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Computational Thinking of Indonesian Junior High School Students in Solving Geometry Problems

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Abstract: Mathematics education in the digital era needs to develop computational thinking as a problem-solving skill relevant to the challenges of the 21st century. This skill is closely related to logic and problem solving, which are the core of mathematics learning, such as in geometry. However, how computational thinking is implemented by students when they face geometry problems still needs to be explored further. This study aims to analyze and describe the computational thinking (CT) of junior high school students in Indonesia in solving geometry problems. The Participants were 25 students in grade VIII of an Indonesian junior high school. This study used a qualitative research design. Data collection techniques were carried out through tests and interviews. Data analysis techniques consisted of data reduction, data presentation, and conclusion. The results showed that 60% of students could use CT to solve geometry problems (achieving KKM), while 40% were still below KKM. CT components that students with scores above KKM can achieve include abstraction, decomposition, and algorithms. Meanwhile, students with low scores were identified as having not achieved any of the specified CT components. The computational thinking of junior high school students in geometry has developed quite well. Integrating CT into geometry learning can be a powerful tool for students to solve complex geometry problems.

Keywords: computational thinking, problem solving, geometry.

▪ INTRODUCTION

Computational thinking (CT) began in the 1960s through Alan Perlis, who argued the importance of students from all disciplines to learn programming and the "theory of computation" (Guzdial, 2008). Subsequently, in the context of K-12 education, computation received attention through constructionist Seymour Papert in 1980 (Grover & Pea, 2013; Denning, 2017). Papert pioneered the development of procedural thinking through LOGO programming (Papert, 1991, 2020). Then, in 2006, Jeanette Wing, through her article, evoked CT with a 21st-century skills perspective (Wing, 2006; Grover & Pea, 2013).

Looking at the History of CT above, we can understand that the concept of computation forms CT. Computation is applying an algorithm to data to obtain the desired result with computational tools (computers). Algorithms are structured or procedural steps in data processing (Backus et al., 1960, 1963). The next shaping concept is thinking, a deliberate exploration of experience for a purpose. That goal can be understanding, decision-making, planning, problem-solving, judgment, and action (de Bono, 1976). Explaining the two constituent concepts of CT helps us understand the definition of CT itself. Angeli et al. (2016) said that until now, there has been no single agreed definition of CT. However, we can still understand the concept of CT; researchers have their definitions of their field of research (Shute et al., 2017). For example, Wing (2006) said that CT involves solving problems, designing systems, and understanding human behavior using basic computer science concepts. Meanwhile, Berland and Wilensky

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(2015) defined CT as the ability to think with computers as tools. They suggested using "computational perspectives" as an alternative to CT to emphasize that CT can be limited by context. From the explanation of the concepts of computation and thinking and the definitions given by the researchers above, it can be understood that CT is a systematic and logical way of thinking based on computational principles that can be applied to various contexts.

Based on the literature study, it is known that CT consists of several components. The components used by researchers vary according to the field of research. Researchers mostly use several CT components, namely, abstraction, decomposition, algorithms, and debugging (Wing, 2006, 2008, 2010; Barr & Stephenson, 2011; Barr et al., 2011; Grover & Pea, 2013; Angeli et al., 2016; Selby & Woollard, 2013; Yadav et al., 2014; Bers et al., 2014; Atmatzidou & Demetriadis, 2016; National Research Council, 2010; Shute et al., 2017). First, abstraction is the act of finding patterns in problems and solutions and thus can be used to generalize solutions to similar problems (Wing, 2006, 2008, 2010; Shute et al., 2017). Secondly, decomposition involves breaking down a complex problem into smaller parts with a systematic process in the solution (Wing, 2006; Shute et al., 2017; Lavigne et al., 2020; Selby & Woollard, 2013). Third, algorithms are abstractions of step-by-step procedures in taking inputs and producing desired outputs (Wing, 2008). Furthermore, Shute et al. (2017) said that algorithms are a logical and organised set of instructions to provide a solution to a problem. Fourth, debugging identifies and corrects errors (Weintrop et al., 2016; Shute et al., 2017).

