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Computational Thinking Ability of Students in Exponential Material Using Problem-Based Learning

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ABSTRACT

Computational thinking merupakan kemampuan yang penting dimiliki karena dapat membantu peserta didik untuk menganalisis dan memecahkan masalah dengan cara yang sistematis, logis, dan kreatif, baik dalam dunia komputasi maupun dalam kehidupan sehari-hari. Penelitian ini bertujuan untuk mengidentifikasi kemampuan computational thinking pada peserta didik melalui pembelajaran berbasis masalah pada materi eksponensial. Penelitian ini menggunakan metode deskriptif kualitatif dengan 34 peserta didik kelas 10 di salah satu SMA di Palembang sebagai subjek penelitian, dengan fokus pada 3 peserta didik yang memiliki kemampuan tinggi, sedang, dan rendah. Penelitian ini dilaksanakan dalam tiga tahap: persiapan, pelaksanaan, dan analisis data. Data dikumpulkan melalui tes tertulis dan wawancara untuk mengukur kemampuan computational thinking peserta didik. Hasil penelitian dianalisis melalui tiga tahapan: reduksi data, penyajian data, dan penarikan kesimpulan. Hasil penelitian menunjukkan bahwa kemampuan computational thinking peserta didik pada materi eksponensial terlihat baik dalam hal pengenalan pola dan abstraksi. Namun, untuk kemampuan dekomposisi dan algoritma, peserta didik masih belum menunjukkan kemampuannya dalam menyelesaikan masalah secara sistematis dengan jawaban yang tepat.

Computational thinking is an important skill to have because it can help students to analyze and solve problems in a systematic, logical, and creative way, both in the world of computing and in everyday life. This study aims to identify the ability of computational thinking in students through problem-based learning on exponential topics. This study used descriptive qualitative method with 34 grade 10 students in one of the high schools in Palembang as research subjects, focusing on 3 students who have high, medium, and low abilities. The research was conducted in three stages: preparation, implementation, and data analysis. Data were collected through written tests and interviews to measure learners' computational thinking skills. The results were analyzed through three stages: data reduction, data presentation, and conclusion drawing. The results showed that students' computational thinking ability on exponential material was good in terms of pattern recognition and abstraction. However, for decomposition and algorithm skills, students still do not show their ability to solve problems systematically with the right answers.

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INTRODUCTION

Education in this 5.0 era demands that the Indonesian education system be capable of producing students who possess real-world practical skills, not just proficiency in reading and writing (Megawati

et al., 2023). One crucial skill to meet this demand is computational thinking, which helps individuals solve everyday problems (Salwadila & Hapizah, 2024). Every student must possess and develop their CT skills alongside technological advancements because these skills are vital for their professional success in the modern digital age (Vallance & Towndrow, 2016). Computational thinking is a new concept in educational research, first introduced by Papert in 1996 and then reintroduced by Jeannette Wing in 2006 (Bråting & Kilhamn, 2021). (Wing, 2006) describes computational thinking as a problem-solving ability that serves as a fundamental skill for everyone, not exclusively for computer scientists. The stages or indicators of computational thinking consist of decomposition, pattern recognition, abstraction, and algorithms (Kalelioglu et al., 2016). Computational thinking ability helps individuals develop a way of thinking to solve complex problems in every context, whether computational or daily life (Mohaghegh & McCauley, 2016). Computational thinking skills have been integrated into various educational programs in many countries, such as Finland, Norway, South Korea, Israel, Poland, New Zealand, and Estonia (Tikva & Tambouris, 2021). According to a study survey published between 2006 and 2018, computational thinking was also included in the elementary school curriculum in 52 countries (Tang et al., 2020). In Thailand, computational thinking was introduced as part of the National Standard Curriculum in 2017 (Junpho et al., 2022). Besides the aforementioned countries, computational thinking has also been implemented in Indonesia, where Mr. Nadiem Makarim, as the Minister of Education and Culture, added two new competencies to the Indonesian children's learning system: Computational Thinking and Compassion (Budiansyah, 2020). This demonstrates the importance of students possessing computational thinking skills to solve problems.

The implementation of computational thinking skills in Indonesia still faces obstacles. This aligns with the results of a pre-test conducted in a 9th-grade class at SMPN 8 Batam, which showed that the computational thinking abilities of most students were still low in solving given problems (Suhardi & Utama, 2022). The lack of implementation in Indonesia is due to the low computational thinking ability of both teachers and prospective teachers (Anggraini et al., 2022). The low computational thinking ability in students is because they still struggle to achieve indicators of computational thinking ability, such as pattern recognition (Jamalludin et al., 2022). Another factor is that students are still unable to solve problems by integrating the information they obtain (Aisy & Hakim, 2023). According to the PISA (Programme for International Student Assessment) results in 2018, Indonesia ranked 73rd out of 78 countries with an average score of 379 (PISA, 2018). The PISA assessment includes indicators of the ability to identify, reflect, formulate, interpret, evaluate, generalize, and utilize information in problems. Levels 4, 5, and 6 in these abilities are related to students' computational thinking skills (Satrio, 2020). Therefore, a learning approach that can support students' computational thinking abilities is needed.

