

Assessing seventh-grade students' computational thinking skills through problem-based learning: Focus on integer addition and subtraction

Hapizah*, Anadia Muli Mariela, Budi Mulyono

Universitas Sriwijaya, Sumatera Selatan, Indonesia

* Correspondence: hapizah@fkip.unsri.ac.id

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Abstract

Computational thinking is a crucial skill that facilitates problem-solving for students. Recognizing its importance, the PISA 2021 framework incorporates computational thinking to enhance problem-solving and mathematical reasoning abilities. However, the proficiency of students in computational thinking remains low in Indonesia due to its infrequent integration into the curriculum. This study aims to evaluate students' computational thinking skills based on the indicators of decomposition, pattern recognition, abstraction, and algorithmic thinking following the implementation of computational thinking-based learning using the Problem-based Learning (PBL) model, specifically on integer addition and subtraction. The research involved 28 seventh-grade students from SMP Negeri 54 Palembang during the first semester of the 2023/2024 academic year. Data were collected through tests and interviews. The findings indicate that students' computational thinking skills are at a medium level. Furthermore, the study examines students' abilities concerning specific computational thinking indicators. It underscores the impact of computational thinking-based learning in enhancing students' ability to design and develop structured and systematic problem-solving strategies.

Keywords: addition, computational thinking, integer, seventh-grade students, subtraction

Introduction

Mathematics serves as a foundational discipline crucial for mastering essential skills among students (Zakiyah et al., 2019), playing a pivotal role in scientific and technological advancements while fostering analytical thinking (Parulian, 2019). According to Regulation No. 22 of 2016 by the Minister of National Education, mathematics education aims to equip

students with problem-solving abilities encompassing problem understanding, model design, solution execution, and accuracy in outcomes (Depdiknas, 2016).

Integer concepts constitute fundamental knowledge necessary for subsequent learning in junior high school (Sidik & Wakih, 2020; Unaenah et al., 2020), focusing particularly on addition and subtraction operations. Proficiency in these operations is vital for practical applications such as age calculations, medication dosages, and measurement tasks (Dewi & Prihatnani, 2022). However, students often face challenges in mastering these operations, particularly in handling integers with different signs and conceptualizing word problems into mathematical equations (Yanala et al., 2021; Ariesandi, 2021).

These difficulties are exacerbated by insufficient critical thinking and analytical skills among students (Saraswati & Agustika, 2020), as reflected in global assessments like the 2018 PISA results indicating below-average mathematical proficiency. Addressing these challenges necessitates integrating computational thinking—a cognitive approach involving problem-solving, system design, and human behavior understanding rooted in computer science principles (Wing, 2010; Wu & Yang, 2022; Kamil, 2021).

Computational thinking emphasizes decomposition, pattern recognition, abstraction, and algorithm development as core skills for problem-solving (Junpho, et al., 2022; Kallia, et al., 2021). These skills enable students to break down complex problems, identify patterns, distill essential information, and devise systematic solutions (Durak et al., 2019).

Despite its integration into education systems globally, computational thinking's application remains limited in Indonesia's mathematics education (Junpho et al., 2022). This gap hinders the development of students' computational thinking skills, particularly in handling integers and analyzing problem patterns effectively (Jamalludin, 2022; Kamil et al., 2021).

Research efforts exploring computational thinking in educational contexts have shown promising outcomes, such as improved critical thinking skills through targeted teaching materials and methodologies (Litia et al., 2023; Rahmania et al., 2023). However, there is a notable research gap in applying computational thinking specifically to integer operations, highlighting the need to investigate its impact on students' mathematical abilities, focusing on addition and subtraction of integers.

This study proposes to address this gap by employing the Problem-Based Learning (PBL) model to introduce innovative teaching materials aimed at assessing seventh-grade students' computational thinking skills in integer addition and subtraction. By integrating computational thinking into mathematics education, this research seeks to enhance students' computational thinking skills and contribute to the advancement of effective teaching strategies in Indonesia.

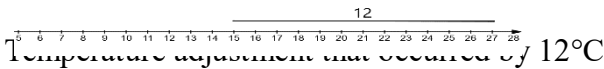
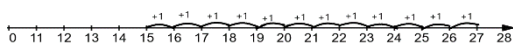
Methods

This research is a descriptive study employing a qualitative approach to explore students' computational thinking abilities in mathematics learning, specifically focusing on the addition and subtraction of whole numbers. The study involves 28 seventh-grade students from SMP Negeri 54 Palembang, conducted during the odd semester of the 2023/2024 school year.