Related to mathematics, some studies that reveal the benefits of CT are those by Chan et al. (2021), who said that CT improves performance in learning mathematics. Furthermore, Atmatzidou and Demetriadis (2016) interviewed students who said "...I think differently and solve problems more easily...". Of course, CT is very urgent and needs to be integrated into mathematics learning. However, there is still a lack of CT research in mathematics education that can be used as a basis for its integration. Based on the systematics literature review of computational thinking in mathematics education conducted by Isharyadi and Juandi (2023), namely by identifying the Scopus database with the keywords "computational thinking AND mathematics education" within five years, only six articles were obtained which were the results of empirical research. The research in question is related to investigating the impact of CT activities on the topic of number patterns in secondary schools (Chan et al., 2021), fostering algorithmic thinking and generalization skills (CT components) using GeoGebra in class XII calculus learning (Van Barkulo et al., 2021), primary school mathematics teachers' understanding of CT (Nordby et al., 2022), reflections of prospective kindergarten teachers, 2022), prospective kindergarten teachers' reflections when designing didactic sequences of mathematics learning with the use of robots (Seckel et al., 2022), analyzing primary school teachers' responses to programming (CT) and its teaching (Pörn et al., 2021) and training students' CT skills in solving everyday problems through mathematical modeling courses (Sunendar et al., 2020). Of course, this is an opening for researchers to study more deeply related to CT in mathematics education. Therefore, this study seeks to describe junior high school students' CT in solving geometry problems. The topic of geometry was chosen because many students understand the concept of area of flat geometry, such as the area of a square, rectangle, triangle, parallelogram, circle and so on, but not many students can calculate the area of land, where the shape of the land is not square, rectangle, triangle, parallelogram, circle or others. The irregular shape of the land makes students think that the concept of the area they understand is useless in solving the problem (Fauzi & Arisetyawan, 2020; Haryanti et al., 2019; Rusyda et al., 2017). This phenomenon makes many students experience difficulties in solving geometry problems (Naufal et al., 2021; Jelatu et al., 2018; Md Yunus et al., 2019; Sulistiowati et al., 2019; Ma'rifah et al., 2019). It is expected that the results of this study can provide valuable value in integrating CT as a problem-solving ability (Hsu et al., 2018) into mathematics learning, especially geometry.

▪ METHOD

Participants

This study was conducted at a public junior high school in Central Lampung Regency, Lampung Province, Indonesia. The participants were VIII grade students, 14 male and 11 female. The twenty-five students were given a test on plane geometry related to area. Furthermore, two students were selected by purposive sampling (Sugiyono, 2018) to be analyzed further through interviews.

Research Design and Procedure

This study uses a qualitative research design. Qualitative research design is a research design based on an interpretive paradigm, used to research in natural settings. In this design, the researcher plays a crucial role as a key instrument, actively engaging with the participants and the data. This approach allows for a more nuanced understanding of the research topic. The design also involves multiple data sources, inductive data analysis, and research results are intended to understand meaning, uniqueness, construct phenomena, and find hypotheses (Sugiyono, 2018; Creswell & Plano Clark, 2017). The qualitative research design was chosen because the researcher wanted to conduct an in-depth exploration and describe the CT skills possessed by junior high school students in solving geometry problems.

The research was conducted through three stages: Preparation/planning, data collection, and data analysis. In the planning stage, activities include literature studies on CT topics, determining research problems and objectives, determining research subjects, creating test instruments, and testing instrument validity. The data collection stage, which was conducted with the specific purpose of gathering comprehensive data, involved giving CT tests on geometry materials and conducting interviews with selected research subjects. Two students for interviews were selected with the following criteria: students who obtained the highest and lowest scores on the CT test. Interviews were conducted to explore information on students' CT skills to clarify students' answers. Furthermore, data analysis is carried out using data reduction techniques, data analysis and interpretation, as well as drawing conclusions from the research results.