Problem-based learning (PBL) is a learning approach that can support students in developing computational thinking skills. PBL is an approach that can improve student learning outcomes, enhance problem-solving skills, and encourage student motivation to participate actively in the learning process (Nargundkar et al., 2014). By using problem-based learning, students are required to think critically in solving problems (Adisel et al., 2021). PBL can also improve students' understanding of the material taught, increase learning outcomes, and make students more active (Fitriyah et al., 2022). Problem-based learning presents problems to students so that they are trained to think critically in finding solutions (Chrisdiyanto et al., 2023). urthermore, through problem-based learning, students can develop problem-solving skills, which are part of CT abilities (Dewi et al., 2021). Thus, the PBL approach is an alternative solution that can support learning activities to achieve positive outcomes for both problem-solving and CT abilities.

The emergence of computational thinking and the presence of basic competencies such as personal problem-solving, which require decomposition, abstraction, representation, and pattern recognition, indicate an opportunity to integrate computational thinking with other subjects, particularly mathematics (Munirah, 2022). In this context, computational thinking becomes a crucial skill, as the use of mathematical and programming concepts in complex problem-solving can enhance students' mathematical conceptual understanding (Maharani et al., 2019).

In mathematics, all topics can utilize computational thinking in teaching and learning. One such topic is exponentials. Exponential material was chosen for this research because it can foster problem-solving skills, thereby enabling students to develop their logical thinking in solving problems (Lestari, 2019). Exponential material is also a prerequisite for several subsequent topics and is even found in subjects other than mathematics, such as biology, physics, and chemistry (Sumirat et al., 2023).

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However, in reality, many students still struggle due to a lack of understanding of the material's concepts, reluctance to write down the steps of problem-solving, and not completing problem solutions (Rezki et al., 2023). Students also find it difficult to understand problem-solving questions because they require logic and reasoning to solve them (Gunawan & Fitria, 2021). According Mulyono & Hapizah (2018), language errors in exponents, sometimes unnoticed by teachers, can also affect students' future learning processes.

Research on the importance of computational thinking skills has been conducted by Setyawan & Astuti (2021), who applied computational thinking-based learning to calculus material, resulting in 73.3% of students understanding the given concepts through the problems provided. Research by Mubharokh & Susanti (2023) showed that the application of E-LKPD based on computational thinking impacted students' mathematical reasoning abilities. The implication of this research is that it can enhance students' critical thinking skills.

Based on these problems, this research was conducted to examine students' computational thinking abilities after using an interactive E-Module on exponential material with problem-based learning, which has been developed. The objective of this study is to observe students' computational thinking abilities in exponential material using problem-based learning.

METHOD

The type of research used in this study is descriptive with a qualitative approach that aims to describe the computational thinking ability of students in exponential material using problem-based learning using non-numeric data such as text and images (Roosinda, 2021). The indicators of computational thinking ability in this study are decomposition, pattern recognition, abstraction, and algorithms. An explanation related to the indicators of computational thinking ability can be seen in Table 1.

Table 1. Indicators of Computational Thinking Ability

Indicator	Descriptor	Aspect
Decomposition	Students describe a complex problem context that can be made simpler	• Identifying existing information • Simplifying found information
Pattern Recognition	Students can look for patterns, similarities, and connections that provide a quick way to solve new problems	• Identifying patterns, similarities, and connections • Formulating ways to solve problems
Abstraction	Students can understand and generalize the formation of patterns, see their basic characteristics, and discard unnecessary details	• Analyzing unnecessary information
Algorithm	Students can understand the flow of solution through clear definitions	• Solving problems according to the steps of work

Source: (Nuvitalia et al., 2022)

This research was conducted in one of the high schools in Palembang in the even semester of the 2023/2024 academic year with 34 tenth-grade students as subjects. The data sources used in this research were test results and interviews. The selection of interview subjects was carried out on 3 students representing each category (high, medium, and low) based on the test results obtained. This research was carried out through three stages:

a. Preparation Stage

In the preparation stage, the researcher formulated the problems to be discussed and determined the indicators to be achieved by reviewing literature related to computational thinking ability, problem-based learning, and exponential material consisting of concepts, properties, and exponential equations. The researcher coordinated with SMA Negeri 8 Palembang to obtain permission and select the class for the research. The researcher also prepared research instruments in the form of teaching modules, learning activities, test questions, and interview guidelines. The test instruments used were first validated by expert validators. Based on the validation results provided by the validator, the instruments used were

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deemed suitable for use with some revisions according to the suggestions given. These suggestions can be seen in Table 2.

