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STUDENT'S COMPUTATIONAL THINKING PROCESS IN SOLVING PISA QUESTIONS IN TERMS OF PROBLEM SOLVING ABILITIES

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ABSTRACT

Computational thinking is the process of solving problems using logic gradually and systematically needed in the field of mathematics. However, the learning applied by the teacher limits the student's ability to develop computational thinking skills. Teachers are accustomed to providing conventional learning and emphasize student's skills in using formulas. One of the treatments that can be used to stimulate student's computational thinking skills is PISA questions. The purpose of this study was to analyze student's computational thinking processes in solving PISA questions in terms of their problem solving abilities. The research data consisted of student answers, think aloud results, and semi-structured interviews. Data analysis techniques are data reduction, data presentation, and drawing conclusions or verification. The results showed that the computational thinking process of students with low problem solving abilities only reached the decomposition stage because students were able to simplify the problem even though it was incomplete, but they were not able to connect mathematical concepts or materials to build a solution. Meanwhile, students with moderate and high problem solving abilities are limited to the pattern recognition stage because they can simplify problems and develop strategies, but make mistakes in using patterns, and there are incomplete steps. So it can be concluded that the computational thinking process of students with low problem solving abilities only reaches the decomposition stage. The computational thinking process of students with moderate and high problem solving abilities is limited to pattern recognition indicators.

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INTRODUCTION

Computational thinking was first introduced by Seymour Papert in 1980. Several developed countries such as the United Kingdom, Australia, Poland, and South Korea have introduced computational thinking starting from elementary and junior high school education (Città et al., 2019). This policy is based on the difficulty of teachers updating monotonous teaching methods that have been used for years (Supiarmo, Turmudi, 2021).

Computational thinking is defined as a series of abstract mental activities that include reasoning processes such as decomposition, pattern mapping, algorithmic thinking, automation, modeling, simulation, assessment, and generalization (Città et al., 2019). Computational thinking is also a process of solving problems using logic gradually and systematically which is not only important in the computer programming process but is also needed by students in various fields including mathematics (Yadav et al., 2017). Computational thinking is needed to help and facilitate students in solving mathematical problems because it involves various skills and techniques that train students to break down problems into small parts that are easy to solve (Lee et al., 2014). In addition, computational thinking can also stimulate students to think creatively in solving problems (Angeli & Giannakos, 2020; Wing, 2014).

The learning applied by the teacher narrows the student's space to develop computational thinking skills (Gadanidis et al., 2017). Teachers are used to giving conventional ones, tend not to innovate in the approach used, and students are more concerned with skills in using formulas. This causes students to be less interested and active in developing their thinking skills. This is in line with the opinion of Tedre & Denning (2016) that the reason why student's computational thinking skills do not develop is the teacher's lack of creativity in innovating learning. Teachers often emphasize learning which requires students to memorize the procedures used to solve mathematical problems, causing student's computational thinking skills to be low (Supiarmo, 2021).

The low computational thinking ability of students is confirmed by the results of the initial studies in class XI MA Daruttauhid Malang and Islamic High School Sabilurrosyad. Through giving initial tests, it shows that students still apply general procedures such as using examples, substitution, and elimination in solving linear programming problems. The stages of computational thinking carried out by students only reached the stage of decomposition and pattern recognition. In addition, students are also not able to use abstraction to solve the given mathematical problem. Student's algorithms skills are also not visible because there are stages of problem solving that students do illogically and systematically. Therefore, it can be concluded that the student's computational thinking ability is still low.

Based on the description above, of course, a solution is needed to develop student's computational thinking processes, one of which is by giving non-routine questions. Through the provision of non-routine questions, it aims to train students to get used to solving problems using computational thinking skills. One type of non-routine question that can be used to stimulate student's higher-order thinking skills, especially computational thinking, is the PISA question (Supiarmo, Turmudi, 2021).

PISA or Program for International Student Assessment, is an international study held every three years to test the higher order thinking skills (HOTS) of students with an age range of 15 years (Supiarmo et al., 2021; OECD, 2013). The OECD Institute (2014) stated that the study was conducted by giving questions in the form of problems that emphasize the competencies and skills of students obtained through formal education in schools and the implementation of these skills in student's daily lives (OECD, 2014). The PISA math questions tested consisted of three components, including content, process, and context (Supiarmo et al., 2021; OECD, 2013).