Instrument

Research instruments are tools used by researchers to collect data from their research subjects. In qualitative research, the main instrument is the researchers themselves (Sugiyono, 2018). Researchers act as research managers and instruments in collecting data through interviews or observations. In addition to researchers, the instruments used are tests and interview guidelines. The test instrument is a test to determine students' CT in solving geometry problems. The test consists of one descriptive question related to the area of flat shapes (quadrilaterals and triangles) developed by researchers. Before being used, the test questions were tested and validated by experts related to content and face validation, with the results of the test questions being valid and suitable for use. Meanwhile, the interview guidelines consist of interview points to clarify the CT test answers. The test instruments and interview guidelines can be seen in the appendix.

Data Analysis

The research data in CT test results and interviews were analyzed qualitatively. Qualitative analysis uses data analysis techniques, including data reduction, data presentation, and conclusions drawing (Miles & Huberman, 1994). Data reduction is selecting the main things or focusing on important things. Thus, researchers must refer to the objectives of the research being carried out (Sugiyono, 2018). Data reduction is done by correcting students' answers and analyzing which CT components appear. This study's CT components consist of abstraction, decomposition, algorithm, and Evaluation of solutions and strategies (Shute et al., 2017). CT component achievement indicators are presented in Table 1.

Table 1. CT component achievement indicators (Shute et al., 2017)

CT Component	Indicators
Abstraction	Taking the essence of the problem, which includes: a. Analyzing problem-related information b. Modeling the problem c. Recognizing patterns in the problem
Decomposition	Breaking down the problem into manageable or solvable parts
Algorithm	Performing sequential, logical, and efficient steps in solving problems
Evaluation of solution and strategies	Evaluating strategies and solutions, which include: a. Detecting errors b. Correcting errors c. Summarising the solution

Each step of problem-solving is analyzed carefully to see whether the problem-solving process has reflected each indicator of each CT component. The research subject is said to have achieved the indicators of each CT component if it reaches 60% or more (Muir et al., 2008) of the total score (according to the scoring guidelines made). The calculation of the score for each CT component is carried out on a scale of 0 to 100 with the formula:

$$\text{score} = \frac{\text{total score obtained}}{\text{maximum score}} \text{x}100$$

Based on the test results, we selected students with the highest and lowest scores to be analyzed more deeply through interviews. Furthermore, the researcher conducted data triangulation by comparing the results of data analysis obtained through tests with data obtained through interviews. Furthermore, data reduction results are presented in the form of tables, figures, and narrative texts related to students' identified CT skills in solving geometry problems.

▪ RESULT AND DISSCUSSION

The CT test results show how the CT skills of junior high school students are in solving geometry problems. The researcher used the minimum completeness criteria (KKM), which is 60/100. The 60% cutoff point was chosen because it is considered a clear marker of the performance shown by the research subjects (Muir et al., 2008). The results of the students' CT test according to the KKM are presented in Table 2. Based on Table 2, 60% of students have been able to solve geometry problems.

Table 2. Results of students' computational thinking (CT) test

Score (S)	Number of students	%	Description
$60 \leq S \leq 100$	15	60%	achieving KKM
$0 \leq S < 60$	10	40%	below KKM

Next, the test results were analyzed for the achievement of CT components (Table 1) from 25 students who were the participants of the study in solving geometry problems. The participants of the study were categorized as achieving the indicators of the CT components if they had achieved 60% or more of the total score for each step of completing the test that reflected the indicators of the CT components. Table 3 presents the distribution of the achievement of each CT component.