Data Collection

The study employs a written test comprising three questions, each containing five prompts aligned with indicators of computational thinking. These indicators include decomposition, pattern recognition, abstraction, and algorithm. The test data analysis will serve as a basis for evaluating students' computational thinking abilities by the end of the study. Table 1 presents the specific test questions administered to the participants.

Table 1. Test Question

Question	Answer
A group of 5 students will climb Mount Dempo, which has an altitude of 3,142 <i>m</i> above sea level. While climbing the mountain, one student found out that the temperature at an altitude of 1000 <i>m</i> above sea level is 27°C and will continue to fall by 1°C every 100 <i>m</i>. After climbing for 6 hours, it is known that the temperature of the mountain is 15°C, so at what altitude is the student? a. What information do you know from the problem above? b. Write down what you need to do to solve the problem! c. Write down the strategies that you can use to solve the problem! d. Based on the strategy you have created, what are the important information that can be used to solve the problem? e. From the key information and strategies, you have created, write down the steps to solve the problem!	a. - Number of people climbing = 5 - Mountain elevation = 3,142 meters above sea level - Temperature at 1000<i>m</i> above sea level = 27°C - Temperature drop of 1°C every 100 <i>m</i> - Climbing time = 6 hours b. 1) Calculate the temperature drop that occurs 2) Calculate the number of times the temperature drop occurs 3) Determine the height of the mountain when it reaches a temperature of 15°C c. 1) Using a number line to calculate temperature drop 2) Using the pattern of temperature drop to calculate how many times the temperature dropped 3) Using addition and subtraction to calculate the height of the mountain when the temperature is 27°C d. - Temperature at 1000<i>m</i> above sea level = 27°C - Temperature drop of 1°C every 100<i>m</i> e. 1) Calculating temperature drop using a number line  2) Counting the number of times the temperature drops  3) Calculating the height of the mountain when it reaches 15°C = number of temperatures drop events × temperature drop distance + mountain height at 27°C

Question	Answer
	$= (12 \times 100) + 1000 = 2.2000$
	So, the temperature of the mountain will reach 15°C when it is at an altitude of 2.200m above sea level.

Following the written test on computational thinking, semi-structured interviews were conducted with 3 research subjects categorized into high, medium, and low computational thinking ability groups. The interviews were designed to complement the data obtained from the test questions by providing additional insights into how students approached and understood the questions. The interview questions were guided by a predefined set of guidelines to ensure consistency and relevance in gathering comprehensive information about the students' problem-solving approaches.

Data Analysis

The data obtained from the written test results will be analyzed and scored based on predefined scoring guidelines for computational thinking ability, as presented in [Table 2](#). These guidelines are designed to ensure consistent and objective evaluation of students' performance across the indicators of computational thinking, including decomposition, pattern recognition, abstraction, and algorithm.

Table 2. Scoring Guidelines for Computational Thinking Skills

Score	Decomposition	Pattern Recognition	Abstraction	Algorithm
0	No answer			
1	Students are able to describe the problems in the problem but are incomplete and ineffective	Students are able to relate concepts, formulas or materials contained in the problem but do not use them to solve problems.	Students are able to separate the unimportant parts of the problem but only a few are taken.	Students are able to solve problems but not sequentially and not according to mathematical rules so that there are errors.
2	Students are able to describe the problems in the problem effectively but incompletely	Students are able to relate concepts, formulas or materials contained in the problem but do not use them appropriately to solve problems.	Students are able to separate the unimportant parts of the problem but not completely	Students are able to solve problems sequentially but not according to mathematical rules
3	Students are able to describe the problems in the problem	Students are able to relate concepts, formulas or materials contained in the problem and	Students are able to sort out the unimportant parts of the problem but do not find the key	Students are able to solve problems according to mathematical rules but not sequentially

Score	Decomposition	Pattern Recognition	Abstraction	Algorithm
4	completely but ineffectively Students are able to describe the problems in the problem completely and effectively	use them to solve problems but not accurately. Students are able to relate concepts, formulas or materials contained in the problem and use them to solve problems precisely and accurately.	elements of the problem. Students are able to sort out the unimportant parts of the problem and find the key elements of the problem completely.	Students are able to solve problems sequentially and according to mathematical rules.

