

# Enhancing Computational Thinking Skills in Solving Two-Variable Linear Equations through Problem-Based Learning in Indonesian Middle Schools

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## ABSTRACT

Computational thinking (CT) is a crucial 21st-century skill that enables individuals to think logically, creatively, and structurally. In mathematics, CT plays a vital role in problem-solving and conceptual understanding. This study examines students' mathematical computational thinking abilities in the context of two-variable linear equation systems. This research employs a descriptive qualitative approach involving 32 eighth-grade students. Data collection includes a test comprising four items aligned with CT indicators: decomposition, pattern recognition, abstraction, and algorithms. Additionally, four students were interviewed based on their performance to gain deeper insights into their CT processes. Findings indicate that students' computational thinking abilities significantly improved following the Problem-Based Learning (PBL) approach. High-performing students successfully demonstrated all CT indicators, effectively analyzing problems, identifying patterns, and applying structured solutions. However, students with lower competency levels struggled with problem identification, pattern recognition, and algorithmic implementation, indicating a need for targeted instructional support. The results underscore the importance of integrating CT into mathematics curricula to enhance logical reasoning and problem-solving skills. The challenges faced by some students highlight the necessity of differentiated instruction and scaffolding strategies to support CT development. This study emphasizes the role of PBL in fostering computational thinking in mathematics education. The findings provide valuable insights for educators and policymakers in designing curriculum strategies that align with 21st-century learning demands.

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## 1. INTRODUCTION

In the digital era, proficiency in problem-solving and higher-order thinking skills is essential for students to navigate complex challenges. Rosnawati (2012) defines complex thinking as a cognitive process involving multiple stages necessary for addressing intricate problems. This necessity has

driven the advancement of computational thinking, which encompasses problem-solving, system design, and data representation through simulations (Li et al., 2020; Haseski et al., 2018; Csizmadia et al., 2015; Wing, 2010; Dede et al., 2013). Seymour (1980; 1996) emphasizes that computational thinking extends beyond computer science, serving as a fundamental competency applicable across various disciplines. As a critical 21st-century skill, computational thinking is increasingly recognized as essential for modern education (OECD, 2019; Haseski et al., 2018). In mathematics education, integrating computational thinking into instruction enhances students' conceptual understanding, enabling them to develop logical reasoning and problem-solving strategies (Ramaila & Shilenge, 2023).

Despite its importance, challenges persist in Indonesian classrooms. In the PISA 2022 framework, computational thinking emerged as a key competency due to the increasing reliance on computational tools in daily life and mathematical problem-solving (Cormann, 2021). Alarmingly, 82% of Indonesian students aged 15 lack adequate understanding of mathematics, scoring an average of 366, well below the global average of 472 (OECD, 2023). This stagnation has persisted for over two decades, with Indonesia consistently ranking in the bottom 15 among participating countries since joining PISA in 2000. The lack of understanding and implementation of computational thinking skills within schools adversely impacts students' abilities.

The lack of understanding and implementation of computational thinking skills in the school environment naturally impacts students' low computational thinking abilities. Research by Kamil et al. (2021), which analyzes computational thinking skills in the context of number patterns in Grade IX, shows that 48% of students fall into the low category. This is marked by students' inability to write down the required information and correctly state the solution steps. These findings indicate a significant number of students struggle to apply computational thinking steps in mathematics. Kamil's research aligns with the findings of Jamna et al (2022), where the study on the computational thinking abilities of middle school students reveals that 5% of students are in the very high ability category, 10% are in the high ability category, meaning they meet all computational thinking indicators; 35% are in the moderate ability category, able to meet the indicators of decomposition and pattern recognition but lacking in algorithms and debugging; and 50% of students are in the low ability category, struggling to meet all computational thinking indicators.

To enhance students' computational thinking abilities, instructional models that foster these skills can be implemented. One such model is Problem-Based Learning (PBL). PBL is chosen because it guides students to focus on practising problem-solving skills, which are fundamental to computational thinking (Barrows, 1986). PBL is a learning model that uses meaningful problems as the basis for learning, ensuring that the acquired knowledge is long-lasting (Arends, 2008; Ward & Lee, 2002). The development of computational thinking through PBL involves activities such as exploring, developing skills, and actively working to solve real-world problems (Jonassen & Gram-Hansen, 2019; Hmelo-Silver, 2004). PBL positively impacts students' thinking abilities by enhancing curiosity, critical thinking, algorithmic skills, and problem-solving abilities (Ma et al., 2021; Rosnawati, 2018; Suhirman, 2021). According to Duch (Maulyda, 2020), problem-based learning is a learning model that uses real-world problems as a context for students to learn critical thinking, develop problem-solving skills, and acquire knowledge of core learning materials. This definition is reinforced by Rezio, Andrade, and Teodoro (2022), who define PBL as a teaching strategy in the field of mathematics that guides the learning process through problem-solving activities, providing opportunities for students to think critically, be creative, and interact mathematically with their peers.

