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Research Article

Computational thinking in mathematical problem solving: Pattern recognition

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ABSTRACT

Computational thinking is increasingly acknowledged as important in education to support the development of problem-solving skills in mathematics. Pattern recognition plays a significant role in solving mathematical problems using computational thinking. This qualitative research explores how students recognize patterns when solving mathematical problems using computational thinking. The study adopts a case study approach, with 46 subjects then chooses two students from the Mathematics Education Study Program selected through purposive sampling. Data collection methods involve tests and interviews in August. The data is qualitatively analyzed, involving reduction, data presentation, and concluding the research findings. The results indicate that the subjects recognized a pattern related to determining the height of a triangle, which was one of the assigned questions. The pattern emerged as the subjects identified the problem, decomposed it, recognized known and unknown information, and identified the relationship between sub-problems and task information. The identified pattern is crucial in addressing the problem in the given task.

Keywords: *Computational thinking, Mathematical problem, Pattern recognition*

Introduction

Computational thinking is increasingly recognized as important in the field of education. The 21st century demands that individuals master various skills to prepare students for success in different fields of life (Apriandi et al., 2023). Computational thinking is not only studied and introduced in the field of computers, but also in mathematics education (Rara, Yuli, Siswono, & Wiryanto, 2022). This supports the foundation of mathematical problem-solving skills.

Computational thinking involves problem-solving, system design, and understanding human behavior, drawing on computer science concepts (Wing, 2006). Wing also stated that computational thinking is a thought process needed for formulating problems and

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solutions. Two important aspects of computational thinking by Wing are the thought process and problem-solving methods. Problem-solving in computational thinking can be achieved by breaking down complex problems into simpler ones, recognizing emerging patterns, abstracting to find general concepts, and developing step-by-step solutions (Bocconi et al., 2016).

Problem-solving in mathematics education is a leading area of research aiming to understand the processes involved and link it to students' mathematical knowledge and competencies (Liljedahl; et al., 2014). While there are numerous teaching methods for mathematics, it is challenging to determine the superior approach, given factors like the academic level of our students (Lacea & Buscano, 2023). Problem-solving allows students to apply their understanding of mathematical concepts, integrate and connect their knowledge, and achieve a more conceptual understanding of mathematics (Lester, 2013). Therefore, problem-solving is crucial in learning mathematics as it increases students' willingness to try and persist in solving problems, helps them develop problem-solving strategies, and makes them aware of multiple solution approaches.

Statistical data from the report shows that in different regions worldwide, there is a correlation between teacher performance and student achievement (Cadag, 2024). The 2018 PISA results stated by Hewi & Shaleh (2020) show that the mathematics abilities of students in Indonesia are still not encouraging, with an average reading score of 371, mathematics score of 379, and science score of 396. These averages are below those of other participating countries. This has triggered various reactions, including those from the Minister of Education and Culture. PISA is used to evaluate the quality of education in Indonesia, particularly in the problem-solving process.

Research conducted by Maharani, Kholid, Pradana, & Nusantara (2019) suggests that computational thinking supports students in solving mathematical problems. Similarly, Susanti & Taufik (2021) state that introducing computational thinking to students helps improve their problem-solving skills by providing structure and focus. To effectively apply problem-solving strategies to similar cases, students must recognize and understand the patterns within the problems they are solving. The ability to recognize these patterns is crucial as it enables students to solve problems under varying conditions.

Selby (2018) explains that computational thinking encompasses aspects such as abstraction, decomposition, pattern recognition, generalization, and automation. In fact, Dong et al. (2019) refer to these aspects as PRADA (Pattern Recognition, Abstraction, Decomposition, Algorithm Thinking). PRADA represents a mindset that transcends specific content areas or tools, assisting individuals in solving problems systematically and in a way that can be generalized.

Pattern recognition, as a crucial aspect of computational thinking, significantly influences the process of solving mathematical problems among students. Choosing the most suitable method can significantly impact students' comprehension, retention, and assimilation of the knowledge imparted by teachers (Roblon et al., 2022). The characteristics of pattern recognition in computational thinking Yasin & Nusantara (2023) can be identified as follows: understanding the problem by gathering relevant information, connecting the questions in the problem with previously acquired knowledge, breaking down problem components, identifying relationships between these components, exploring all possible relationships to identify regularities or repetitions, and estimating the patterns discovered.

By further exploring how students employ pattern recognition in the mathematical problem-solving process, this research will contribute to the understanding of computational thinking's role in mathematics education. Its primary aim is to investigate how students recognize patterns when solving mathematical problems within the framework of computational thinking.

Methods

Research Design

This research employs qualitative methods and purposive sampling to examine how students identify patterns in solving mathematical problems through computational thinking. The research follows a case study approach, focusing on students' pattern recognition in computational thinking while solving Planar Geometry problems.