Table 2. Test Instrument Revision Results at the Preparation Stage

Initial Design	Revision Results
Every problem should include a picture or illustration of the problem 3. Pak Ibra membuat *puzzle* dari kayu berbentuk segitiga siku-siku. Panjang sisi miring *puzzle* tersebut adalah 2^{2x+3} cm. Panjang dua sisi lainnya adalah 8 cm dan 2^{4x+2} cm. nilai x yang memenuhi panjang sisi-sisi *puzzle* tersebut?	Every problem has been supplemented with an image as an illustration of the problem  3. Pak Ibra membuat *puzzle* dari kayu berbentuk segitiga siku-siku. Panjang sisi miring *puzzle* tersebut adalah 2^{2x+3} cm. Panjang dua sisi lainnya adalah 8 cm dan 2^{4x+2} cm. nilai x yang memenuhi panjang sisi-sisi *puzzle* tersebut?

b. Implementation Stage

In this stage, the researcher carried out learning in the subject class four times. The first meeting was on the concept of exponentials, the second on properties of exponentials, and the third on exponential equations. In the fourth meeting, the researcher conducted a written test consisting of 3 problems with several questions containing validated computational thinking ability indicators. The results of the written test will be analyzed according to computational thinking ability and used to determine the research subjects for interviews. Interviews were used to support the potential effects of the interactive E-Module used, as well as to obtain additional data or further information regarding students' test answers. The purpose of this interview was also to explore whether the learning using the interactive E-Module previously conducted helped in solving the given problems

c. Data Analysis Stage

In this stage, the researcher processed and analyzed the data obtained from written tests and interviews with students who were the focus of the research subjects. The data were analyzed by comparing the results obtained from the tests and interviews. After that, the data were described and summarized according to the computational thinking ability indicators.

RESULT AND DISCUSSION

In the results and discussion, the researcher describes the results obtained when conducting research on students' computational thinking ability in exponential material. Before collecting test data, students were given learning using an Interactive E-Module on exponential material that had been developed by the researcher and was based on computational thinking using problem-based learning. Subsequently, test data collection was carried out with a time allocation of 70 minutes. The test questions were done offline using each student's mobile phone, which could be accessed on the Interactive E-Module. The test consisted of 3 different problems, and each problem had several questions related to computational thinking ability in solving the given problems. After obtaining the written test results and recommendations from the teacher, 3 students consisting of high, medium, and low abilities were selected as the focus research subjects, namely APJ (high ability student), MRPV (medium ability student), and NAA (low ability student). From the analyzed results of the completed test questions, the appearance of computational thinking ability indicators is shown in Table 3.

Table 3. Appearance of Students' Computational Thinking Indicators

No	Student Name	Indicators Achieved			
		Decomposition	Pattern Recognation	Abstraction	Algorithm
1	APJ	✓	✓	✓	✓
2	MRPV	✓	✓	✓	-
3	NAA	-	✓	✓	-

Description:

✓ = all descriptors for the indicator are met

- = ada beberapa deskriptor pada indikator tidak terpenuhi

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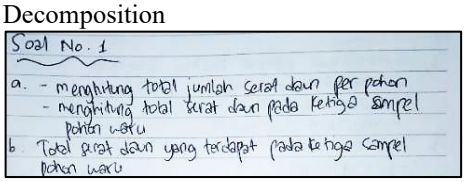
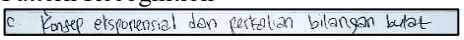
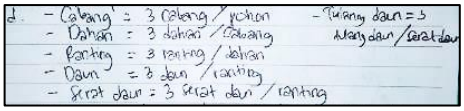
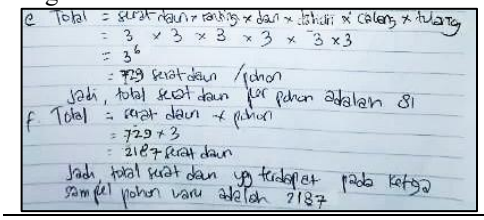
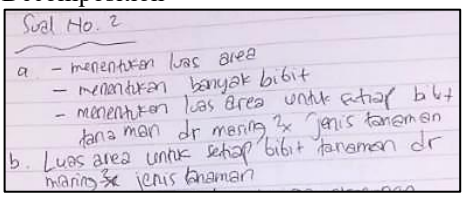
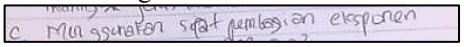
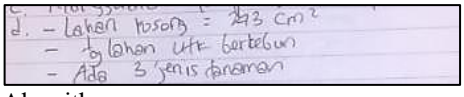
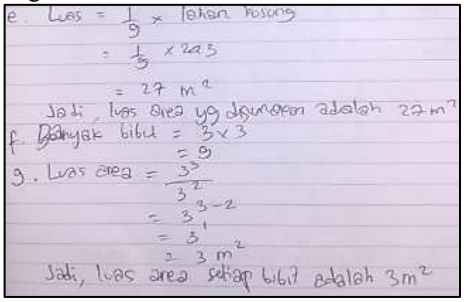
Table 4. Answers and Interview Results for Problem 1 Subject APJ

Written Test	Interview
Decomposition  Pattern Recognition  Abstraction  Algorithm 	Researcher : According to APJ, to solve problem 1, what steps did you take to solve the problem? APJ : When I want to find the total leaf fibers in the three samples of Waru trees, I have to first find the total number of leaf fibers per tree, then I can get the total leaf fibers in the three samples of Waru trees. Researcher : What method did you use in that step? APJ : Using the concept of exponentials, sir, so it becomes $3 \times 3 \times 3 \times 3 \times\ 3 \times 3 = 729$ Researcher : After getting the total number of leaf fibers per tree, what else needs to be done? APJ : The total number of leaf fibers per tree that has been obtained is multiplied by 3 because the number of Waru trees is 3.