Table 3. Distribution of computational thinking (CT) components achievement

No	CT Components	Number of students	%
1	*Abstraction*	15	60%
2	*Decomposition*	13	52%
3	*Algorithm*	13	52%
4	*Evaluation of solution and strategies*	13	52%

Based on the test results, an average of 52% of students have achieved the CT component. This means 52% of students can use CT skills to solve geometry problems. Confirmation of the test results was carried out through interviews with two students with the highest scores (S1) and the lowest (S2). This interview aims to ensure the achievement of the CT component based on the test results. The following describes computational thinking (CT) S1 and S2 in solving geometry problems (data triangulation results).

Description and Analysis of CT of Students Who Obtained the Highest Score (S1)

The steps of the solution written by S1 for solving the geometry problem are given in Figure 1. Based on Figure 1, each CT component (abstraction, Decomposition, Algorithm, and Evaluation of solution and strategies) used in solving geometry problems by S1 can be analyzed.

Abstraction

Abstraction is taking the essence of the problem, which includes analyzing information related to the problem, recognizing patterns in the problem, and modeling the problem. The solution steps taken by S1 begin by naming the required corner points. S1 knows that to calculate the total cost that must be spent as wages for installing marble and

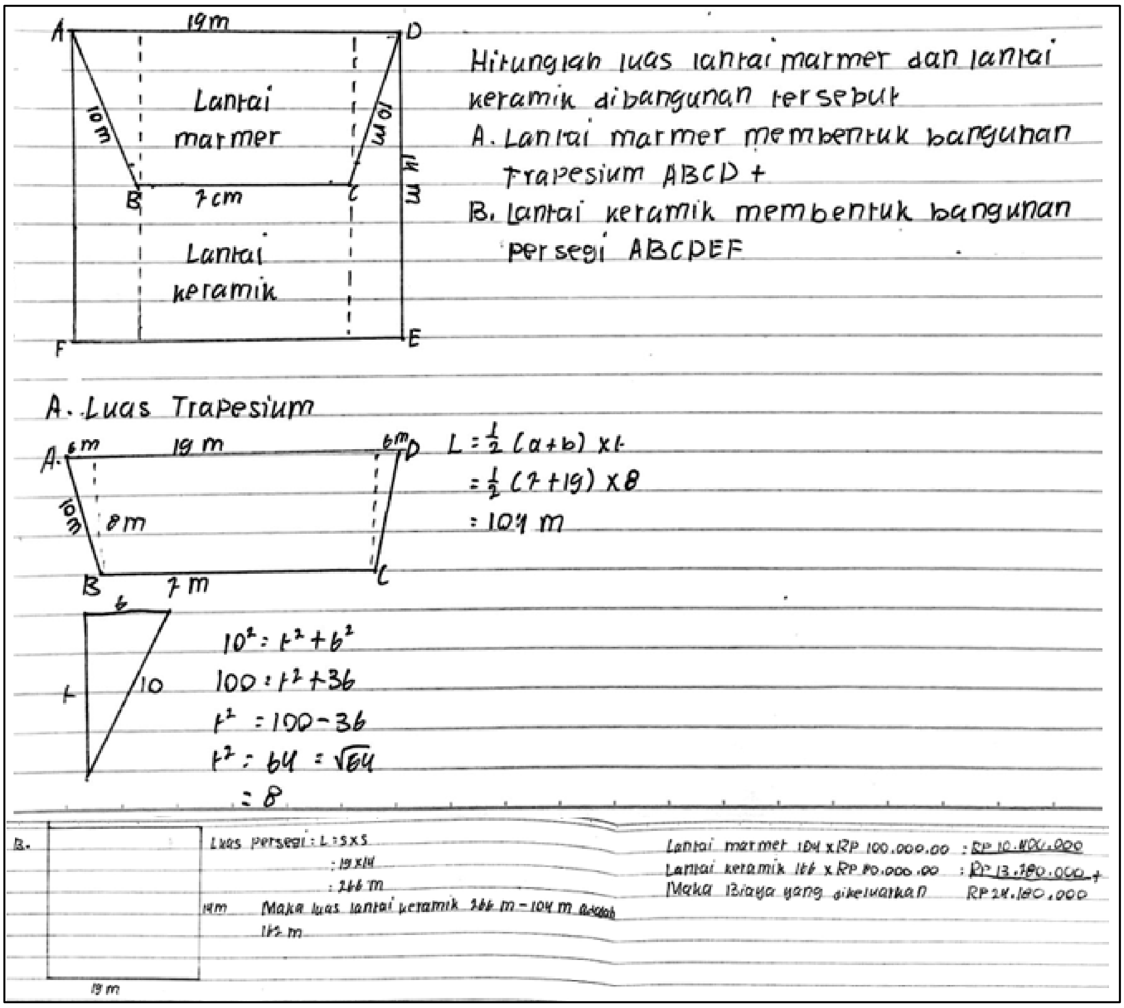
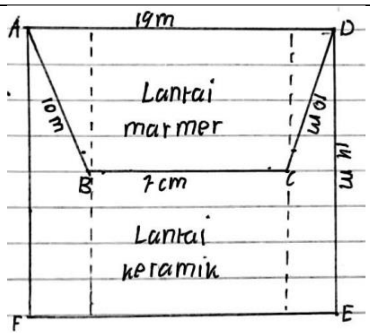