Sample and Data Collection

The research includes 46 sixth-semester students enrolled in the Mathematics Education Study Program at the University of Muhammadiyah Malang. The selection of these students is based on their knowledge and understanding of the mathematical concepts relevant to this study. Two students with high mathematical abilities are chosen as subjects through purposive sampling, taking into consideration their proficiency in problem-solving and communication skills.

Data is collected through tests and interviews. The test consists of problem-solving tasks, which yield students' work results in solving mathematical problems. These results are analyzed to identify students' pattern recognition in computational thinking. Additionally, the research subjects participate in interviews to gain further insights into their approach to pattern recognition in completing the given tasks.

Data Analyzed

Qualitative data analysis is conducted throughout the data collection process and after its completion. The researchers follow the data analysis stages proposed by Miles & Huberman (2018), which involve data reduction to obtain a clear understanding and facilitate the identification of patterns. The data is presented in narrative form, providing descriptive accounts. Conclusions are drawn by reconciling the test and interview results, enabling a comprehensive understanding of pattern recognition in solving mathematical problems through computational thinking.

Result and Discussion

This study involved two highly skilled students in solving mathematical problems. A group of 46 participants were given mathematical problem-solving tasks, and from this group, two subjects with exceptional mathematical abilities were selected for interviews. The purpose of these interviews was to understand how these subjects used pattern recognition in computational thinking to solve mathematical problems. The interviews were conducted in person, face to face. The following section will outline the process of pattern recognition in mathematical problem-solving tasks, based on the subjects' work results and excerpts from the interview transcripts.

Pattern recognition involves identifying patterns or similarities within the sub-problems of a given mathematical problem. When a problem is broken down, patterns often emerge, which can help in solving complex problems more efficiently.

Based on the subjects' work results and the interviews conducted, it was found that they recognized patterns by determining the height of the triangle in the given task. Through their observations, both subjects first identified the problem to be solved in the task. They correctly identified that the problem involved finding the sum of the areas of two triangles that formed a trapezoid. From this problem, the subjects then determined the missing information in the task and used it to find the sum of the areas of the two triangles. One crucial piece of information needed was the area of each triangle, specifically the PTS triangle and the STR triangle. In the context of computational thinking, these two areas represented the decomposition of the problem. Thus, it can be concluded that the subjects performed decomposition after resolving the problem identification process. The following are excerpts from the interview transcripts of both subjects.

Excerpts interview transcripts of Subject 1

Researcher	:	*What patterns do you identify from this assignment?*
Subject 1	:	*You are already familiar with multiple triangles. The sum of the areas of the PUT triangle and the STR triangle equals 55. Find the height. Determine the height by employing the area formula. Currently, the height is unknown. For instance, if TP represents the x-height, then TC equals PS minus x-height, resulting in 15-x.*

Researcher : *What's next?*
Subject 1 : *Look for the area.*
Researcher : *How?*
Subject 1 : *The height of the triangle is uncertain, yet the area is known. This knowledge is utilized to ascertain its height.*

Excerpts interview transcripts of Subject 2

Researcher : *What patterns do you observe in this task?*
Subject 2 : *Perhaps the discrepancy determines the altitude. For altitude, I employed 2 equations. Therefore, if I utilize what is given, the area of the triangle is 45. By dividing the triangle into 2 right triangles, I can determine the altitude. Consequently, if you are seeking the altitude, the formula for a right-angled triangle, known as Pythagorean's theorem, can be used by subtracting the base squared from the hypotenuse squared and taking the square root, yielding 15 altitudes.*
Researcher : *What is the next step?*
Subject 2 : *After discovering the altitude, we ascertained that the triangle had an area equivalent to 55 at that point. To proceed, I applied the same method as in number one: expanding the triangle firstly by half of the base multiplied by the height. The first triangle is the PUT triangle, denoted as $\frac{T_1 \cdot t_1}{2}$, and the second one is the STR triangle, $\frac{a \cdot t_2}{2}$. Subsequently, I substituted the given values and obtained 55, matching the question. It is known that the base is a T_1 and a, but the altitude is still unknown, hence obtaining the equation $3t_1 + 4t_2 = 55$. There is another aspect to consider: the height of the trapezoid is known to be 15, resulting in 2 equations $t_1 + t_2 = 15$. By utilizing these two equations, the altitude of the STR triangle can be determined to be 10 cm. I obtained this result through the method of elimination.*

Figures 1 and 2 depict the outcomes of pattern recognition work conducted on subject 1 and subject 2.