Subject APJ has met all indicators of computational thinking ability. Based on APJ's answers in table 4, APJ was able to perform decomposition. This is known from APJ's written answer, where she wrote what was asked and the steps, she took to solve the problem. The pattern recognition indicator was evident when APJ wrote that she could use the concept of exponentials and integer multiplication. The abstraction indicator in the answer was seen from APJ, who was able to sort out important information that she could use to solve the problem. In the algorithm indicator, APJ was able to accurately find the total leaf fibers per tree and could use that answer to solve the main problem, which was finding the total leaf fibers in the three samples of mango trees. This was confirmed during the interview with subject APJ (table 4).

Table 5. APJ Answers and Interview Results for Problem 2 Subject APJ

Written Test	Interview
Decomposition  Pattern Recognition  Abstraction  Algorithm 	Researcher : In problem 2, is the problem the same as problem 1? APJ : Different, sir, if problem 2 is to find the area for each plant seedling of each type of plant Researcher: What steps did you take to solve the problem? APJ : First, determine the area to be used, then determine the number of seeds to be planted, after that, you can get the area for each plant seedling of each type of plant Peneliti : What method did you use in that step? APJ : The area to be used is divided by the number of seeds to be planted using the exponential division property, sir, $\frac{a^m}{a^n} = a^{m-n}$

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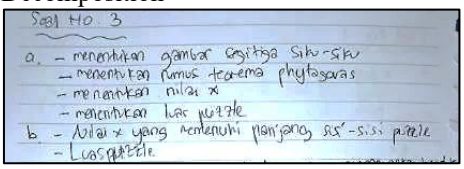
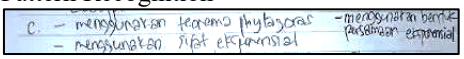
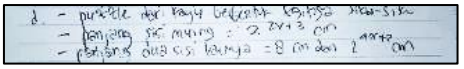
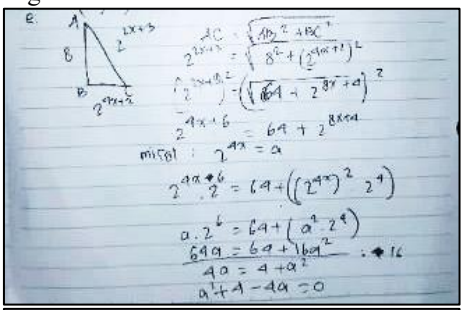
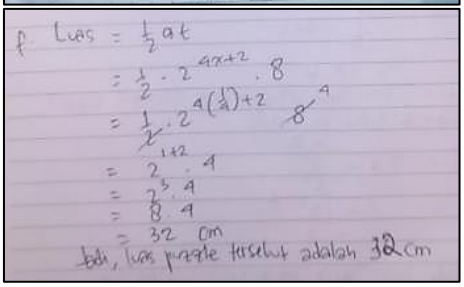
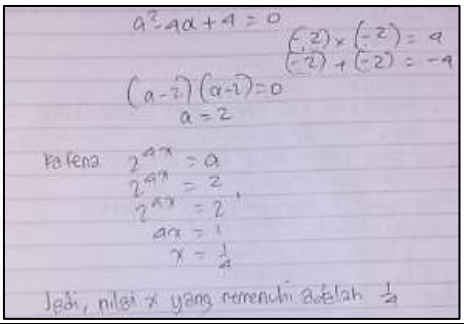
Based on table 5, it can be seen that APJ's answer has met all indicators of computational thinking ability. In the decomposition indicator, APJ has written what was asked and the steps she took to solve the problem. In the pattern recognition indicator, APJ wrote that she could use the exponential division property. The abstraction indicator also showed that APJ wrote important information that she could use to solve the problem. In the algorithm indicator, it was seen that APJ was able to find the area used and the number of seeds to be planted, and these two answers could be used to solve the main problem, which was finding the area for each plant seedling of each type of plant. This was confirmed during the interview with subject APJ (table 5).