The System of Linear Equations in Two Variables (SPLDV) is closely related to everyday life topics. However, many students still struggle to solve problems related to SPLDV. The majority of students have difficulty understanding concepts, developing new ideas, finding methods to solve SPLDV, and modeling mathematics to solve mathematical problems (Amalia et al., 2023; Bahir & Mampouw, 2020; Larasati & Julie, 2023; Farida & Lukman Hakim, 2021; Yahya, 2019). This is supported by research

conducted by Pebriyani (2020), which shows that 66.7% of students make errors in reading instructions and understanding concepts, and 77.8% make errors in the process of solving problems.

Based on the issues students face in solving SPLDV problems, the benefits provided by the PBL model have the potential to develop students' computational thinking, including decomposition, pattern recognition, abstraction, and algorithms. Previous research by Dewi et al (2024); Pratiwi & Akbar (2022) states that the PBL learning model positively influences students' computational thinking abilities. Additionally, research by Manullang & Simanjuntak (2023) indicates that learning using the Problem-Based Learning model has a greater impact on computational thinking skills. Despite several studies related to the PBL model and computational thinking, more research is needed to measure students' computational thinking abilities. The application of the PBL learning model is expected to help students systematically, effectively, and efficiently solve complex problems and provide opportunities for students to explore cognitive skills in mathematics. A learning model needs to be designed to train students to think like a computer, systematically, effectively, and efficiently in solving real-life problems. Therefore, this study aims to identify students' computational thinking abilities before and after the implementation of the PBL learning model in solving Systems of Linear Equations in Two Variables (SPLDV), specifically describe the challenges students face in solving SPLDV problems, and encourage them to solve problems through the integration of computational thinking steps such as decomposition, pattern recognition, abstraction, and algorithms.

## 2. METHODS

The approach used in this study was a mixed-methods approach with a sequential explanatory design. This research involved two stages of data collection procedures: the first stage included collecting quantitative data and analyzing the results, followed by collecting qualitative data to provide a more detailed explanation of the quantitative findings (Creswell & Creswell, 2022). Qualitative data were obtained through interviews regarding students' thinking processes about their written test answers, while quantitative data were obtained through test results consisting of four SPLDV questions. Quantitative data were used to assess the differences in the average computational thinking abilities of students before and after the application of the problem-based learning model in solving SPLDV problems. Meanwhile, qualitative data examined students' computational thinking abilities using mathematical concepts to solve problems based on very high, high, moderate, and low abilities.

This study was conducted in an eighth-grade class at a middle school in Yogyakarta, involving 32 students with varying academic abilities as research subjects. The sample for the qualitative research was selected using purposive sampling, with 4 students chosen based on very high, high, moderate, and low academic performance. The learning process took place over four sessions using student worksheets designed according to the Problem-Based Learning (PBL) model. The students' activities during the learning process are summarized in Table 1.

**Table 1.** Students' activities in PBL

No	Meeting	Student's Activities, Mathematical Content and Process
1	First	<p><b>Student orientation to the problem</b> – The teacher provided motivation to the students by presenting a contextual problem regarding the prices of flour and syrup from a store and prepared the students to actively engage in problem-solving.</p> <p><b>Organize student</b> - The teacher displayed a video for the students to observe regarding real-life problems related to the material on systems of linear equations in two variables (SPLDV).</p> <p><b>Individual and group research guide</b> – The students discussed with their classmates.</p> <p><b>Develop and present the work</b> – The teacher asked the students to present their findings in front of the class.</p> <p><b>Analyze and evaluate the problem-solving process</b> - The teacher analyzed and evaluated the activities that had been carried out by asking several questions to reinforce the material covered that day.</p>
2	Second	<p><b>Student orientation to the problem</b> - The teacher provided a picture related to economic activities, specifically about fruit prices per kilogram.</p> <p><b>Organize student</b> - The teacher divided the students into several groups, each consisting of 4 members.</p> <p><b>Individual and group research guide</b> - The students discussed with their group members.</p> <p><b>Develop and present the work</b> - The students created a mathematical model from the provided problem, converting the system of linear equations in two variables into a graphical form. The students reviewed their answers using the substitution method.</p> <p><b>Analyze and evaluate the problem-solving process</b> - The teacher analyzed and evaluated the activities that had been conducted by asking several questions to reinforce the material covered that day.</p>
3	Third	<p><b>Student orientation to the problem</b> - The teacher provided a real-life problem related to determining the area of a field.</p> <p><b>Organize student</b> - The teacher divided the students into several groups, each consisting of 4 members.</p> <p><b>Individual and group research guide</b> - The students discussed and filled out the LKPD worksheet.</p> <p><b>Develop and present the work</b> - The students created mathematical models based on the provided problem and solved it using the elimination method.</p> <p><b>Analyze and evaluate the problem-solving process</b> -. The teacher analyzed and evaluated the activities that had been carried out by asking several questions to reinforce the material learned that day.</p>
4	Fourth	<p><b>Student orientation to the problem</b> - The teacher provided a diagram to determine the house numbers in a cluster.</p> <p><b>Organize student</b> - The teacher divided the students into several groups, each consisting of 4 members.</p> <p><b>Individual and group research guide</b> – Students discussed with their group members.</p> <p><b>Develop and present the work</b> - Students created mathematical models from the provided problems and solved the SPLDV problems using a mixed-method approach.</p> <p><b>Analyze and evaluate the problem-solving process</b> - The teacher analyzed and evaluated the activities conducted by asking several questions to reinforce the material learned that day.</p>