After scoring the test results of each student, then the total scoring will be carried out as follows:

$$\text{Score} = \frac{\text{number of scores obtained}}{\text{maximum number of scores}} \times 100$$

The test results obtained by each student will be categorized based on the level of computational thinking ability. The categories of students' computational thinking ability are shown in [Table 3](#).

Table 3. Category of Computational Thinking Ability

Category Score	Category
$N \geq (\bar{x} + SD)$	High
$(\bar{x} - SD) < N < (\bar{x} + SD)$	Medium
$N \leq (\bar{x} - SD)$	Low

Data obtained through interviews will be qualitatively analyzed using the Miles and Huberman model, involving stages of data reduction to simplify and focus on research objectives, followed by data presentation in a structured format, such as a table of questions and answers, to enhance clarity and convey information effectively. Finally, conclusions will be drawn based on the organized data presentation, summarizing findings to be included in the study's final report.

Results and Discussion

This study examines students' computational thinking abilities based on indicators of decomposition, pattern recognition, abstraction, and algorithm following the implementation of mathematics learning infused with computational thinking using a Problem-Based Learning (PBL) model. The implementation spanned two sessions, where students received student worksheets as teaching materials and collaborated in groups to solve problems. Each group had an observer monitoring student activities. The learning sessions included two different

worksheets, with offline meetings allocated 80 minutes each and online meetings 60 minutes each. [Figure 1](#) illustrates the activities during offline meetings.

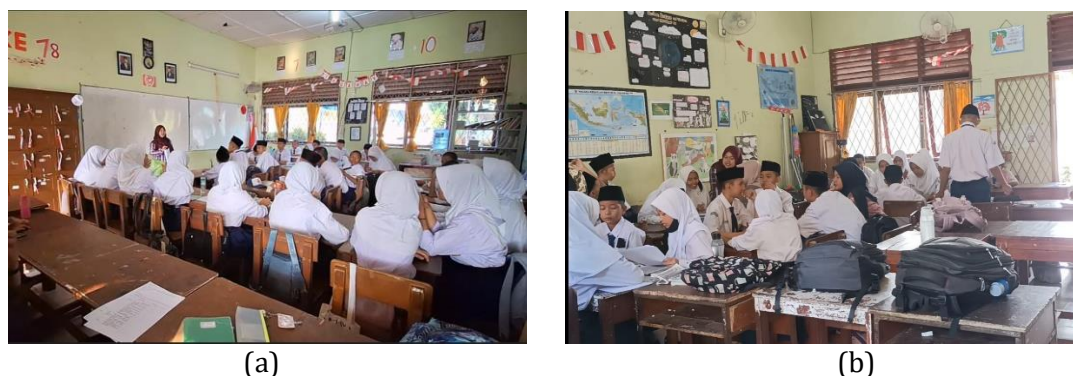


Figure 1. Learning Activities Based on Computational Thinking

The test was administered after implementing mathematics learning with a Problem-Based Learning (PBL) approach oriented towards computational thinking. It was conducted online using Google Meetings, with a duration of 2 lesson hours (60 minutes). From the test results, it was observed that some students were unable to answer all questions. [Table 4](#) presents the maximum score, minimum score, and average score obtained from the test results.

Table 4. Maximum and Minimum Scores Obtained by Students

Number of Students	Minimum Score	Maximum Score	Average	Standard Deviation
28	0	63	24	18.16

The test results, conducted with 28 students, yielded an average score of 24. Scores ranged from a minimum of 0 to a maximum of 63. The categorization of students' computational thinking abilities based on these test results is presented in [Table 5](#).

Table 5. Student Test Results' Category

Category Score	Number of Students	Percentages	Category
$N \geq 42,16$	5 People	17.86%	High
$5,84 < N < 42,16$	18 People	64.28%	Medium
$N \leq 5,84$	5 People	17.86%	Low

Researchers also analyzed the manifestation of indicators of students' computational thinking abilities, with the average scores for these indicators presented in [Table 6](#).