Table 6. Answers and Interview Results for Problem 3 Subject APJ

Written Test	Interview
Decomposition  Pattern Recognition  Abstraction  Algorithm   	Researcher : To solve problem 3, what steps did you take to solve the problem? APJ : I drew a right-angled triangle first to make it easier for me to do the next steps Researcher: What did you do next? APJ : Using the Pythagorean formula to get the value of x so that the value of x can be used to determine the area of the puzzle Researcher : When using the Pythagorean formula, did the value of x immediately appear?? APJ : No, sir, when using the Pythagorean formula, an exponential equation will be obtained, and when the equation is solved, the value of x will be obtained. Researcher : Can all the information in that problem be used to solve the problem? APJ : There is some important information that can be used, sir Researcher : So, you already know which information is important and which is not important to use? APJ : Yes, sir

In table 6, APJ's answer has met all indicators of computational thinking ability. APJ was able to perform decomposition. This is known from APJ's written answer, where she wrote what was asked and the steps, she took to solve the problem. The pattern recognition indicator was evident when APJ wrote that she could use the Pythagorean theorem, exponential

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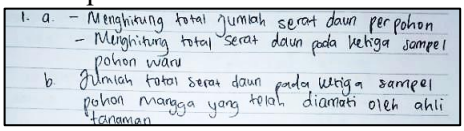
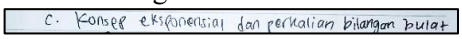
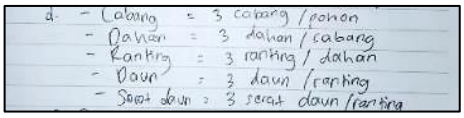
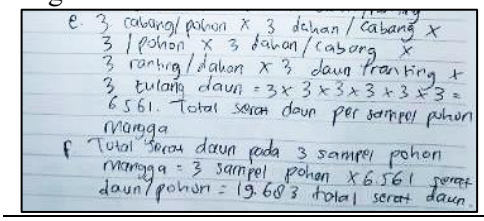
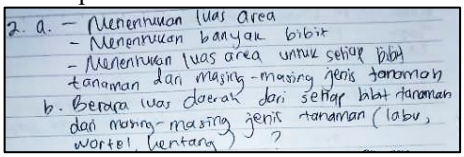
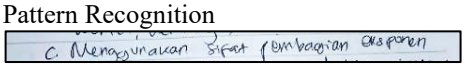
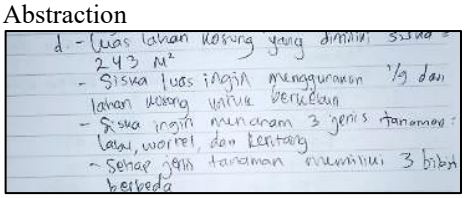
properties, and the form of exponential equations. The abstraction indicator in the answer was seen from APJ, who was able to sort out important information that she could use to solve the problem. In the algorithm indicator, APJ was able to accurately find the value of x that satisfies the side length of the puzzle and could use that answer to solve the main problem, which was finding the area of the puzzle. This was confirmed during the interview with subject APJ (table 6).

Table 7. Answers and Interview Results for Problem 1 Subject MRPV

Written Test	Interview
Decomposition  Pattern Recognition  Abstraction  Algorithm 	Researcher : Did you have any difficulty working on part e? MPRV : No, sir Researcher : How did you solve this? MPRV : Exponential concept, sir, $3 \times 3 \times 3 \times 3 \times 3 \times 3$ Researcher : Do you think this answer is correct? Try to re-calculate! MPRV : Oh yes, sir, it should be $3^6 = 729$ leaf fibers/tree. I miscalculated. This means f is also miscalculated, sir, to $729 \times 3 = 2.187$ leaf fibers

Subject MRPV has met some indicators of computational thinking ability. Based on MRPV's answers in table 7, MRPV was able to perform decomposition. This is known from MRPV's written answer, where he wrote what was asked and the steps, he took to solve the problem. The pattern recognition indicator was evident when MRPV wrote that he could use the concept of exponentials and integer multiplication. The abstraction indicator in the answer was seen from MRPV, who was able to sort out important information that he could use to solve the problem. In the algorithm indicator, there was a calculation error made by MRPV in finding the total leaf fibers in each sample of mango trees. After an interview with the subject, he only realized the error (table 7).

Table 8. Answers and Interview Results for Problem 2 Subject MRPV

Written Test	Interview
Decomposition  Pattern Recognition  Abstraction  Algorithm	Researcher : In problem 2, what is asked? APJ : For problem 2, find the area for each plant seedling of each type of plant Researcher: What steps did you take to solve the problem? APJ : First, determine the area to be used, then determine the number of seeds to be planted, after that, you can get the area for each plant seedling of each type of plant Researcher : What method did you use in that step? APJ : Using the exponential division property by dividing the area used for gardening, which is "$3^3 = 27$", and the number of seeds to be planted, which is "$3^2 = 9$"