The mathematical problems contained in the PISA questions do not only emphasize student's knowledge of concepts but also their application of these concepts to solve problems (OECD, 2014; Supiarmo, 2021). In addition, PISA questions test student's ability to formulate and analyze problems, create mathematical models, compare procedures, and use appropriate algorithms to answer problems. Therefore, PISA questions are one of the best methods to explore student's HOTS abilities globally (OECD, 2013).

The abilities possessed by students in solving PISA questions are certainly not the same, because each student has different abilities (OECD, 2013). The difference in ability is inseparable from the role of the students themselves in developing their soft skills (Supiarmo, Turmudi, 2021). The soft skill that enables student's computational thinking abilities is problem solving ability.

Problem solving is defined as a series of activities that enable students to find solutions to problems (Tambunan, 2019; Tippmann et al., 2017). Problem solving is also a process carried out by students to overcome or solve a problem through stages, including defining the problem, finding out the main factors causing the problem, finding solutions, and applying these solutions so that existing problems can be solved (Gog et al., 2020; Supiarmo, 2021). Problem solving is very important to master because students will encounter various types of problems both in the learning process and in everyday life (Mathew et al., 2019). Problem solving is a competency that must be prioritized for students so that they can apply and adapt strategies to solve other problems in different contexts (Halpern, 2014).

Previous research on the computational thinking process in solving PISA questions, and its relationship with student's soft skills has been carried out, namely the research of Supiarmo et al. (2021) on the analysis of student's computational thinking processes in solving PISA questions on change and relationship content. In this study, the subjects used were junior high school students who already had mathematical knowledge, especially the material for a two-variable linear equation system. The purpose of this research was to reveal the computational thinking ability in terms of student's self-regulated learning.

The novelty of this research lies in the analysis of student's computational thinking processes in solving PISA questions on linear programming based on their problem solving abilities at the high school level. This is also supported by the absence of research related to the analysis of student's computational thinking processes in solving PISA questions, as seen through the category of problem solving abilities. Therefore, the purpose of this research was to analysis student's computational thinking process in solving PISA questions in terms of problem solving abilities.

METHOD

This research method is descriptive with a qualitative approach. The prospective subjects involved in this study were 98 students from class XI MA Daruttauhid Malang and SMA Islam Sabilurrosyad. Subject selection was carried out using a purposive sampling technique, in which students were given a problem solving test related to linear programming. Then the researchers grouped students based on problem solving abilities, which they referred to as the categorization of Samo's problem solving abilities (2017).

The subjects taken were six students, including two with low problem solving abilities, two with moderate problem solving abilities, and two with high problem solving abilities. Furthermore, the six subjects were given a computational thinking ability test (CTAT), which was adopted from the PISA questions for linear programming. In addition, the CTAT has also been validated by material experts and learning experts, as well as a readability test. The CTAT questions used are as follows:

1. Dua media massa koran di Jakarta sedang membutuhkan orang untuk bekerja sebagai penjual koran. Iklan yang menunjukkan bagaimana kedua media massa membayar gaji penjual koran disajikan dalam Gambar 1 dan 2.

INDOPOS

Dibutuhkan segera!

Penjual koran dengan gaji:

Rp.1.500,00 per koran, jika Anda mampu menjual sampai dengan 210 koran dalam satu minggu, ditambah Rp.10.000,00 per koran yang selebihnya terjual.

Gambar 1. Iklan Indopos

KOMPAS

Apakah anda mau dibayar tinggi dalam waktu singkat?

Ayo!!!

Jual koran kami dan dapatkan Rp.500.000,00 per minggu, ditambah bonus Rp.300,00 per koran yang terjual.

Gambar 2. Iklan Kompas

Melihat kedua iklan tersebut, Budi tertarik dan memutuskan untuk melamar menjadi penjual koran. Oleh karena itu, ia perlu mempertimbangkan antara bekerja di Indopos atau Kompas. Buatlah grafik yang menggambarkan bagaimana pendapatan pekerja kedua media massa koran!