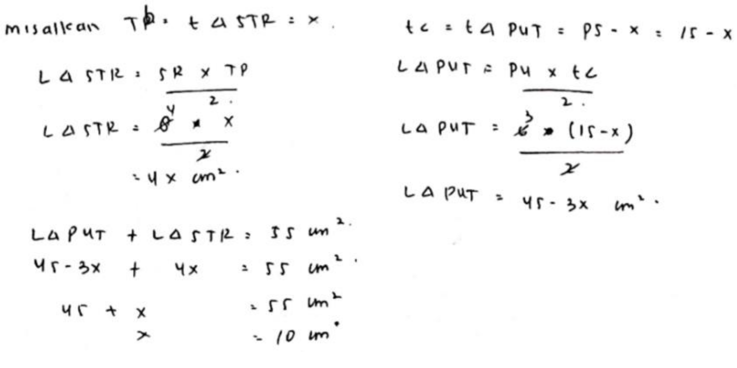

Figure 1. Work Result: Subject 1

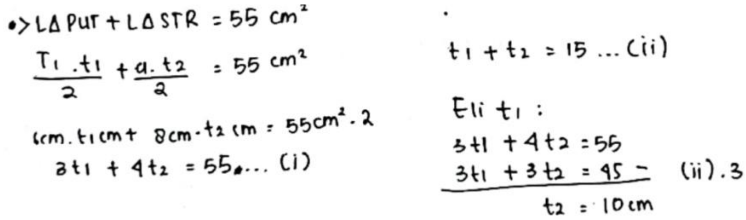

Figure 2. Work Result: Subject 2

Based on the interview excerpt and examining Figure 1 and Figure 2, it is evident that both subjects, after decomposing the task, were focused on determining the area of each triangle, which was the main question. In order to find the area of the triangle, both subjects realized that there was an unknown quantity, namely the height of the STR triangle.

Subsequently, the two subjects proceeded to determine the height of the STR triangle. They employed different methods to do so. Subject 1 represented the height as a variable using x, while subject 2 used a different variable t_2.

Subject 1 utilized the formula for the area of a triangle and substituted the base and height of each triangle. They then proceeded to use the equation $\mathrm{L\Delta PUT} + \mathrm{L\Delta STR} = 55$ substituting the values of the triangle area until the x value equaled 10. Meanwhile, subject 2 used the equation $\mathrm{L\Delta PUT} + \mathrm{L\Delta STR} = 55$ and the sum of the height of the PUT triangle and the height of the STR triangle. Subject 2 derived equation 1 $3t_1 + 4t_2 = 55$ and equation 2 $t_1 + t_2 = 15$ from this example. Subsequently, they employed the elimination method and determined that x was equal to 10. Despite the different methods used by the two subjects, they ultimately arrived at the same conclusion - the pattern in the task involved determining the height of the triangle.

The height of the STR triangle can be considered a pattern in the given task because height is a recurring element or similarity that is frequently utilized in determining the area of the STR triangle. In accordance with the definition of pattern recognition presented by (Selby, 2018), it emphasizes the process of generalization. Generalization is a powerful component of problem-solving that helps define computational thinking. (Dong et al., 2019) state that Pattern Recognition refers to the observation and identification of patterns, trends, and regularities in data, processes, or problems.

Therefore, it can be concluded that pattern recognition in computational thinking, while solving mathematical problems, involves the following steps:

a. Identifying the problem to be resolved
b. Decomposing the problem to be solved
c. Identifying the known information about the problem
d. Identifying the unknown information in the problem
e. Determining the unknown information using known information
f. Identifying similarities or patterns during the problem decomposition process
g. Searching for relationships in the identified patterns or similarities by utilizing the known information
h. Utilizing the patterns or similarities that have been identified while solving the problem

Various strategies can be employed to recognize patterns in computational thinking for solving mathematical problems. These strategies can be sequentially executed from point (a) to point (h). By following this sequence, it becomes easier to recognize patterns and solve problems. As mentioned by Labusch et al. (2019). Computational thinking should commence with identifying the problem to be solved. Subsequently, the problem decomposition stage can be carried out as mentioned by (Susanti et al., 2023). Analyzing the problem to be solved enables the identification of patterns or similarities in the sub-problems, which aids in determining the problem in the given task.

This study illustrates how recognizing patterns in mathematical problems can facilitate problem solving. Further experimentation on diverse complex problems with different materials is necessary to demonstrate the applicability of pattern recognition steps to various types of mathematical tasks.

Conclusion

Based on the description of the results and discussion, it can be concluded that both subjects successfully recognized patterns in the given mathematical problems. The common pattern identified by both subjects involved determining the height of the triangle. To find the height, information about the sum of the two triangle areas provided in the task and the area of the triangle given in the task were utilized. Both subjects recognized this pattern by first identifying the problem in the task, followed by decomposing it into several sub-problems.

From these sub-problems, they discovered patterns and similarities. Finally, they sought relationships by utilizing the known information from the assignment and the problems presented in the assignment.

This study only used one task instrument, so we could not observe the consistency in the subjects' actions when recognizing patterns in similar problems. For future research, it is hoped that we can develop instruments specifically designed to identify how a person thinks computationally when solving mathematical problems, as computational thinking must involve complex problems. Furthermore, this study only used one problem-solving task. In future research, it is hoped that more than one task instrument will be used to understand how patterns are recognized in similar or other problems.

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