The instrument of students' computational thinking was the long answer problems on the system of linear equations in two variables, adapted to the four aspects computational thinking by csizimadia (2015). These indicators were selected because they encompass essential steps in the process of solving complex mathematical problems. Each indicator plays a significant role in assessing students' abilities to understand, analyze, and solve problems using a systematic thinking approach, which is

relevant to the concept of the System of Linear Equations in Two Variables (SPLDV). The indicators can see in Table 2.

**Table 2.** The Indicators of students' computational thinking


Aspect of computational thinking	Indicator	No
Decomposition	Students were able to decompose data and problems into simpler parts.	1
Pattern recognition	Students were able to identify, recognize, and develop patterns or relationships to understand data or strategies used to solve a problem.	1
Algorithm	Students could organize the correct sequence of steps to obtain a solution to a problem.	2
Abstraction	Students were able to decide which information about an entity/object should be retained and which information should be disregarded.	3

Validation was conducted on the content of the instrument. This validation aimed to determine the extent to which the test could measure students' abilities (Allen & Yen, 1979). Content validity was established by obtaining assessments from mathematics education lecturers and mathematics teachers at the school. The results from the validators were calculated using ANATES. According to Retnawati (2016), if the validation results show a figure of 0.5, it is considered valid. In addition to the validity test, the instrument's reliability was calculated by testing it on five students from different classes. Reliability was calculated using Cronbach's Alpha formula with the aid of IBM SPSS 25 software. According to Ebel and Frisbie (1991), an instrument was considered reliable if the Cronbach's Alpha value was above 0.7. With a reliability value of 0.725, this instrument could be categorized as having adequate or good reliability. This meant that the instrument produced consistent and stable measurement results when it was used with different groups of students or at different times. The computational thinking questions on the pre-test and post-test had the same level of difficulty, but the number of contexts used differed. The post-test questions were presented in figure 1.

1. The difference between twice the first number and twice the second number is 4, and the difference between six times the first number and twice the second number is 12.

- Determine the first and second numbers!
- If the third number is -2, determine the fourth and fifth numbers?

2. Solve the problem below to the best of your ability!



During this semester break, Maya spends her vacation in Semarang city. Maya plans to buy Semarang's special souvenirs, which are lumpia and wingko babat, for her parents and friends. Maya buys 5 boxes of lumpia and 5 boxes of wingko for Rp280,000.00. Since it seems insufficient, Maya buys 5 boxes of lumpia and 7 boxes of wingko for Rp328,000.00.

- What is the price of one box of lumpia and wingko that Maya buys?
- Write down the procedure (steps) of the method you choose to solve the problem?

3. Solve the following problem to the best of your ability!

The Indonesian national team wins 6-0 against the Brunei Darussalam national team in the first round of the 2026 World Cup qualifiers at Gelora Bung Karno Stadium (GBK), Jakarta, on Thursday, October 12, 2023. Inside Gelora Bung Karno Stadium, there is a rectangular soccer field. The perimeter of the field is 346 m. If the difference between the length and width is 37 m, what is the area of Gelora Bung Karno Stadium?

**Figure 1.** The post-test instruments

Quantitative data from the post-test and pre-test results of students' computational thinking abilities were calculated using the formula:

$$Value = \frac{Scored\ Obtained}{Maximal\ Score} \times 100\%$$

A paired Sample T-Test was conducted using the paired sample T-Test method to examine the differences in the average computational thinking abilities of students in solving a system of linear equations in two variables before and after implementing learning with the PBL model. Prerequisite tests were conducted before performing the test for differences in means, including normality and homogeneity tests. The validity of qualitative and quantitative data was verified through the triangulation of semi-structured interviews. The assessment guide from the Ministry of Education and Culture (2017) was used to determine the categories of students' computational thinking abilities.

**Table 3.** Category of Computational Thinking

Score	Category
$90 \leq x < 100$	Very High
$80 \leq x < 90$	High
$70 \leq x < 80$	Medium
$X < 70$	Low

### 3. FINDINGS AND DISCUSSION

#### 3.1 Student's Computational thinking skills before and after problem-based learning

Table 4 presents the pre-test and post-test scores of the students, organized into four distinct proficiency categories: low, medium, high and very high. By categorizing the test results in this manner, the table provides a clear and structured comparison of student performance across different levels of achievement in both assessments.

