the logical consequences of each angle on the resulting length and height values.

Evaluation

SP's evaluation process is very thorough. He verifies his calculations against the two constraints of the problem: the maximum height limit (1.5 m) and the longest horizontal projection. In the transcript, SP evaluates the angles 45° and 30°:

[PP2-14]: "Which ones meet the criteria, and which ones don't?"

[SP2-14]: "That means it meets forty-five."

[PP2-19]: "One point four, so between thirty and forty-five, you choose forty-five?"

[SP2-19]: "Yes, because we're looking for the longest one."

In the end, in label [SP2-9T], SP revised their decision and chose the angle 30°, as it produced the longest X value (1.73 m) while keeping the height below the maximum limit (1 m < 1.5 m).

Explanation

SP clearly wrote the final conclusion of his thought process on label [SP2-10T]:

"So the slope angle is 30°."

He also provides a written argument on label [SP2-9T]:

"Because the x being sought is the longest, which is 1.73."

In the interview, SP consistently explains the reasons behind his choices:

[SP2-27]: "Because, um, find the longest one."

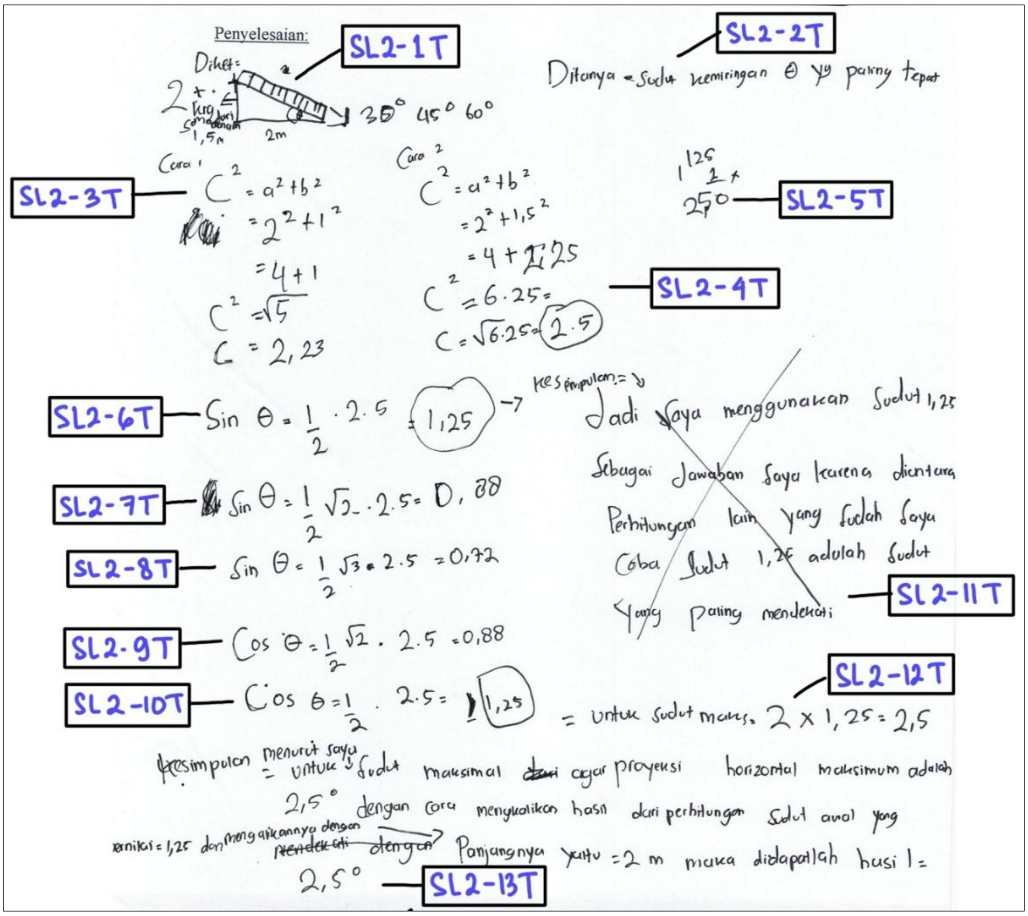
Self-regulation

The self-regulation process is evident in label [SP2-7T], where SP crossed out the previous calculation that was considered ineffective and switched to making a systematic table in label [SP2-5T]. Awareness of monitoring and improving this thinking process was expressed in the interview:

[PP2-30]: "Did you follow your initial plan with the steps you had outlined, or did you change course midway?"

[SP2-30]: "Changed midway."

2. Critical Thinking Processes of Male Students (SL) in Solving Trigonometry Problems



Source: SL Subject Answer Sheet

Figure 3.

Interpretation

Visually, in label [SL2-1T], SL appears to be making an initial interpretation by drawing a sketch and writing down the numbers 2 m and 1.5 m. However, the interview revealed obstacles in the process of interpreting the meaning of units. SL did not distinguish between the scalar value of the calculation and the unit of degrees.

> *[PL2-7]: "Is 2.5 meters or degrees?"*
>
> *[SL2-7]: "Because the question asks for an angle, so it's in degrees."*

Analysis

During the analysis stage, SL encountered difficulties in connecting relevant concepts. In label [SL2-3T], SL attempted to use the Pythagorean Theorem $c^2 = a^2 + b^2$, which was irrelevant because the length of the hypotenuse was already known (2 meters). The chosen strategy was not appropriate for finding the angle.