Figure 1. CTAT questions

The data for this study consisted of answers, think aloud and the results of semi-structured interviews with the subject. The three data sets were analyzed based on the following computational thinking process indicators:

Table 1. Indicators of Student's Computational Thinking Processes

Computational Thinking Process Indicators	Sub-Indicator
Decomposition	Students can identify information that is known and ask for help with the problems given.
Pattern Recognition	Students can find similar or different patterns, which are then used to build problem solving skills.
Abstraction	Students can reach conclusions by eliminating elements that are not needed when carrying out problem solving plans.
Algorithms	Students can describe the systematic, logical steps used to find solutions to a given problem.

The data analysis technique was carried out through three main stages consisting of data reduction, data presentation, and drawing conclusions or verification.

RESULTS AND DISCUSSION

Results

a. Computational Thinking Process of Students with Low Problem Solving Ability in Solving PISA Problems

According to the categorization of problem solving abilities by Samo (2017), S1 and S2 are subjects with low problem solving abilities. This is because the two subjects reached the sufficient category in understanding the problem only, while in formulating strategies, implementing plans, and re-examining S1 and S2 they were in the less category. In the following, research data related to S1 and S2 computational thinking processes are presented in order to solve PISA questions.

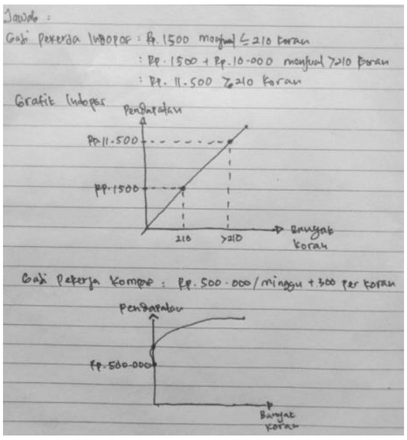

Figure 2. S1 Work

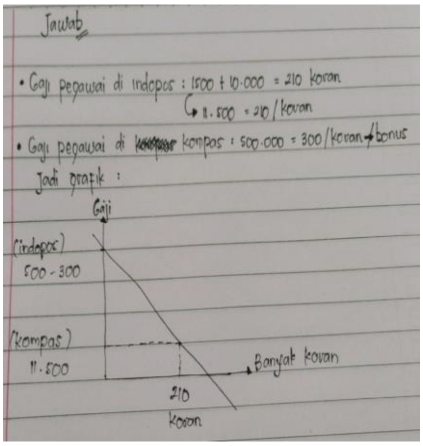

Figure 3. S2 Work

Based on Figures 2 and 3, at the stage of understanding the problems, S1 and S2 can directly identify and describe the problems as being simpler, although not complete. S1 simplifies the problem by comparing the income of the workers of the two mass media newspapers based on spoken or thought aloud expressions conveyed. However, it turned out that at the time of the interview, S1 was able to describe important information related to what was known and asked about the PISA problem. The master's degree can simplify the problem because it can find out the differences in the basic income and bonus of workers at Indopos and Kompas in detail based on interviews and describe the known information related to how the graphs depict the income of the workers of the two mass media newspapers.

Furthermore, at the strategy planning stage, S1 and S2 were unable to relate the problem to mathematical concepts or material that had been studied to solve it. S1 made a mistake in the mathematical modeling of workers' income. By modeling the income of Indopos workers, 1,500 sold 210 newspapers and 11,500 sold > 210 newspapers, while the modeling income for Kompas workers was Rp. 500.000.00 per week plus a bonus of Rp. 300.00 per newspaper. This resulted in S1's error in the next step in graphing the income of Indopos and Kompas workers, which was also found to be wrong because the line formed was linear. The error occurred because S1 immediately made a graph by matching the salary and the number of newspaper sales that workers received without creating an objective function first. S1 only performs a match in determining the intersection point of the two graphs.

Meanwhile, S2 did not first look for the objective function to draw the graph. S2 only performs the addition operation between workers' salaries and bonuses. In addition, the graph formed has parallel lines that depict workers' salaries remaining the same. So, through the results of the work, it is known that S2 cannot relate the problem to the mathematical concepts or procedures that have been obtained, so that S2 can be said to be unable to do pattern recognition.

Based on the problem solving steps taken as a whole, it can be seen that S1 and S2 do not know the right mathematical concepts or materials to solve the problem. Therefore, the two subjects have not been able to achieve the indicator of pattern recognition in computational thinking. Thus, directly, S1 and S2 cannot reach the next indicator, namely abstraction and algorithms.

b. The Computational Thinking Process Students with problem solving ability are in Solving PISA Problems

Samo (2017) notes that S3 and S4 are subjects who have moderate problem solving abilities. This is because S3 and S4 can reach the category of sufficient in understanding the problem, sufficient in formulating strategies, and sufficient in carrying out plans, but the category is lacking in re-examining. In the following, research data related to the S3 and S4 computational thinking processes are presented in order to solve PISA questions.