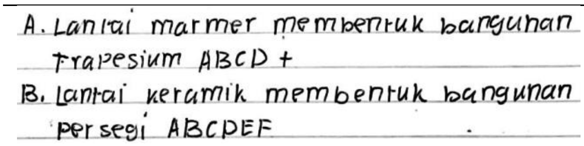
Figure 1. Steps for solving problems by s1

ceramic floors, it is necessary first to find the area of each floor that will be installed with marble and ceramics. The floor that will be installed with marble is seen as a trapezoid, precisely trapezoid ABCD, and the floor that will be installed with ceramics is seen as ABCDEF. In this case, S1 analyzes the problem, recognizes patterns, and models the problem (Figure 2).



Lantai marmer is marble flooring

Lantai keramik is ceramic flooring



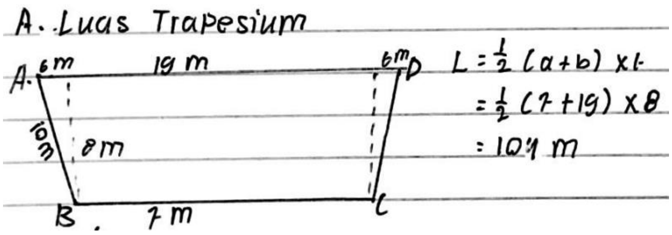
A. The mamer floor forms a trapezoid building ABCD +
B. The ceramic floor forms a square building ABCDEF

Figure 2. Abstraction thinking by S1

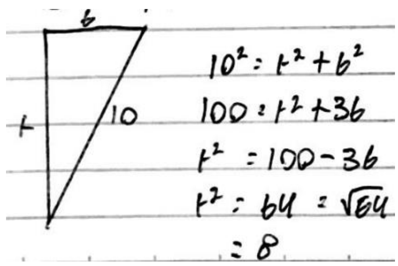
This result is confirmed by the interview with S1, who stated, "... I can understand the problem in the question. I tried to break the floor sketch into two flat shapes, namely trapezoid and square...". Based on this interview, it was confirmed that students could understand the problem and recognize patterns. S1 can analyze problem information thoroughly and accurately. This is indicated by S1 understanding the problem that must be solved, and the information in the question is sufficient to solve the problem (for example, when calculating the height of trapezoid ABCD using the Pythagorean Theorem concept, S1 can determine the length of one of the unknown sides of the shape, namely 6 m). S1 can also recognize patterns correctly, even though the patterns understood are as written in the answer: trapezoids, triangles, and rectangles.