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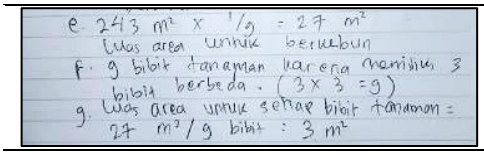
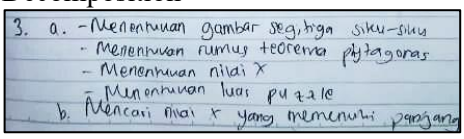
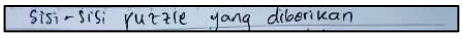
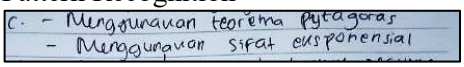
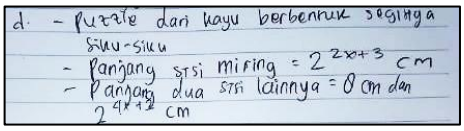
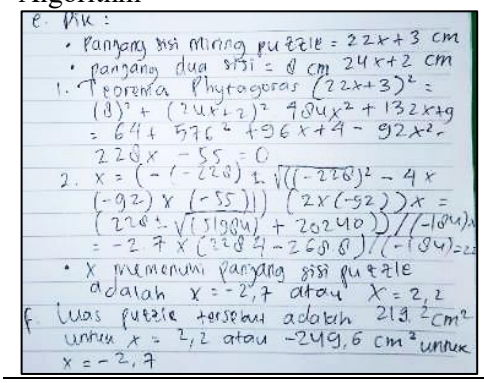
Written Test	Interview
	

Based on table 8, it can be seen that MRPV's answer has met some indicators of computational thinking ability. In the decomposition indicator, MRPV has written what was asked and the steps he took to solve the problem. In the pattern recognition indicator, MRPV wrote that he could use the exponential division property. The abstraction indicator also showed that MRPV wrote important information that he could use to solve the problem. In the algorithm indicator, it was seen that MRPV was able to find the area used and the number of seeds to be planted, and these two answers could be used to solve the main problem, which was finding the area for each plant seedling of each type of plant. This was confirmed during the interview with subject MRPV (table 8).

Table 9. Answers and Interview Results for Problem 3 Subject MRPV

Written Test	Interview
Decomposition   Pattern Recognition  Abstraction  Algorithm 	Researcher : Did you have any difficulty working on part e? MRPV : No, sir. Researcher: How did you solve this? MRPV : Pythagorean theorem, sir, and it will form an exponential equation Researcher : Is this answer correct in your opinion? Please check again! MRPV : Oh yes, sir, I made a mistake in writing, it should be $(2^{2x+3})^2 = 8^2 + (2^{4x+2})^2$, so all my calculations are wrong Researcher : Please look at f, how did you solve that problem? MRPV : Using the triangle area formula, sir. Researcher : Please check what you have done again! MPRV : Yes, sir, because of the writing and calculation errors in part e, the calculation in f also had an error, sir. It should be $l = \frac{1}{2} \times 2^{4x+2} \times 8$ where the value of x is $\frac{1}{4}$.

In table 9, MRPV's answer has met some indicators of computational thinking ability. MRPV was able to perform decomposition. This is known from MRPV's written answer, where he wrote what was asked and the steps, he took to solve the problem. The pattern recognition indicator was evident when MRPV wrote that he could use the Pythagorean theorem and exponential properties. The abstraction indicator in the answer was seen from MRPV, who was able to sort out important information that he could use to solve the problem. In the algorithm indicator, there was a writing error that resulted in a calculation error made by MRPV in finding the value of x that satisfies the side length of the puzzle. After an interview with the subject, he only realized the error (table 9).

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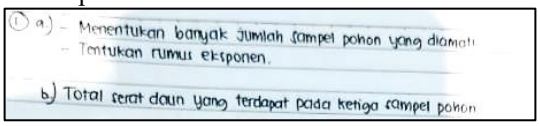
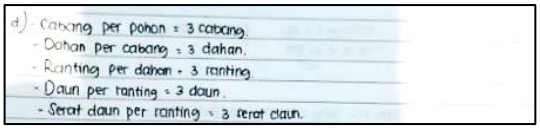
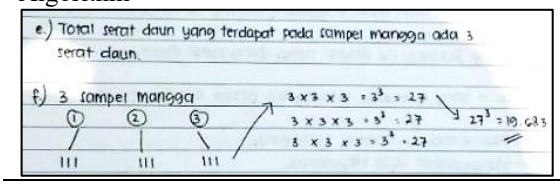
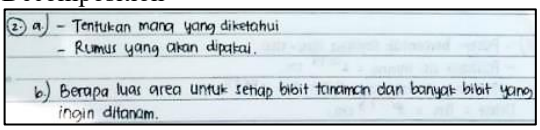
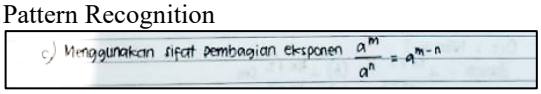
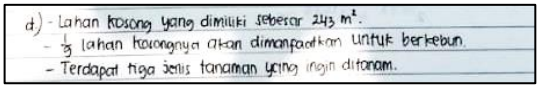
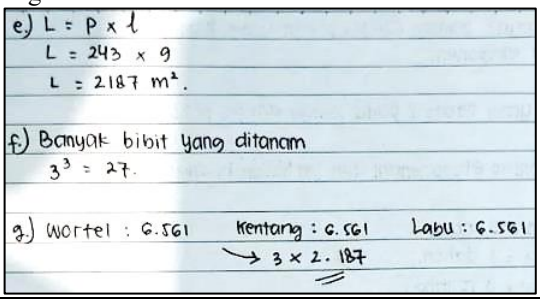
Table 10. Answers and Interview Results for Problem 1 Subject NAA