**Table 4.** Grouping of Pre-Test and Post-Test Result of Student's

Interval	Category	Frequency (Pre-test)	Percentage (%)	Frequency (post-test)	Percentage (%)
$90 \leq x < 100$	Very High	1	3.125	4	12.5
$80 \leq x < 90$	High	1	3.125	10	31.25
$70 \leq x < 80$	Medium	3	9.375	4	12.5
$X < 70$	Low	27	84.375	14	43.75
	Total	32	100	32	100
Descriptive Statistics					
	Mean Score	Minimum Statistics	Maximum Statistics	Std Deviation Statistics	Variance Statistics
Pre-test	37.38	0	91	26.527	703.661
Post-test	62.06	2	98	28.568	816.125

The research results showed a difference in student learning outcomes between the pre-test and post-test. The pre-test was conducted to measure the initial abilities of the research subjects before implementing learning with the problem-based learning model. The data indicated that the average pre-test results were in the low category. This was because mathematics learning in schools still tended

to use a conventional approach focused on memorization without understanding the context of the problems, causing students to be less trained in critical and analytical thinking, which is the core of computational thinking.

Based on Table 4, it is observed that only one student achieves the very high category on the pre-test and the number increases to four students on the post-test. The percentage of students in the low computational thinking ability category shows a significant decrease from the pre-test to the post-test, dropping by 40.625%, from 84.375% in the pre-test to 43.75% in the post-test. Additionally, the number of students in the high-ability category increases from one student to ten students after implementing the PBL model. Similarly, the number of students with moderate ability increases from 9.37% to 12.5%. These changes indicate an improvement in students' computational thinking abilities after applying the PBL model.

After implementing the PBL model in mathematics learning, a paired sample t-test is conducted to assess the significant difference in pre-test and post-test scores. Preliminary tests, including normality and homogeneity tests, are performed first. The Kolmogorov-Smirnov normality test results in a value of 0.946, indicating that the data is normally distributed. The homogeneity test produces a significant value of 0.583, which exceeds 0.05, indicating that the pre-test and post-test data on students' computational thinking skills are homogeneous. After completing the prerequisite tests, a paired sample t-test is conducted to ensure a significant difference in the average computational thinking skills of students before and after the implementation of the PBL model. The hypothesis used is as follows:

*H<sub>0</sub>: There is no significant difference in the average computational thinking skills of students before and after the implementation of the PBL model.*

*H<sub>1</sub>: There is a significant difference in the average computational thinking skills of students before and after the implementation of the PBL model.*

**Table 5.** Result of paired sample t-test

Pair 1 pretest – posttest	Mean	t	df	Sig. (2-tailed)	95% confidence interval of the differesnce	
					Lower	Upper
	-24.688	-6.325	31	0.000	-32.649	-16.726

The results of the paired t-test are presented in Table 5. The test results show a significance value of  $0.000 < 0.05$ , indicating that  $H_0$  is rejected, thus there is a difference in the average computational thinking skills before and after the implementation of the PBL model.

### 3.2 Students' computational thinking skills in solving system of linear equations in two variable problems

In the process of qualitative data analysis, four students were selected to represent the categories of very high, high, medium, and very low in computational thinking skills in solving linear equations in two variables. The chosen subjects were S6 (low), S17 (medium), S9 (high), and S24 (very high).

#### 3.2.1 The answers from students with low computational thinking skills for Question 1

Question 1 represented an indicator of decomposition and pattern recognition in computational thinking. Through the decomposition indicator, students were expected to identify problems and break

down data into simpler parts. This was followed by pattern recognition, where students were expected to identify and recognize number patterns and develop strategies to solve the problem.

**Figure 2.** S6's answers in solving problem number 1

Based on S6's answer, they were not yet able to break down the problem from the given system of linear equations in two variables. S6 only made assumptions without outlining the next steps to obtain the values of the first and second numbers in order to answer the next question, which was to determine the values of the fourth and fifth numbers. To gain more in-depth information, an interview was conducted with S6.

- Researcher : Why didn't you answer question number 1?  
 S6 : I don't understand what the question means. I think the question is difficult.  
 Researcher : Try to write down what you know and understand about the question.  
 S6 : I can't solve it; the question is different from usual.

Based on the interview and the students' answers, the students struggled to understand the problem, as it was evident that they were unable to break down and model the problem into a mathematical form. Consequently, the student was unable to proceed with the problem-solving process in the aspect of pattern recognition.

### 3.2.2 The answers from students with medium computational thinking skills for Question 1

S17 has been able to model the linear combination system of two variables into a mathematical form, and disaggregate information so that it can determine the value of the first number, but when determining the values of the second number there is an error in the concept of division. So S17 cannot proceed to the second question, which is to determine the fourth and fifth numbers.