Decomposition and Algorithm

After S1 recognized the pattern on the floor sketch, S1 then broke down the problem into manageable or solvable parts (Decomposition) and took steps to solve the problem (Algorithm) (Figure 3). The first problem solved was determining the area of the marble floor or the area of the trapezoid ABCD. Then, selecting the area of the ceramic floor, S1 did not calculate the area of the ceramic floor directly but used the area of the trapezoid that had been calculated. The method used by S1 to calculate the area of the ceramic floor was the total floor area minus the marble floor area.



S1 used the concept of the Pythagorean Theorem to determine the height of trapezoid ABCD.



S1 uses the method of the total floor area minus the marble floor area to determine the ceramic floor area.

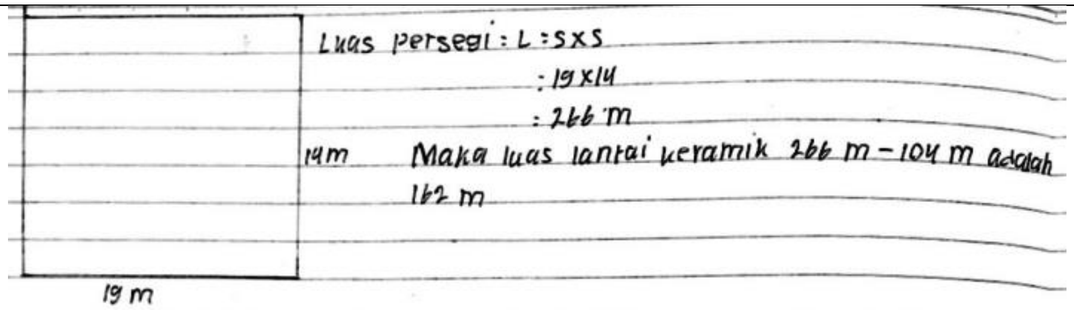


Figure 3. Decomposition and algorithm stage by S1

Based on the interview results, it was confirmed that S1 could model the problem correctly; this was shown by S1 when looking for the floor area to be tiled. S1 understood it as the total floor area minus the floor area to be tiled. Then, S1 broke down the problem into parts that could be managed or solved well. S1 also took sequential, logical, and efficient steps in solving the problem. This was shown by S1 when looking for the area of the trapezoid first, followed by the area of the rectangle so that the floor area to be tiled was obtained. Uniquely, S1 did not do any further decomposition when determining the area of the tiled floor; S1 utilized the total floor area minus the floor area to be tiled so that the calculations carried out by S1 were very efficient.

Evaluation of Solution and Strategies

The core activity in this component is to evaluate strategies and solutions, which include detecting errors, correcting errors, and concluding solutions. After each floor area is obtained, S1 concludes the solution to the given problem by multiplying the floor area to be installed with marble by the cost of installing marble and multiplying the floor area to be installed with ceramics by the cost of installing ceramics, then adding them up. However, in this step S1 made a mistake, precisely when writing the total cost of ceramic installation services, S1 wrote 166 x Rp. 80,000.00 should be 162 x Rp. 80,000.00 thus the conclusion made is not quite right. Figure 4 shows S1's answer as part of the evaluation of solutions and strategies. Based on the interview results, it was confirmed that S1 could not detect and correct errors when solving problems, (such as the unit of area, should be m^2 not m, the ABCDEF building is called the square ABCDEF building, and there are incorrect calculations). This is because S1 ran out of time to evaluate his answers, so the conclusions produced also contained several errors. In this case, S1 has not reached the CT component Evaluation of solution and strategies.