Written Test	Interview
Decomposition  Pattern Recognition  Abstraction  Algorithm 	Researcher : In part e, where did you get the result of 3 leaf fibers? NAA : I'm confused about how to find the solution, sir. Researcher : So, you're confused about how to solve it, aren't you? NAA: Yes, sir, I'm confused Researcher : For part f, is the calculation for each tree $3 \times 3 \times 3$? NAA : Yes, sir, that's how it's done

Subject NAA has met some indicators of computational thinking ability. Based on NAA's answers in table 10, NAA has not been able to perform decomposition. This is known from the answer, which was inaccurate in writing down the steps she took to solve the problem. The pattern recognition indicator was evident when NAA wrote that she could use the concept of exponentials and integer multiplication. The abstraction indicator in the answer was seen from NAA, who was able to sort out important information that she could use to solve the problem. In the algorithm indicator, there was a misconception from NAA when writing the answer, so the answer written was inaccurate. After an interview with NAA, it was found that she did not know how to find the total leaf fibers in each sample of mango trees and the total leaf fibers in the three samples of mango trees. Therefore, NAA directly wrote down the answer like that.

Table 11. Answers and Interview Results for Problem 2 Subject NAA

Written Test	Interview
Decomposition  Pattern Recognition  Abstraction  Algorithm 	Researcher : For part e, how about it? Any confusion? NAA : Yes, sir, I'm confused about what method to use because I don't understand the intended area, so I wrote it using the formula $L = p \times l$ Researcher : Are you also confused about parts f and g? NAA : Yes, sir, I don't know how to find the answers for f and g, so I just wrote it like that. Researcher : So you're confused about what to use to solve it? NAA : Yes, sir

Based on table 11, it can be seen that NAA's answer has met some indicators of computational thinking ability. In the decomposition indicator, NAA was less precise in writing down the steps she

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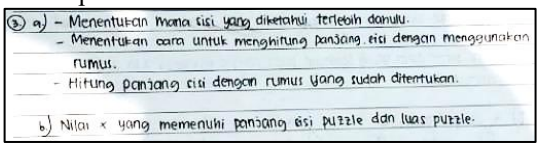
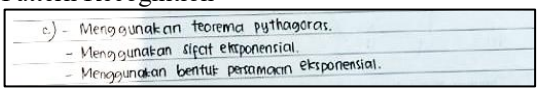
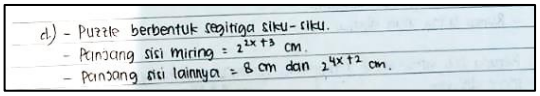
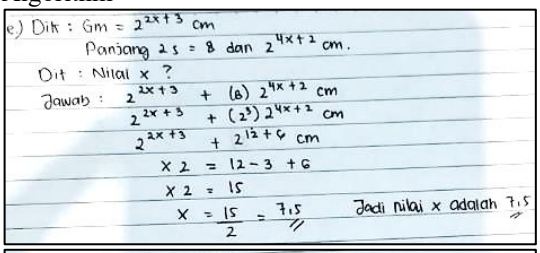
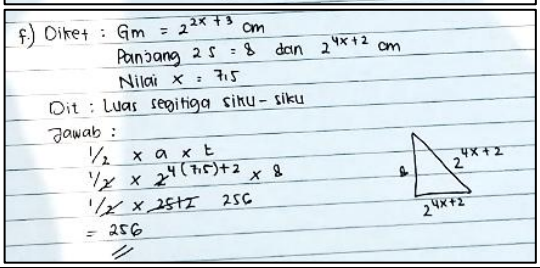
took to solve the problem. In the pattern recognition indicator, NAA wrote that she could use the exponential division property. The abstraction indicator also showed that NAA wrote important information that she could use to solve the problem. In the algorithm indicator, there was a misconception from NAA when writing the answer, so the answer written was inaccurate. After an interview with NAA, it was found that she did not know how to find the area used, the number of seeds to be planted, and how to find the area for each plant seedling of each type of plant.

