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# CHALLENGES IN DEVELOPING JUNIOR HIGH SCHOOL STUDENTS' COMPUTATIONAL THINKING SKILLS IN MATHEMATICS THROUGH PROBLEM-BASED LEARNING

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***ABSTRACT***

This research aims to analyze students' computational thinking abilities in mathematics learning through problem-based learning. A qualitative approach with a case study design was employed. The research was conducted at SMP Negeri 1 Cibinong, Bogor Regency, West Java. The subjects were three ninth-grade students who had studied material on exponents and roots, selected based on the teacher's recommendations. Data were collected through computational thinking tests and interviews. Based on the analysis, it was found that students, despite their teachers implementing problem-based learning, still lacked strong computational thinking skills. The suboptimal implementation of PBL and the students' unfamiliarity with problem-solving contributed to their difficulty in effectively applying computational thinking skills. In conclusion, the use of problem-based learning in mathematics, particularly in the topics of exponents and roots, has not yet enabled students to fully develop computational thinking skills.

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## INTRODUCTION

Computational Thinking (CT) is the process of thinking used to formulate problems and devise strategies to determine or select effective, efficient, and optimal solutions. Effectiveness refers to taking actions that directly address the problem at hand. Efficiency is related to the strategies, methods, and resources employed, while optimality refers to finding the best solution under specific conditions. For example, to navigate through rain, someone with a car can drive, while someone without a car may use an umbrella or another tool. Computational thinking is not a new concept, but rather a crucial skill that has been emphasized in computer science since the 1960s (Denning, 2009; Grover and Pea, 2013). Therefore, a deeper understanding of CT skills is essential for successful implementation.

In mathematics learning, students have not yet developed adequate computational thinking (CT) skills. According to Mufidah (2018), students struggle to solve problems by connecting the information they receive, resulting in low computational thinking abilities, which need improvement. Supiarmo's (2021) research also found that students were unable to think computationally in mathematics because they could not apply abstraction and algorithmic thinking to solve problems. Furthermore, in the research conducted by Supiarmo, Mardhiyatirrahmah, and Turmudi (2021), it was found that students' computational thinking was limited to the stages of decomposition and pattern recognition. They struggled to apply abstractions to mathematical problems and lacked algorithmic thinking, as their problem-solving process was neither logical nor systematic.

Jamalludin (2022) highlighted that students' inability to write down the information necessary for solving problems is a reflection of their low level of computational thinking, which stems from not being accustomed to thinking computationally. Students' CT abilities, particularly in abstraction, are underdeveloped, as they cannot determine which information should be retained or disregarded (Putri, 2022). Similarly, Nurwita (2022) identified several challenges with students' computational thinking abilities in mathematics. Students struggled with abstraction, decomposition, and generalization: they could not identify important information, break down complex problems into manageable parts, or generalize and conclude their problem-solving steps.

The evidence suggests that students' computational thinking abilities remain low. This issue, particularly in mathematics learning, needs to be addressed. Teachers can facilitate improvement by integrating technology and focusing on problem-solving, specifically through problem-based learning. Emphasizing the problem-solving process enhances students' ability to develop CT skills, as problem-solving is central to computational thinking (Jonassen & Gram-Hansen, 2019). Integrating CT with problem-solving can be an effective instructional approach (Kwon, Ottenbreit-Leftwich, Brush, Jeon, & Yan, 2021).

When using Problem-Based Learning (PBL), it is important to consider that PBL has been proven to enhance computational thinking skills. Kurniati et al. (2018) showed that students' mathematical computational thinking improves when using PISA-based student worksheets within the PBL model. This is further supported by Marhaeni, Andriyani, and Rusmilah (2021), who found that student worksheets in a PBL setting effectively increase students' computational thinking skills. The reason is that PBL-based worksheets guide students through problem-solving processes, encouraging them to develop strategies such as decomposition, abstraction, pattern recognition, and algorithmic thinking. By using problems as a starting point, PBL stimulates students' computational thinking. These worksheets are structured according to the stages of problem-based learning, making them an effective tool for fostering computational thinking.

The steps in problem-based learning (PBL) can support the development of computational thinking skills. According to Tyas (2017), the steps in PBL are as follows: a) students are introduced to a problem (problem orientation); b) students form heterogeneous groups of 5-6 people with teacher guidance; c) students receive student worksheets (LKPD) distributed by the teacher to each group; d) students collect relevant information related to the problem in the LKPD; e) students solve the problem in groups and then present their findings; and f) students participate in evaluations guided by the teacher.