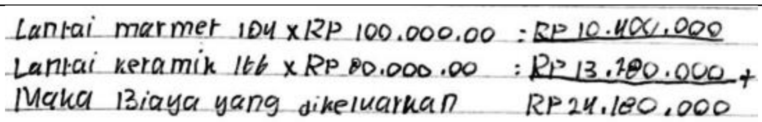
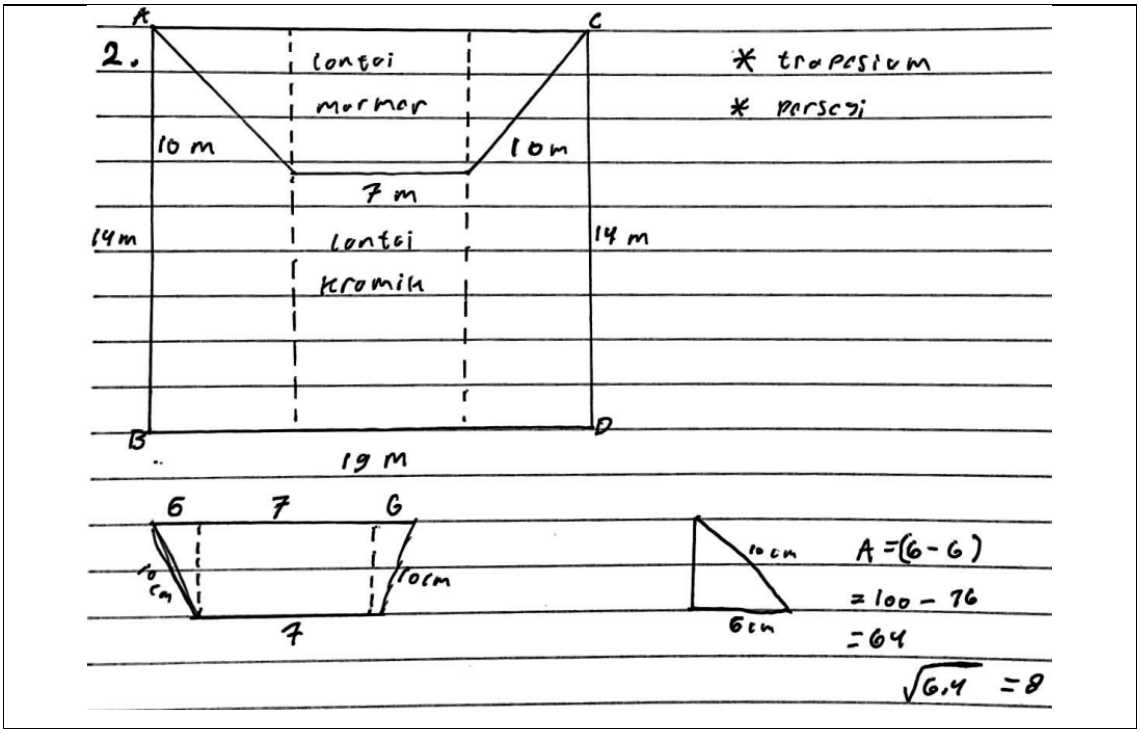


Figure 4. Conclusion stage of problem solution by S1

Based on what has been explained above, S1 has achieved the components of computational thinking (CT): abstraction, decomposition, and algorithm. The achievement of these three CT components shows that students have developed computational thinking in solving problems, followed by high scores in solving geometry problems. The results of previous studies also revealed that students with strong CT skills would be better prepared to solve complex problems, which leads to higher academic achievement (Barr et al., 2011; Grover & Pea, 2013; Shute et al., 2017; Hsu et al., 2018).

Description and Analysis of CT of Students with the Lowest Score (S2)

The steps of the solution written by S2 for solving the geometry problem are given in Figure 5. The analysis of each CT component used in solving the geometry problem by S2 is described below.



Figur 5. Problem solving by S2

Abstraction

In the problem-solving process, S2 gave names to the corner points of the rectangle and not all the corner points of the trapezoid. After sketching the floor and giving some names to the corner points of the shape, S2 then broke down the floor sketch into a rectangle and a trapezoid. Based on the interview results, it was confirmed that S2 knew the problem that had to be solved, but S2 analyzed the problem information with many shortcomings and was inaccurate. S2 knew that the floor pattern that would be installed with marble formed a trapezoidal plane, but when asked what the formula for the area of a trapezoid was, S2 could not answer it. This was also seen from what S2 had written on the answer sheet. In addition, S2 was also unable to apply the concept of the Pythagorean Theorem when determining the height of the trapezoid. Thus, the researcher concluded that S2 could break down the problem but still had many shortcomings.