Table 12. Answers and Interview Results for Problem 3 Subject NAA

Written Test	Interview
Decomposition  Pattern Recognition  Abstraction  Algorithm  	Researcher : Did you have any difficulty working on part e? NAA : Yes, sir, I did, I'm confused why it turned out like this Researcher : How did you solve this? NAA : Pythagorean theorem, sir Researcher : Please check what you wrote again! NAA : Oh yes, sir, I made a mistake in writing, it should be $(2^{2x+3})^2 = 8^2 + (2^{4x+2})^2$, so all my calculations are wrong

In table 12, NAA's answer has met some indicators of computational thinking ability. NAA has not been able to perform decomposition. This is known from the answer, which was inaccurate in writing down the steps she took to solve the problem. The pattern recognition indicator was evident when NAA wrote that she could use the Pythagorean theorem, exponential equation forms, and exponential properties. The abstraction indicator in the answer was seen from NAA, who was able to sort out important information that she could use to solve the problem. In the algorithm indicator, there was a writing error that resulted in a calculation error made by NAA in finding the value of x that satisfies the side length of the puzzle. After an interview with the subject, she only realized the error.

Computational thinking (CT) is one of the things that can help students identify and analyze problems and assess the effectiveness of designed solutions (Wu et al., 2024). Computational thinking and mathematics become formative constructs that can positively assess computational thinking, and computational thinking will also positively assess mathematics (Lee et al., 2023). Learning using problem-based learning can be used to observe computational thinking abilities. The steps in problem-based learning can improve computational thinking ability in the problem orientation and student organization stages by enhancing their ability to describe what information is known and asked in the given problem (Hsu et al., 2018). In addition, it was also seen when students discussed in groups to solve

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problems in learning activities. Furthermore, in the guiding inquiry stage, students can be given an active role in collaborating to solve group problems, thereby creating curiosity and motivating them to solve problems. Then, in the developing and presenting results and analyzing stages, students' confidence can be seen when reflecting and evaluating the results of the discussions that have been carried out. The learning process using problem-based learning can increase student activity in the learning process because students have a thinking process in finding information based on discussions and solving their problems (Prisiska et al., 2017)

From the results of this study, for the decomposition indicator, some students had not met this indicator because it was not evident when they determined what steps needed to be taken before solving the given problem. However, when writing what was asked from the given problem, all students were able to answer correctly. This is in line with what was stated by Hauda & Mulyono (2024) that students are usually able to identify what is asked in a problem, which indicates a good initial understanding of the core problem. However, difficulties arise when they have to translate that understanding into concrete steps to solve the problem. In the pattern recognition indicator, all students were able to accurately determine what methods could be used to solve the given problem, which indicates that the pattern recognition indicator has been met. In the abstraction indicator, no obstacles were experienced because all students were able to write down important information that could be used to solve the given problem, which indicates that the abstraction indicator has been met. However, in the algorithm indicator, some students were still less precise in answering the problems accurately, so this indicator was not fully evident. When students looked for the total leaf fibers in each sample of mango trees, they sometimes made calculation errors. This is in line with what was stated by Meldawati & Kartini (2021) that calculation errors are sometimes experienced by students in solving a given problem225. In problems related to exponential equations, some students often make errors in writing the form of the exponential equation itself, so the answer they get is less accurate226. Students also still do not understand well what steps need to be taken to find the answer accurately. Junengsih & Sutirna (2022) also stated that students make errors when working on problems due to a lack of knowledge, which results in students not understanding the problem and having difficulty solving it.

CONCLUSION

Based on the results and discussion of the research, pattern recognition ability and abstraction are computational thinking ability indicators that appeared and were met in all research subjects. As for decomposition ability, only in high and medium ability students, namely APJ and MRPV, did the indicators appear and were met. The algorithm ability indicator only appeared and was met in high ability students, namely APJ, while in medium ability students (MRPV) and low ability students (NAA), the algorithm ability indicator had not fully appeared and been met. This is because students were still confused in solving problems and made errors in writing and calculation.

In this study, there were obstacles, namely that students were still not accustomed to solving problem-based questions systematically, especially using computational thinking ability. This was seen when students worked on the given learning activities and test questions; they were able to write what was asked, what methods could be used, and what information could be used to solve the given problem, but they experienced difficulty in determining what steps needed to be taken before solving the given problem, which includes decomposition ability, and solving the main problem to get the answer to the given question, which includes algorithm ability in computational thinking.

Based on these findings, the suggestion for future researchers is the creation of learning modules containing problem-based questions that can focus students on practicing and getting used to solving problem-based questions using computational thinking so that computational thinking ability can emerge in all students.

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Data availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics, Consent to Participate, and Consent to Publish declarations: The research was conducted ethically, with the consent of participants and respect for their privacy and rights. All learning activities and data collection were performed in accordance with good educational practice, ensuring no harm or disadvantage to participants. This research was conducted with research permission from Dinas Pendidikan Provinsi Sumatera Selatan (Ref No: 420/1615/SMA.1/Disdik.SS/2024). The research findings were also presented to reviewers during the results seminar, and the research report has received approval from the Head of LPPM."

Author Contribution

M.A.F: Validation, Formal analysis, and Writing-review and editing.

H: Responsible for conceptualization, Writing the original draft, Editing and visualization, Investigation, Methodology, and Project administration.

M.I: Validation and Formal analysis.

All authors had approved the final version

Conflict of Interest

The authors declare that there is no conflict of interest.

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