**Figure 3.** S17's answers in solving problem number 1

Subsequently, an in-depth interview was conducted with S17 to gather the information and troubleshooting strategies that had been written.

- Researcher : On question one, are you sure your answer is correct?  
 S17 : Yeah, I'm sure it's right. I've found great values of the first and second numbers.  
 Researcher : Let's see in determining the value of b, is it true like that?  
 S17 : Yeah, it's true. Why don't you answer the next question?

S17 : I didn't find any further patterns to find the fourth and fifth numbers, because the first number 2, the second number 8, and the third number -2.

Based on the interview, S17 demonstrated a good understanding of the problem. However, an error in algebraic operations prevented them from identifying the next number pattern needed to answer the following question. Based on their response, the student became confused because the subtraction result was 0, leading to the value of  $bb$  being 8. This indicates that the student experienced a misconception regarding division operations while solving the problem.

### 3.2.3 The answers from students with high computational thinking skills for Question 1

S9 has been able to decipher information from the linear cohesion system of two variables and determine the values of the first number, and the second number well. However, it cannot proceed to the second question of determining the fourth and fifth numbers.

a. Selisih 2 kali bilangan pertama dan 2 kali bilangan kedua = 4  
Selisih 6 kali bilangan pertama dan 2 kali bilangan kedua = 12

$$\begin{array}{r} 2x + 2y = 4 \\ 6x + 2y = 12 \\ \hline -4x = -8 \\ x = 2 \end{array}$$

Substitusi  $x = 2$  ke  $2x + 2y = 4$

$$\begin{array}{r} 2x + 2y = 4 \\ 2(2) + 2y = 4 \\ 2y = 4 - 4 \\ y = \frac{0}{2} \\ y = 0 \end{array}$$

The difference between 2 times the first number and 2 times the second number is 4.  
The difference between 6 times the first number and 2 times the second number is 12.

b. Bilangan ke hgo -2  
Bilangan k-4 dan k-5 ?

Third number is -2  
4th and 5th number?

Figure 4. S9's answers in solving problem number 1

Interviews were conducted with S9 to gather information and troubleshooting strategies that had been written.

Researcher : On question one, are you sure your answer is correct?

S9 : Yeah, I'm sure it's right. I've found great values of the first and second numbers.

Researcher : Why don't you answer the next question?

S9 : I'm still confused about finding the next number pattern.

Based on the interviews, S9 understands the problem well and runs the process systematically. But the ability to recognize patterns is still unfulfilled, so it can't find the next number pattern to answer the next question.

### 3.2.4 The answers from students with very high computational thinking skills for Question 1

S24 answered question 1 skillfully. S24 has met the computational thinking indicators of decomposition and pattern recognition very well.

a) Bilangan pertama : a  
Bilangan kedua : b

$$\begin{array}{r} 2a - 2b = 4 \\ 6a - 2b = 12 \quad - \\ \hline -4a = -8 \\ a = -8 / -4 \\ a = 2 \end{array}$$

$$\begin{array}{r} 2a - 2b = 4 \quad | \times 6 \quad | 12a - 12b = 24 \\ 6a - 2b = 12 \quad | \times 2 \quad | 12a - 4b = 24 \quad - \\ \hline -8b = 0 \\ b = 0 / -8 \\ b = 0 \end{array}$$

b) Bilangan pertama : 2      Jadi, 2, 0, -2, -4, -6  
Bilangan kedua : 0      bilangan keempat -4  
Bilangan ketiga : -2      bilangan kelima -6  
Bilangan keempat : -4  
Bilangan kelima : -6

Figure 5. S24's answers in solving problem number 1

In-depth interviews were conducted with S24 in order to obtain information on the problem-solving strategy used.

- Researcher : On question one, are you sure your answer is correct?  
S24 : Yeah, I'm sure it's right. I've found the big values of the first and second numbers and found the number patterns to determine the value of the fourth and fifth numbers.
- Researcher : What method did you choose to solve the matter?  
S24 : I used the elimination method, first I eliminated b to find the value of a which is the first number. Then I eliminate a to obtain the value b which is a second number.
- Researcher : How did you determine the values of the fourth and fifth numbers?  
S24 : I have previously found the values of the first and second numbers 2 and 0. In the case of known the third number is -2. So obtained the row of numbers 2, 0, -2. From this row it is seen that any number minus 2, then it can be determined the value of the fourth number and the word is -4 and -6.

Based on the interview, S24 has met the decomposition indicators and pattern recognition of computing thinking abilities very well. S24 is able to decipher information on the subject to find the values of the first and second numbers, which then find the patterns of the row of numbers in determining the value of the fourth and fifth numbers.