Decomposition and Algorithm

Based on the test results, it is known that S2 cannot break down the problem into manageable parts. S2 has also not been able to carry out the steps to solve it correctly. The first calculation was carried out on the trapezoid; S2 first broke down the length of the rectangle side, which was 19 meters into 6 meters, 7 meters, and 6 meters, to get the height of the trapezoid. However, when doing the calculation, namely to get the height of the trapezoid, S2 took unclear steps even though the concept that should be applied is the Pythagorean Theorem. Based on the interview results, it was confirmed that S2 was constrained in solving the area of the trapezoid, which impacted the process of finding the area of the floor that would be tiled. In this case, S2 could not create a model related to the problem. The sequential, logical, and efficient steps in solving the problem by S2 still have many shortcomings. S2 knows the steps to solve the problem but cannot do the calculations, real and precise, so the desired solution or problem-solving is not obtained.

Evaluation of Solution and Strategies

Because S2 is constrained in analyzing problems correctly and completing calculations, it impacts S2's inability to conclude solutions to the problems given. Based on the interview results, it was confirmed that S2 has not been able to detect and correct errors. S2 did not realize that the concept of the Pythagorean Theorem that was written was incorrect.

Thus, based on the explanation above, S2 only recognizes patterns in problems. However, in general, S2 has not been able to achieve the CT components, including abstraction, decomposition, algorithm, and evaluation of solutions and strategies in solving problems. Low overall student scores will follow the low ability of students to solve problems in solving geometry problems. This aligns with the opinion of Hsu et al. (2018), who stated that low scores will follow low CT as a problem-solving ability.

From the description of problem-solving carried out by the two research subjects above, it can be seen that students who mainly master the components of CT can solve problems despite some shortcomings. This is due to the absence of "evaluation of solutions and strategies," so the answers produced are errors. In contrast, the research subjects lacked mastery of the CT components. Of course, it can be understood that mastery of CT will help students solve problems effectively and efficiently (Barr et al., 2011; Weintrop et al., 2016; Shute et al., 2017). Weintrop et al. (2016) said that CT allows students to conceptualize, analyze, and solve complex problems by selecting and applying appropriate strategies and tools. It is true that Pei et al. (2018) said that in geometry problem solving, there are CT practices such as modeling and breaking down problems into sub-problems that are easier to solve. In other sources, some CT components that play a role in solving geometry problems are abstraction, generalization, decomposition, algorithm, and debugging (Hanid et al., 2022). If such CT practices are not mastered, it is not surprising that students have difficulty or even think that the broad concepts they understand are useless in solving problems (Fauzi & Arisetyawan, 2020; Haryanti et al., 2019; Rusyda et al., 2017).

▪ CONCLUSION

Computational thinking, one of the important skills in the 21st century, can be a valuable tool to help students analyze and solve geometry problems. The CT analysis of high school students on geometry problems showed that 60% of students had achieved the KKM on the CT test. This means that students can use CT skills to solve geometry problems. CT components that can be achieved for students who have achieved KKM (S1) include abstraction, decomposition, and algorithm. Meanwhile, 40% of students get CT test scores below KKM, which means they cannot use CT to solve geometry problems. Furthermore, students with the lowest scores (S2) can only recognize patterns in problems, and in general, S2 has not achieved the specified CT components.

The analysis of strategies and approaches students use in solving geometry problems is expected to provide in-depth insight into students' thinking processes and how CT improves their ability to solve complex mathematical problems. The results of this study are also expected to contribute to the academic literature in mathematics education and provide practical recommendations for developing more effective curricula and teaching methods for integrating CT into geometry learning. The limitation of this study is that only one geometry problem was used. Further research can be conducted using more instruments to be more representative in describing students' CT.

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