These stages align with key aspects of computational thinking (CT). In the problem orientation stage, students break down larger problems into smaller, more manageable ones—this corresponds to the decomposition stage in CT. During the information gathering stage, students filter out unnecessary details to focus on the core problem, which aligns with the abstraction stage in CT. At the problem-solving stage, students collaborate to identify patterns and solve the problem systematically, preparing them for presentations—this relates to the pattern recognition and algorithmic thinking stages in CT.

Thus, each stage of PBL is closely linked to supporting the achievement of computational thinking skills. This description highlights the effectiveness of problem-based learning in helping students develop their computational thinking skills.

Based on the discussion above, this research aims to describe students' computational thinking abilities in mathematics, specifically focusing on the material related to powers and root forms taught using Problem-Based Learning. The description is framed around four computational thinking indicators: decomposition, pattern recognition, abstraction, and algorithmic thinking.

## METHOD

This research adopts a qualitative approach with a case study design. The choice of a case study design is based on the research goal, which is to understand students' computational thinking abilities in the context of numbers involving powers and root forms. The research process consists of several stages: 1) selecting the research subjects; 2) developing the research instruments; 3) collecting the data; 4) analyzing the findings; and 5) interpreting the data.

The research subjects were three ninth-grade students from the 2023/2024 academic year at SMP Negeri 1 Cibinong, Bogor Regency, West Java, who had studied material on powers and root forms using problem-based learning. The school is a model institution in Bogor Regency and holds an A accreditation, making it one of the most representative junior high schools in the area. Bogor Regency was chosen for this study due to its status as one of the largest regencies in West Java. The subjects were selected based on recommendations from mathematics teachers. The research focused on the topic of numbers involving powers and root forms because it closely aligns with the indicators of computational thinking.

The instruments used in the study were a computational thinking ability test and an interview guide. The test consisted of four questions, each representing one of the computational thinking indicators, adapted from Csizmadia (2015) and validated by experts. The computational thinking indicators include decomposition, pattern recognition, abstraction, and algorithmic thinking, as shown in Table 1.

Table 1. Indicators of Computational Thinking Skill

| Material | Indicators of Computational Thinking Skill | Question | Form | Number |
|---|---|---|---|---|
| Power and Root | **ABSTRACTION** Students can focus on important information and disregard irrelevant details, making the problem easier to solve. | A rectangular tray measuring 60 cm by 30 cm will be used to serve traditional West Java cakes. If the entire edge of the tray is to be decorated with banana leaves shaped like equilateral triangles, each with a side length of 33 cm, and the decoration is sold at IDR 3000 per cm, determine the minimum number of banana leaves needed to cover the entire edge of the tray. | Essay | 1 |
| Power and Root | **ALGORITHMIC THINKING** Students are able to solve problems systematically. | The average weight of an angklung is 5 kg. A truck with a maximum capacity of 500 kg is used to transport crates, each containing 5 angklung. What is the maximum number of crates that the truck can carry? | Essay | 2 |
| Power and Root | **DECOMPOSITION** Students can break down problems into smaller, simpler ones. | A competition will be held on August 17 in a rectangular field with sides measuring 235 m, 305 m, 1520 m, and 1045 m. The field will be enclosed with a rope. If the competition committee provides 5080 m of rope, will it be enough? Explain. | Essay | 3 |
| Power and Root | **PATTERN RECOGNITION** Students can identify patterns, similarities, or differences in a problem. | What is the 10th term of the series: 22, 42, 62, 82, ...? | Essay | 4 |

## RESULT AND DISCUSSION

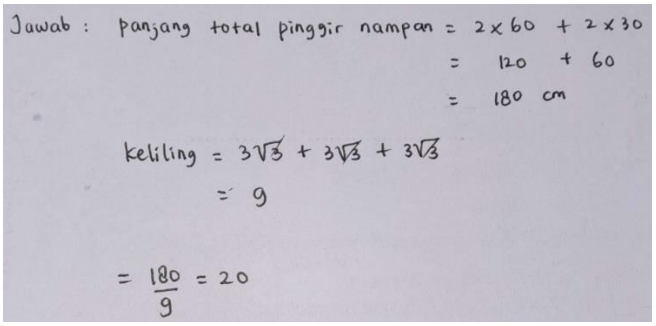
To identify students' computational thinking skills, descriptive questions related to the material on powers and root forms are presented. The analysis of students' abilities is conducted for each computational thinking indicator based on their responses to the given questions.

### *Analysis of Students' Abilities on Abstraction Indicators*

Question 1 assesses the abstraction indicator. Based on this question, students' responses were analyzed, including the initial strategy used by one of the students, as shown in Figure 1.