### 3.2.6 The answers from students with low computational thinking skills for Question 2

Question number two represents the algorithm indicator of computational thinking. In question number two, students are asked to put together the correct sequence of steps to get a solution to a problem.

$$\begin{array}{l}
 1 \text{ Kotak lumpia : } L \\
 1 \text{ Kotak wingko : } W \\
 \\
 5L + 5W = 280.000 \\
 5L + 7W = 328.000 \quad - \\
 \hline
 -2W = -48.000 \\
 W = 24.000 \\
 \\
 5L + 5W = 280.000 \quad | \cdot 7 \quad | \quad 35L + 35W = 196.000 \\
 5L + 7W = 328.000 \quad | \cdot 5 \quad | \quad 25L + 35W = 1640.000 \quad - \\
 \hline
 10L \quad \quad = 1444.000 \\
 L \quad \quad = 144.400
 \end{array}$$

**Figure 6.** S6's answers in solving problem number 2

S6 was able to compile a sequence of steps in determining the price of one wingko box, but had an error in calculating the value of one lumpia box. In the process of drafting a strategy, S6 didn't write it down. To find out more detailed information, interview S6.

Researcher : How did you formulate a strategy in solving issue number two?

S6 : I'm doing an elimination, and using the elimination method.

Researcher : Are you sure of your answer?

S6 : Actually, I'm not sure about the value of the lumpia price. Because it's too high.

Based on interviews and students' answers, it can be concluded that students have been able to decide on strategies for solving mathematical problems. However, the execution is still experiencing calculation errors, resulting in confusion when moving on to the next step.

### 3.2.7 The answers from students with high computational thinking skills for Question 2

$$\begin{array}{l}
 a. \text{ Lumpia : } x \\
 \text{Wingko : } y \\
 \\
 (I) \quad 5x + 5y = 280.000 \\
 (II) \quad 5x + 7y = 328.000 \quad - \\
 \hline
 -2y = -48.000 \\
 y = 24.000 \\
 \\
 5x + 7y = 328.000 \\
 5x + 7(24.000) = 328.000 \\
 5x + 168.000 = 328.000 \\
 5x = 328.000 - 168.000 \\
 5x = 160.000 \\
 x = \frac{160.000}{5} \\
 x = 32.000
 \end{array}$$

**Figure 7.** S9's answers in solving problem number 2

S9 has answered the question number 2 correctly, which is to determine the value of the price of a box of lumpia and one box of wingko. For that, an interview was conducted to get in-depth information on the answers from S9.

Researcher : How did you formulate a strategy in solving issue number two?  
 S9 : I'm doing the distribution of the lumpia value as  $x$  and the wingko value as  $y$ . Then make a mathematical model of the known information.  
 Reasearcher : How did you find the price value of wingko and lumpia, explain?  
 S9 : First, I did an elimination method to find the wingko price value. Next, I subtitled the wingko price to one of the equations to find a lumpia price value.

Based on interviews conducted, the S9 has met the indicator thinking computing part of the algorithm. S9 is able to determine the strategy in determining the price value of 1 lumpia box and 1 wingko box. It's just that S9 doesn't write down the strategy used in detail on the question answer sheet. For more detailed information, an interview with S9 was conducted.

### 3.2.8 The answers from students with very high computational thinking skills for Question 1

<p>a. Misalkan  <math>x</math> : 1 kotak lumpia  <math>y</math> : 1 kotak wingko</p> <p>• Eliminasi  <del><math>5x + 5y = 280.000 \dots (1)</math></del>  <del><math>5x + 7y = 328.000 \dots (2)</math></del>  <hr style="width: 100px; margin-left: 0;"/> <math>-2y = -48.000</math>  <math>y = \frac{-48.000}{-2}</math>  <math>y = 24.000</math></p> <p>• Substitusi <math>y = 24.000 \dots (1)</math>  <math>5x + 5y = 280.000</math>  <math>5x + 5(24.000) = 280.000</math>  <math>5x + 120.000 = 280.000</math>  <math>5x = 160.000</math>  <math>x = 32.000</math></p>	<p>Jadi harga 1 kotak lumpia adalah 24.000 dan harga 1 kotak wingko 32.000.</p> <p>b. 1. Memisalkan 1 kotak lumpia sebagai <math>x</math> dan 1 kotak wingko <math>y</math>                  2. Eliminasi nilai <math>x</math> untuk memperoleh nilai <math>y</math> (1 kotak wingko)                  3. Substitusi nilai <math>y</math> ke persamaan 1 untuk memperoleh nilai <math>x</math> (1 kotak lumpia)                  4. Menyimpulkan.</p>	<p>So the price of 1 box lumpia is 24.000 and the price of 1 box of wingko is 32.000</p>
		<ol style="list-style-type: none"> <li>1. Let 1 box of lumpia be <math>x</math> and 1 box of wingko be <math>y</math></li> <li>2. Eliminate the <math>x</math> value to get the <math>y</math> value (1 box of wingko)</li> <li>3. Substitute the <math>y</math> value into equation 1 to get the <math>x</math> value (1 lumpia box)</li> <li>4. conclude</li> </ol>

Figure 8. S24's answers in solving problem number 2

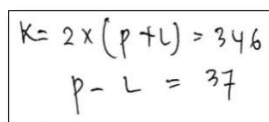
S24 had answered question number 2 perfectly. S24 met the algorithm indicators of computational thinking. Furthermore, an interview was conducted to understand S24's strategy in solving the linear equations system of two variables.