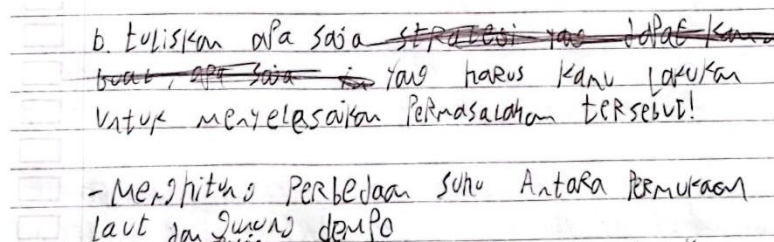
Table 6. Percentage of Student Ability Based on Computational Thinking Indicators

Computational Thinking Indicators	Percentage
Decomposition	50 %
Pattern Recognition	21.43 %
Abstraction	42.86 %
Algorithm	60.71 %

The computational thinking indicators were evaluated based on students' answers. Upon analyzing the responses, researchers identified instances where students' answers did not align with the indicators of computational thinking. The descriptions of answers that deviated from these indicators are as follows:

Decomposition

For the decomposition indicator, students are expected to break down the problem into simpler and more manageable stages. The stages outlined by the students should represent the steps necessary to solve the problem.

**Figure 2.** Student's Answer Not Aligned with the Decomposition Indicator

As illustrated in Figure 2, the student's answer does not align with the decomposition indicator, indicating an inability to break down the problem into simpler, more manageable parts. The student's response merely outlines the steps for calculating the difference in sea surface temperature and Mount Dempo, which are not the necessary stages to solve the given problem. The stages written are insufficient for addressing the problem comprehensively. The results of the interview with the student are as follows:

- P : In question b, we are asked to write down what we have to do, if from your answer we have to calculate the temperature difference between the surface of the ocean and the mountain. Can you explain what that means?*
- C : Yes, so we want to find the height of the mountain where the students are. So we have to find the temperature difference from the initial temperature when we want to climb to the temperature after the students go up.*

The results of problem-solving and student interviews indicate that students can verbally decompose problems by mentioning several stages of completion. However, based on the student's response in Figure 2, the answer does not align with the decomposition indicator. This suggests that the student's decomposition ability is still low, as they have not been able to articulate the simpler and more manageable stages required to solve the problem effectively.

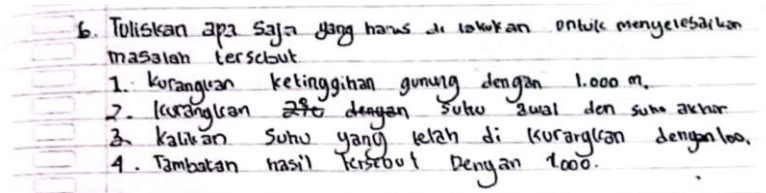


Figure 3. Student's Answer Aligned with the Decomposition Indicator

In Figure 3, the student's answer demonstrates an ability to decompose the problem effectively. Based on Figure 3, the student's response aligns with the decomposition indicator, as they have broken down the problem into several stages: 1) Subtracting the height of the mountain by 1000m, 2) Subtracting the initial temperature from the final temperature, 3) Multiplying the resulting temperature difference by 100, and 4) Adding the product to 1000. These steps represent the correct approach to solving the problem according to the decomposition indicator. The results of the interview with the student are as follows:

P : What do you think we should do to find the height of the student?

FQ : What we have to do is like what we have written in the answer. First we have to reduce the height of the mountain by 1000m. then subtract the initial temperature from the final temperature. After that multiply the temperature that has been reduced by 100. Finally add the result to 1000.

The results of problem-solving and interviews demonstrate that the student's decomposition ability is excellent. The student is able to articulate and write down simpler and more manageable stages required to solve the problem on the answer sheet, as well as verbally explain these stages effectively.

Pattern Recognition

For the pattern recognition indicator, students are expected to identify and associate existing problems with relevant concepts, formulas, or previously learned material to solve the given problems.

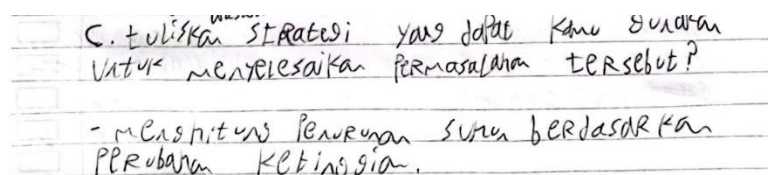


Figure 4. Student Answer Not Aligned with the Pattern Recognition Indicator

Figure 4 illustrates a student's response that fails to recognize patterns, concepts, or material necessary to solve the problem in accordance with the pattern recognition indicator. However, at this stage, the student (Student 1) outlined the steps required to solve the problem, as shown in Figure 4, which involves breaking down the problem into simpler stages—a feature of the decomposition indicator. The results of the interview with Student 1 regarding the pattern recognition indicator are as follows:

P : What is the concept or material used in solving the problem?