> *[SL2-6]: "The maximum angle I can get from the 2-meter length of the solar panel is calculated using sin and cos, which results in 1.25 multiplied by 2."*

This quote shows that SL's analysis process is stalled due to a misconception about trigonometric functions.

Inference

The inference process carried out by SL produced an illogical conclusion. In labels [SL2-4T] and [SL2-12T], SL performed arithmetic operations: $2 \times 1{,}25 = 2{,}5$. He concluded that the correct angle was 2.5 degrees.

[PL2-1]: "The question is, what is the most appropriate angle of inclination for maximum projection? What angle did you use?"

[SL2-1]: "An angle of 1.25."

This conclusion is invalid because the question asks to choose one of the special angles (30°, 45°, 60°), not to create a new angle.

Evaluation

The evaluation process in SL did not run optimally. Although he crossed out "Method 1" on the [SL2-3T] label (attempting to evaluate the strategy), he did not continue to evaluate the final result (2.5 degrees) to see if it was reasonable or met the constraints of the question. When asked about his confidence:

[PL2-8]: "Are you sure about your answer?"

[SL2-8]: "Yes."

SL did not double-check whether his answer matched the special angle options provided.

Explanation

On labels [SL2-11T] and [SL2-13T], SL wrote the conclusion:

"So I used an angle of 1.25... for the maximum angle 2 x 1.25 = 2.5."

The argument presented is circular and based on incorrect calculations (confusing side length with angle size), so the explanation does not represent a valid justification.

Self-regulation

An attempt at self-regulation emerged when SL switched from "Method 1" to "Method 2" ([SL2-3T] to [SL2-4T]). However, this improvement did not address the root of the conceptual error. In the final interview, SL decided to stop the thinking process without rechecking.

[PL2-10]: "It's done, do you want to check it again or is it enough?"

[SL2-10]: "It's enough."

Discussion

This study aims to describe the critical thinking process of vocational high school students in solving trigonometry problems. The findings show contrasting differences in the flow and depth of critical thinking processes between female and male students.

1. Regularity vs. Impulsivity in the Analysis and Inference Process

   SP demonstrated a systematic critical thinking process. The decision to change strategies midway through the task (Label [SP2-7T] to [SP2-5T]) indicated a structured thinking process. The use of tables as an analysis tool enabled SP to make evidence-based inferences, comparing 1.73 m with 1.4 m before making a decision. In contrast, SL demonstrates a process that tends to be impulsive and speculative. The mistake of using Pythagoras ([SL2-3T]) to find the angle indicates a superficial analysis process. The inference that concludes an angle of 2.5 degrees ([SL2-12T]) indicates a disconnect between the results of the thinking and the context of the problem constraints (special angles).

2. Quality of the Evaluation and Self-Regulation Process

   The key findings in this study lie in the implementation of the Evaluation stage. SP carried out a layered evaluation process: checking the height requirement (<1.5 m) and checking the maximum length requirement. This is clearly recorded in dialogues [PP2-19] to [PP2-21]. Meanwhile, SL did not carry out a thorough meaning evaluation process. He only focused on the arithmetic calculation procedure (1.25 x 2) without evaluating whether the number "2.5" was logically a roof slope degree. SL's statement of confidence ([SL2-8]) even though the answer was irrelevant shows that the cognitive monitoring process (metacognition) in SL was not as effective as SP's, who was more reflective. These results emphasize that in solving trigonometry problems, the implementation of self-regulation processes (recognizing errors and changing strategies) and evaluating solutions to contextual problems are important stages that distinguish the quality of students' critical thinking processes.

CONCLUSION

Based on the analysis and discussion of the critical thinking processes of vocational high school students in solving trigonometry problems, the following conclusions were drawn:

1. Critical Thinking Process of Female Students

   Female students demonstrated a systematic, reflective, and structured critical thinking process. At the interpretation and analysis stage, female students tend to describe problems in detail and are able to connect trigonometry concepts appropriately. The main strength of female students lies in the evaluation and self-regulation process, where they actively monitor their train of thought, recognize mistakes in the middle of the process, and perform multiple verifications of problem constraints before drawing final conclusions.
2. Male Students' Critical Thinking Process

   Male students demonstrate a critical thinking process that tends to be intuitive but impulsive. Although capable of initial visualization (interpretation), male students' thinking process is often hampered by misconceptions at the analysis stage, such as incorrect use of basic formulas. The inference process is not based on valid data evidence. The most prominent weakness is seen in the lack of optimal evaluation and self-regulation, where students tend to be quickly satisfied with answers without double-checking the logic and context of the given problem constraints.

Overall, the findings of this study conclude that there is a variation in the characteristics of the critical thinking processes between the two Vocational High School students, specifically regarding the depth of evaluation and self-regulation when solving trigonometry problems.

SUGGESTIONS/RECOMMENDATIONS

Based on the results of the analysis and discussion as well as the conclusions regarding the critical thinking processes of vocational school students in solving trigonometry problems, the following suggestions/recommendations can be made:

1. Knowing that there are differences in the critical thinking processes of male and female students, it is hoped that teachers can design learning that supports students' critical thinking processes according to their gender, for example, through differentiated learning.
2. Male students tend to be less optimal in the process of evaluating and regulating themselves when solving problems, so special attention from teachers is needed, for example, by asking reflective questions such as "Does this answer make sense?" or "Does this strategy meet all the requirements of the question?" to help male students evaluate themselves.
3. Research studies are still limited to the critical thinking processes of vocational high school students in solving trigonometry problems from a gender perspective. For further research, it is recommended that the review be changed to high school students with other materials or that the review be changed to gender differences so that the results obtained are more varied.

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