Researcher : How did you devise a strategy to solve question number 2?  
 S24 : The first step I took was to consider  $x$  as the price of 1 box of lumpia, and  $y$  as the price of 1 box of wingko.  
 Researcher : What method did you use to find the price of wingko and lumpia? Please explain.  
 S24 : The method I used was the mixed method. First, I used the elimination method to find the price of wingko. Then, I substituted the price of wingko into one of the equations to find the price of lumpia. I concluded that the price of 1 box of lumpia was Rp24,000, and the price of 1 box of wingko was Rp32,000.

Based on the interview conducted, S24 had met the algorithm indicators very well. S24 was able to devise a strategy for solving the system of linear equations effectively and efficiently, then described the step-by-step strategy used in sentence form.

### 3.2.9 The answers from students with low computational thinking skills for Question 3

Question number 3 represented the abstraction indicator of computational thinking. In question number 2, the students were asked to decide what information about a known entity/object should be retained and what information should be ignored. Question number 2 was related to determining the area of a field when the perimeter of the field and the difference between the length and width of the field were known.



$$K = 2 \times (p + l) = 346$$

$$p - l = 37$$

**Figure 9.** S6's answers in solving problem number 3

S6 wrote a mathematical model for the perimeter of the field and the difference in length and width but did not continue the information obtained to the next step. To gain deeper insights, an interview was conducted with S6.

*Researcher* : How did you simplify this problem to make it easier to understand?

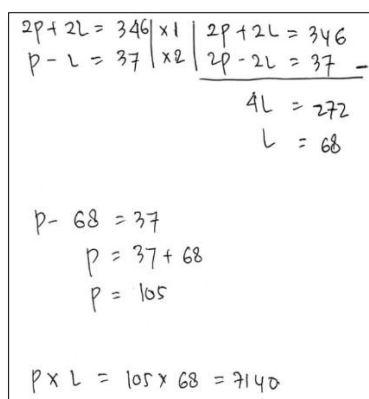
S6 : From the information provided in the question, I found that the perimeter of the field was 346 m<sup>2</sup> and the difference in length and width was 37 m.

*Researcher* : What patterns or similarities did you find in the question?

S6 : I was confused about how to continue my answer because the mathematical model was different from what I'm used to.

Based on the interview and S6's answers, S6 was not yet able to simplify the important information obtained and had difficulty managing the complexity of the problem. This indicates that the student relied on examples or underlying concepts.

### 3.2.10 The answers from students with medium computational thinking skills for Question 3



$$\begin{array}{l} 2p + 2l = 346 \quad \times 1 \\ p - l = 37 \quad \times 2 \\ \hline 2p + 2l = 346 \\ 2p - 2l = 74 \quad - \\ \hline 4l = 272 \\ l = 68 \end{array}$$

$$p - 68 = 37$$

$$p = 37 + 68$$

$$p = 105$$

$$p \times l = 105 \times 68 = 7140$$

**Figure 10.** S17's answers in solving problem number 3

In general, S17's answer was correct, but they did not specify the important elements of the problem in detail. Therefore, an in-depth interview was conducted with S17 to understand the meaning of the answer given.

- Researcher : How did you simplify this problem to make it easier to understand?  
 S17 : From the problem, I obtained the information that the perimeter of the field was 346 m<sup>2</sup> and the difference in length and width was 37 m. To determine the area of the field, I had to find the length and width of the field.
- Researcher : What would happen if one of the elements of this problem were removed?  
 S17 : Of course, it would be impossible to determine the area of the field. This is because the perimeter of the field and the difference between the length and width are interconnected in determining the length and width. For this reason, I used a mixed method.

Based on the interview and S17's answers, S17 was able to identify the key elements of the problem and ignore irrelevant details. S17 was able to conceptually transform the information and understand how these elements are interconnected in a broader context.

### 3.2.11 The answers from students with very high computational thinking skills for Question 3

Misalkan  
 p : panjang  
 l : lebar

Keliling :  $2p + 2l = 346 \dots (I)$   
 Selisih panjang & lebar :  $p - l = 37 \dots (II)$

$$\begin{array}{r|l} 2p + 2l = 346 & | \quad 2p + 2l = 346 \\ p - l = 37 & | \quad 2p + 2l = 74 \quad - \\ \hline & 4l = 272 \\ & l = \frac{272}{4} \\ & l = 68 \end{array}$$

Substitusi  $l = 68$  ke persamaan (II).

$$\begin{array}{l} p - l = 37 \\ p - 68 = 37 \\ p = 37 + 68 \\ p = 105 \end{array}$$

Jadi, Luas lapangan =  $p \times l = 105 \times 68 = 7140 \text{ m}^2$

Figure 11. S24's answers in solving problem number 3

S24 had written the answer perfectly. Based on the answer provided, S24 was able to identify the key elements of the problem and ignore irrelevant details. Additionally, S24 was able to clearly represent abstract concepts, showing the core structure of the problem. To gain deeper insight, an interview was conducted with S24.