CA : The same as question b, we have to find the difference in temperature but by adding and subtracting.

The results of the interview with Student 1 indicated a lack of understanding of the guiding question related to the pattern recognition indicator. This is evident from the student's answers, both in the problem-solving task and the interview, which show an inability to recognize patterns and associate them with relevant concepts, formulas, or materials necessary for problem-solving.

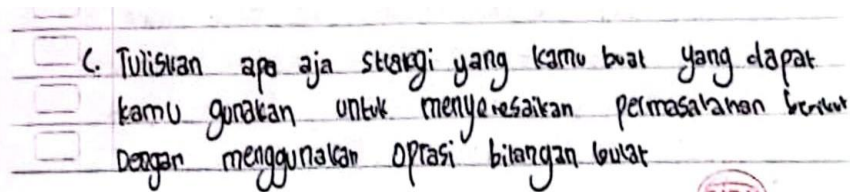


Figure 5. Student Answers Aligned with the Pattern Recognition Indicator

Figure 5 illustrates student responses that meet the pattern recognition indicator. It shows that the student demonstrates an ability to recognize patterns and associate relevant concepts, materials, or formulas to solve the problem, specifically by using the arithmetic operations of addition and subtraction of whole numbers. The results of the interview are as follows:

P : From the steps to solve the problem, what concepts or materials can we use?

FQ : I think arithmetic operations like addition, subtraction, multiplication.

The interview results indicate that the student provided the correct answer in alignment with the pattern recognition indicator. This demonstrates the student's ability to recognize patterns and associate relevant concepts, formulas, or materials with solving the given problems.

Abstraction

In the abstraction indicator, students are expected to identify and extract important information relevant to solving problems by omitting irrelevant details.

☐ d. berdasarkan strategi yang telah kamu buat.
☐ apa saja informasi penting yang dapat digunakan
☐ untuk ~~menyelesaikan~~ menyelesaikan permasalahan tersebut?
☐ - Penurunan suhu 1°C setiap 100 m

Figure 6. Student's Answer Not Aligned with the Abstraction Indicator

Figure 6 depicts student responses that do not align with the abstraction indicator, as they fail to effectively abstract information from the given problems. Based on Figure 6, the student's answers that do not meet the abstraction indicator criteria include only one crucial piece of information that can be used to solve the problem. However, crucial details such as the height of Mount Dempo, the initial temperature of the mountain at 1000m, and the temperature after climbing for 6 hours were omitted by the student. Therefore, while there is some progress in meeting the abstraction indicator, it is not fully achieved. The results of the interview are outlined below:

- P : What do you think from the problem in question number one is the important information to solve the problem?
- CA : According to me, the information in question number one is about a group of students consisting of 5 people. Then they climbed Mount Dempo which is 3,142 meters above sea level. The temperature at 1000m is 27°C and will continue to drop by 1°C every 100m. after 6 hours of climbing the temperature is 15°C .

The results of problem-solving and interviews indicate that students have not effectively identified and sorted out important information that is essential for solving problems. This demonstrates that students have not yet demonstrated appropriate abstraction skills in relation to the given problems.

☒ D. berdasarkan strategi yang kamu buat apa saja informasi penting yang dapat digunakan untuk menyelesaikan permasalahan tersebut
☐ Gunung Dempo memiliki ketinggian 3.142m di atas permukaan laut ketinggian 1.000 m suhu gunung dempo 27°C dan akan turun terus 1°C per 100 m setiap 6 jam suhu gunung tersebut adalah 15°C . berapa ketinggian maka siswa tersebut.