Question 1:

> *A rectangular tray measuring 60 cm by 30 cm will be used to serve traditional West Java cakes. If the entire edge of the tray is to be decorated with banana leaves shaped like equilateral triangles, each with a side length of 33 cm, and the decoration is sold at IDR 3000 per cm, determine the minimum number of banana leaves needed to cover the entire edge of the tray.*




*Translation*

Answer: total length of tray edge

$= 2 \times 60 + 2 \times 30$

= 120 + 60

= 180 cm

Perimeter = $3\sqrt{3} + 3\sqrt{3} + 3\sqrt{3}$

= 9

$\frac{180}{9} = 20$

Figure 1. Strategy for students' initial steps in question number 1.

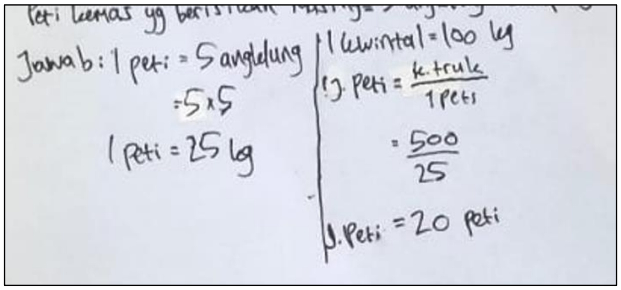
In Figure 1, the students were unable to identify the important information in the given problem. For example, they overlooked details like the price of banana leaves, and they failed to clearly write down the crucial elements of the question. Based on interview results, the students primarily focused on arriving at the final answer rather than first identifying the key details. If students are still concerned with information like the price of banana leaves, they may struggle to understand its relevance in solving the problem. Therefore, the finding from the first step of question number 1 indicates that students have not yet mastered the abstraction process—namely, focusing on the core aspects of the problem while disregarding irrelevant details.

***Analysis of Students' Abilities on Algorithmic Thinking Indicators***

The questions containing algorithmic thinking indicators are found in question number 2. The solution strategies used by the students were quite similar. A representative example of the students' answers is shown in Figure 2.

Question 2:

> *The average weight of an angklung is 5 kg. A truck with a maximum capacity of 500 kg is used to transport crates, each containing 5 angklung. What is the maximum number of crates that the truck can carry?*




*Translation*

Answer:

1 box = 5 angklung

= 5 x 5

1 box = 25 kg

1 quintal = 100 kg

number of boxes = $\frac{Capacity\ of\ Truck}{1\ box}$

= $\frac{500}{25}$

= 20 boxes

Figure 2. Strategy for students' solution steps for question number 2.

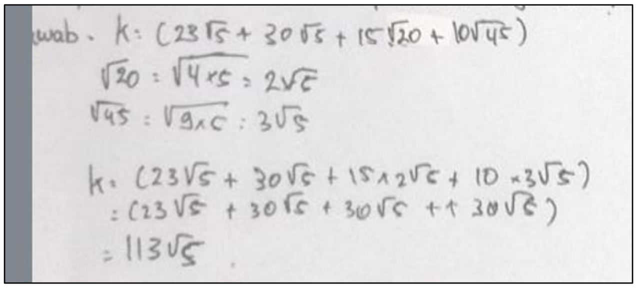
In Figure 2, students have not solved the problem algorithmically or systematically. This can be seen from the completion stages which are not written down systematically. The things written are like separate points and are not related to each other. Apart from that, the information provided by students is also incomplete so it can cause ambiguity for those who read it. In this case, it was found that in the step of solving problem number 2, students had not thought algorithmically, that is, solving problems systematically.

### *Analysis of Student Abilities on Decomposition Indicators*

The question containing the decomposition indicator is included in question number 3. Question 3:

> *A competition will be held on August 17 in a rectangular field with sides measuring 235 m, 305 m, 1520 m, and 1045 m. The field will be enclosed with a rope. If the competition committee provides 5080 m of rope, will it be enough? Explain.*

Based on this question, answers were obtained from students who carried out the strategy for solving the steps presented in Figure 3.



*Translation*

Answer:

Perimeter =

$(23\sqrt{5} + 30\sqrt{5} + 15\sqrt{20} + 10\sqrt{45})$

$\sqrt{20} = \sqrt{4 \times 5} = 2\sqrt{5}$

$\sqrt{45} = \sqrt{9 \times 5} = 3\sqrt{5}$

Perimeter = $(23\sqrt{5} + 30\sqrt{5} + 15 \times 2\sqrt{5} + 10 \times 3\sqrt{5})$

$= (23\sqrt{5} + 30\sqrt{5} + 30\sqrt{5} + 30\sqrt{5})$

$=113\sqrt{5}$

Figure 3. Figure 2. Students' Solution Strategy for Question 3.