- Researcher : How did you simplify this problem to make it easier to understand?  
 S24 : From the problem, I obtained the information that the perimeter of the field was 346 m<sup>2</sup> and the difference in length and width was 37 m. To determine the area of the field, I had to find the length and width of the field.
- Researcher : What would happen if one of the elements of this problem were removed?  
 S24 : It would be impossible to determine the area of the field. This is because the perimeter of the field and the difference between the length and width are interconnected in determining the length and width. For this reason, I used a mixed method.
- Researcher : How did you break this problem down into smaller parts?

S24 : I identified the information provided, then determined the relevant formula from the question. Based on the information, I had to focus on determining the length and width of the field. After obtaining the length and width, I could substitute them into the area formula. The final result I obtained was that the area of the field was  $7,140 \text{ m}^2$ .

Based on the interview and S24's answers, S24 was able to identify the key elements of the problem and ignore irrelevant details. S24 was able to conceptually transform the information and understand how these elements were interconnected in a broader context.

The analysis results showed a difference in the average computational thinking ability of students before and after the learning process using the PBL model. Test results and interviews revealed that eighth-grade students who met the indicators of very high computational thinking ability mastered the four computational thinking indicators: decomposition, pattern recognition, abstraction, and algorithms. However, students with low computational thinking ability had not met these indicators due to their inability to break down information, recognize patterns, abstract information, and determine effective strategies for solving problems.

This aligns with previous research by Pratiwi & Akbar (2022) and Dewi et al. (2024), which found significant differences in students' computational thinking ability when applying the problem-based learning (PBL) model. Similarly, Asokawati et al. (2023) stated that if PBL is well-designed and actively involves students in the learning process, it can continuously encourage critical thinking and creativity. In addition, PBL has been proven to help students develop higher-order thinking skills and problem-solving abilities. PBL enables students to confront real-world problems, providing hands-on learning experiences that help them develop thinking and problem-solving skills applicable to more complex situations (Choon et al., 2021 & Low, 2024).

Research by Yohannes et al. (2021) demonstrated that the PBL model could improve students' critical thinking skills in mathematics. The challenges presented in PBL not only reflect real-world difficulties but also include simulations designed to enhance students' problem-solving and critical thinking abilities (Yulianti et al., 2023). It can therefore be concluded that PBL can serve as an effective alternative teaching method. The systematic integration of the PBL model can encourage students to develop critical, creative, and computational thinking skills. By engaging students in solving real-world problems, providing hands-on learning experiences, and fostering higher-order thinking skills, PBL plays a crucial role in enhancing students' critical thinking abilities across various subjects.

Findings from the study revealed several characteristics of PBL during implementation. PBL emphasizes group-based learning, which requires extended time for discussion. This point is supported by Arends & Kilcher (2010), who stated that PBL involves a series of stages: initiation, planning, investigation, and demonstration. Additionally, Schmidt outlined the characteristics of PBL as follows: (a) problems act as drivers for learning, (b) students work in groups for a certain period during the learning process, (c) teachers function as facilitators and guide learning activities, (d) learning involves the teacher's active role, (e) students are consciously engaged in the learning process, and (f) the curriculum prioritizes self-directed learning. These stages and characteristics often demand substantial time, making it a challenge to implement PBL within the limited timeframes available in schools. Teachers must address this by designing more flexible learning schedules to allow students ample time for discussion and exploration of knowledge. The group-based learning approach used in PBL can also incorporate differentiated instruction to maintain student engagement across varying ability levels.

#### 4. CONCLUSION

There was a difference in the average computational thinking ability of students before and after the learning process using the PBL model. PBL became an effective alternative teaching method for improving students' computational thinking ability. By engaging students in solving real-world problems, providing hands-on learning experiences, and developing higher-order thinking skills, PBL played an important role in enhancing students' critical thinking abilities across various subjects. Eighth-grade students who met the indicators of very high computational thinking ability had mastered the four indicators of computational thinking: decomposition, pattern recognition, abstraction, and algorithm. However, students with low computational thinking ability had not yet met these indicators.

This study only covered three problems and used a limited context. Future research is expected to develop instruments and expand them to other cognitive variables. Expanding these instruments could include areas such as literacy, mathematical reasoning, and other cognitive skills, allowing for a more comprehensive understanding of how PBL affects different aspects of student learning. Additionally, the implications of using PBL to foster computational thinking in classrooms should be explored further. Teachers and policymakers could benefit from practical strategies and guidelines that stem from the findings, such as integrating PBL more systematically into curricula and providing targeted training for educators to effectively implement this approach in diverse educational settings.

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