Figure 7. Student Answers Aligned with the Abstraction Indicator

Figure 7 demonstrates that students can appropriately perform abstraction. It argues that the student's response aligns with the Abstraction Indicator, as they have effectively included all pertinent information required to solve the problem. This includes details such as the height of Mount Dempo (3,142 meters above sea level), the initial temperature of the mountain at 1000m altitude, the temperature decrement of 1°C per 100m, and the temperature after 6 hours of climbing. The information provided by the student is comprehensive and relevant to solving the given problem. The results of the interview are detailed below:

- P* : Based on the steps and concepts of the material we have discussed, what do you think is the important information that can be used to solve the problem?
- FQ* : What is certain is the height of the mountain demponya kak. Then, the temperature of the mountain at an altitude of 1000m is 27°C and will continue to drop 1°C every 100m. finally, the temperature of the mountain after 6 hours of climbing is 15°C.

The results from both problem-solving activities and interviews indicate that students have demonstrated understanding of the given problem. They were able to effectively perform abstraction by identifying and organizing important information essential for solving the problem at hand.

Algorithm

In the algorithm indicator, students engage in the problem-solving process by executing calculations according to the steps outlined in the decomposition stage.

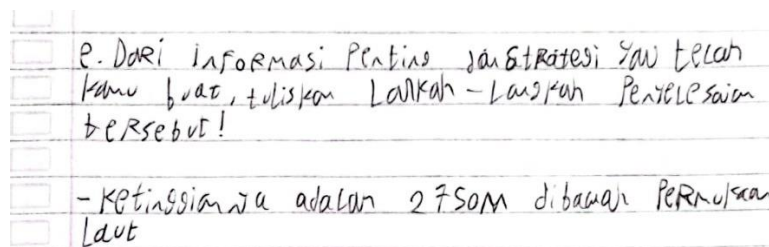


Figure 8. Student's Answer Not Aligned with the Algorithm Indicator

Figure 8 illustrates student responses that do not meet the algorithm indicator, as they have not correctly executed the problem-solving algorithm in the appropriate sequence. It shows that students only provide the final result of the problem, which is the height of 2750 meters above sea level. However, they do not include the calculation steps required to arrive at this final result. The results of the interview are outlined below:

- P* : So, from the whole process of solving the problem, what does CA think?
- CA* : I'm not sure sis. I was still confused to write down the steps in question b and I was also confused to do the calculation in question e. So, for answer e, I wrote the final answer directly.

The results from both problem-solving activities and interviews indicate that students have not effectively executed problem-solving algorithms. Students exhibited confusion in determining solution steps during the decomposition stage, leading to difficulties in carrying out the problem-solving algorithm.

☐	c.	Dari informasi tersebut tuliskan langkah-langkah pe
☐		nyelesaian masalah.
☐		
☐		$1000 = 27^{\circ}\text{C}$ Jadi: $1000 + 1200 = 2200 \text{ m}$
☐		$1^{\circ}\text{C} = \text{per } 100 \text{ m}$ maka ketinggian
☐		$27 - 15 = 12^{\circ}\text{C}$ maka siswa adalah: 2200 m
☐		$12^{\circ}\text{C} = 1200 \text{ m}$
☐		

Figure 9. Student Answers Aligned with the Algorithm Indicator

Figure 9 demonstrates that the student's answer aligns with the Algorithm indicator, as they can perform the problem-solving algorithm according to the steps outlined in the decomposition stage. However, the student's answer does not sequentially list the stages of solving the problem, as follows:

$$\begin{aligned}
 1000 \text{ m} &= 27^{\circ}\text{C} \\
 1^{\circ}\text{C} &= \text{per } 100 \text{ m} \\
 27 - 15 &= 12^{\circ}\text{C} \\
 12^{\circ}\text{C} &= 1200 \text{ m} \\
 1000 + 1200 &= 2200 \text{ m}
 \end{aligned}$$

The results of the interview are listed as follows:

- P : How do you solve the problem?
- FQ : The last answer was asked to write down the solution. So, I just calculated it and got the result that the height of the student was 2200m.
- P : Do you think the solution stage in question e and the steps you made in question b are appropriate?
- FQ : Actually, I have, but I'm also confused, like there's something that doesn't match. The problem is that I immediately counted.

The results from both problem-solving activities and interviews indicate that students can execute the solution algorithm reasonably well. However, students still exhibit confusion in articulating the solution steps, which leads to non-sequential presentation of the steps.