In Figure 3, the students are unable to solve the problem by breaking it down into smaller sub-problems. This is evident from their approach, where they calculate the overall circumference directly without simplifying the problem into smaller parts. If the students had first simplified elements like the square root, it would have made solving the problem easier. It was observed that in solving step number 3, the students were not yet able to decompose the problem by dividing it into smaller sub-problems.

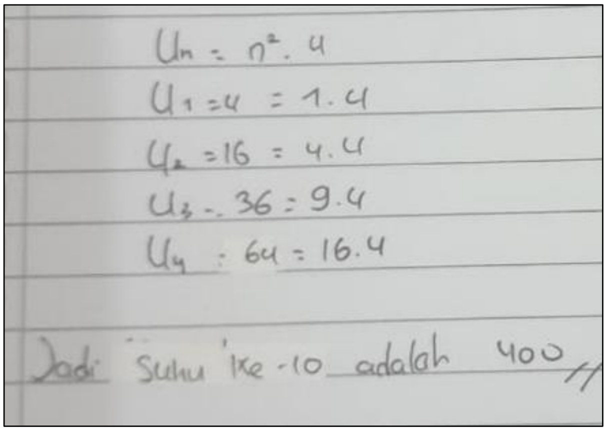
### *Analysis of Students' Ability on Pattern Recognition Indicators*

The question containing the pattern recognition indicator is found in question number 4.

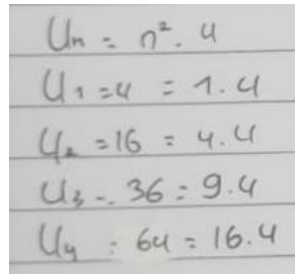
Question 4:

*What is the 10th term of the series: 22, 42, 62, 82, ...?*

Based on this question, students' answers were analyzed, and their solution strategies are presented in Figure 4.




*Translation*




So, the $10^{th}$ term is 400

Figure 4. Students' Solution Strategy for Question 4.

In Figure 4, it can be seen that the students are able to recognize the pattern of numbers with the given powers. Additionally, they can identify the pattern of the nth term, allowing them to determine the 10th term in the question. This indicates that the students have mastered the computational thinking indicator of pattern recognition.

Based on the results of the research conducted, there is a tendency for students to use computational thinking to solve each problem. In Figure 1, the students were able to identify key information in the given problem. For example, they ignored the price of banana leaves and focused solely on the quantity needed. If the students had considered the price, they might have struggled to understand its relevance to solving the problem. Thus, in the first step of question number 1, it was found that the students had successfully employed abstraction by focusing on the core issue and disregarding irrelevant details.

In Figure 2, the students solved the problem algorithmically or systematically. This is evident in the first step, where they calculated the load carried by each crate. Then, they determined how many crates could be transported based on the truck's load capacity, ultimately arriving at the total number of crates that could be moved. Therefore, in solving question number 2, it was found that the students were able to think algorithmically, solving the problem systematically.

In Figure 3, the students solved the problem by breaking it down into smaller sub-problems. They first calculated the circumference, then simplified the square root of the rope's availability, compared the available rope with what was needed, and finally concluded that the rope length was insufficient. In this case, it was observed that in solving question number 3, the students were able to decompose the problem by dividing it into smaller parts.

In Figure 4, it is clear that the students were able to recognize the pattern of numbers with given powers. Moreover, they identified the pattern of the nth term, which enabled them to determine the 10th term in the question. This indicates that the students mastered the computational thinking indicator of pattern recognition.

Based on this analysis, the students show great potential for further development. Students with high computational thinking abilities tend to achieve the best academic results in mathematics (Helsa, 2023). In addition, based on the results of the three students' work, it is evident that they have mastered aspects of algorithmic thinking, problem decomposition, abstraction, and pattern recognition. According to the interview results, this success can be attributed to the effective implementation of problem-based learning (PBL). Teachers were able to apply PBL optimally, allowing students to achieve each aspect of computational thinking being assessed. During PBL, teachers also conducted periodic evaluations and took various steps to address potential challenges, such as clearly defining assessment criteria from the outset, creating detailed rubrics, and providing a more comprehensive picture of student progress.

## CONCLUSION

Based on the research results, it was found that students whose teachers implemented problem-based learning (PBL) still did not demonstrate strong computational thinking skills. The implementation of PBL was not optimal, and the students' lack of familiarity with problem-solving made it difficult for them to effectively apply computational thinking skills. In conclusion, the use of PBL in mathematics learning—particularly with topics involving powers and root forms—has not yet helped students achieve strong computational thinking skills. As a recommendation for future research, learning can be enhanced by using other models or by optimizing the implementation of PBL to improve computational thinking abilities.

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