Discussion

Computational thinking-based learning, implemented through the PBL model, plays a pivotal role in guiding students' problem-solving strategies. This approach exposes students to authentic problems aligned with computational thinking frameworks, fostering structured approaches to problem formulation and solution (Kamil et al., 2021). In our study involving 28 students, results categorized 17.86% as high achievers, 64.28% as medium achievers, and 17.86% as low achievers in computational thinking ability. However, a detailed analysis based on computational thinking indicators revealed significant areas of deficiency. For example, only 50% of students effectively decomposed problems into manageable stages, contradicting claims of proficient decomposition skills as suggested by Widiyawati (2022). Many students also

tended to list problem details rather than outline systematic solution steps, often omitting initial calculations, as noted by Nasiba (2022). Interviews with students in the medium and low categories highlighted their ability to verbally decompose problems but demonstrated challenges in structuring these stages in written responses.

In terms of pattern recognition, only 21.43% of students successfully linked learned concepts or formulas to problem-solving tasks, contrasting with findings by Kamil et al. (2021) indicating higher proficiency in this area. Most students persisted in listing procedural steps instead of integrating relevant concepts into their responses, as documented in Supiarno's (2021) research. Interviews suggested that lack of focus and participation in class discussions impeded students' ability to comprehend and apply pattern recognition indicators effectively.

Conversely, 42.86% of students demonstrated adequate abstraction skills by identifying essential information relevant to problem-solving, consistent with Nasiba's (2022) observations. However, some students struggled to differentiate between abstracting information and performing calculations, erroneously incorporating the latter as part of abstraction rather than algorithmic processing. Interviews indicated that inadequate problem decomposition hindered students' ability to discern necessary information for each stage of problem-solving (Supiarno et al., 2021).

Regarding the algorithm indicator, 60.71% of students successfully executed problem-solving algorithms, yet several encountered challenges in documenting sequential steps comprehensively, echoing findings Rahmania et al. (2023). Issues included misinterpretation of problem requirements, computational errors, and faulty conclusions, compounded by difficulties in grasping fundamental arithmetic concepts as highlighted by Bange (2021). Interviews revealed that some students struggled with problem understanding, affecting their ability to design and execute problem-solving processes as required by the algorithmic indicator (Supiarno et al., 2021).

While the study categorizes students predominantly in the medium range for computational thinking, as emphasized by Kamil et al. (2021), performance across all indicators remained below 50%. This underscores the ongoing challenge of familiarizing students with computational thinking-based problem-solving approaches. Nonetheless, the implementation of computational thinking-based learning has begun to shape students' frameworks for computational thinking, establishing a foundation for future improvements.

Conclusion

Following the implementation of computational thinking-based learning with 28 students, the study reveals that a majority of students exhibited medium-level computational thinking abilities. Notably, 5 students (17.86%) demonstrated high-level proficiency, whereas 18 students (64.28%) achieved medium-level proficiency, and 5 students (17.86%) performed at a low level. Specifically, students' performance across computational thinking indicators showed 50% proficiency in decomposition, 21.43% in pattern recognition, 42.86% in abstraction, and 60.71% in algorithmic thinking. Challenges in achieving higher scores, particularly in pattern recognition, were attributed to students' misconceptions stemming from their interpretation of

leading questions, leading to inaccuracies in their responses. Additionally, the study identified a lack of habitual problem-solving practice in computational thinking as a contributing factor.

This research is also constrained by several limitations. The relatively small sample size of 28 students from a single school limits the generalizability of findings to broader student populations. Furthermore, the focus solely on specific computational thinking indicators related to addition and subtraction may not fully capture the overall computational thinking abilities across various mathematical domains. Moreover, the qualitative nature of the study, while valuable for exploring student perceptions and behaviors, would benefit from complementary quantitative assessments to enhance the validity and reliability of findings.

To address these limitations and build upon the current study, future research should consider expanding the participant pool to encompass a more diverse range of students from multiple educational institutions. Incorporating both qualitative and quantitative methodologies would provide a comprehensive understanding of computational thinking development. Moreover, integrating computational thinking-based learning more consistently into curriculum frameworks could foster habitual problem-solving skills among students. Additionally, investigating the longitudinal effects of such interventions and exploring other mathematical topics beyond basic operations would enrich our understanding of computational thinking's broader impact on students' cognitive development.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. Furthermore, ethical issues, including plagiarism, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies, have been thoroughly addressed by the authors.

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