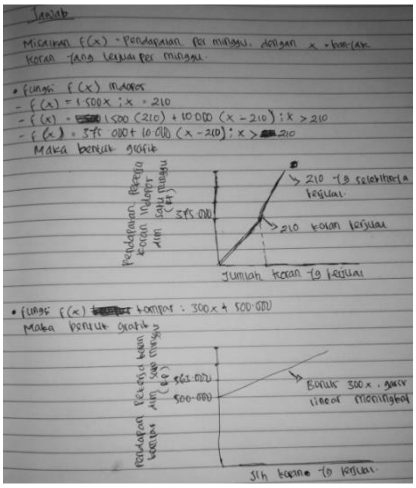

Figure 4. S3 Work

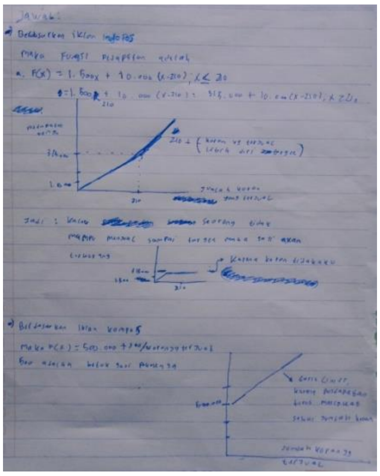

Figure 5. S4 Work

Based on Figures 4 and 5, it is known that in understanding the problem, S3 and S4 can break down the problem into smaller, simpler elements. S3 can directly describe the problem by comparing the incomes of workers at Indopos and Kompas, making it possible to get a higher income. This is known through the results of interviews and think alouds delivered by S3 when solving problems. Then S4 breaks down the problem into simple but not exhaustive parts. However, through the results of the interview, it turned out that S4 was able to explain in detail the important information contained in the problems given. This explains why S3 and S4 can describe the information that is known and ask about the income and bonuses that may be obtained by the workers of the two mass media newspapers. The description of the problem carried out by S3 and S4 explained that the two subjects carried out decomposition.

Furthermore, in formulating strategies, S3 and S4 can relate the problems given to the linear programming material that has been studied previously. The two subjects illustrate this by using f(x) to represent worker income and x to represent the number of newspapers sold in one week.Then S3 creates two functions that describe the salaries of Indopos employees: f(x) = 1,500x and f(x) = 375,000 + 10,000 (x-210).However, in the second Indopos income function, an error occurred in performing the multiplication operation. S3 calculates that the result of 1500×210 is 375,000. This error has an impact on the income function of the second Indopos worker found by S3 to be incorrect. It differs from S4, which produces the objective function but makes an error in producing the income function of Indopos workers, whereas S4 produces only one function, namely f(x) = 315,000 + 10,000 (x-210).

Even though S3 and S4 made mistakes, the examples proved that the two subjects had prior knowledge in accordance with the problem, so they were able to relate the given problem to mathematical material, especially linear programming, to build a solution. This explains that S3 and S4 can achieve pattern recognition indicators in computational thinking in solving problems given PISA questions.

As for the stage of implementing the plan, S3 and S4 experienced errors and did not solve the problem in a systematic stage where there were incomplete steps. S3 made an error when forming functions and graphs that describe the incomes of Indopos workers, and did not draw any conclusions from the graphs of the incomes of Indopos and Kompas workers that were found. Meanwhile, S4 made an error where the income function of Indopos workers found only one and did not draw any conclusions about the final solution. Therefore, S3 and S4 have not reached the abstraction stage, and, of course, the two subjects also have not been able to reach the algorithm thinking stage because there are errors and there are still incomplete and systematic steps in solving the problem in the PISA problem.

c. Computational Thinking Process of Students with High Problem Solving Ability in Solving PISA Problems

S5 and S6 are subjects with high problem solving abilities according to the categorization of Samo's problem solving abilities (2017). This is because the two subjects reached a good category in understanding the problem, a good category in formulating strategies, a good category in carrying out plans, and a sufficient category at the stage of re-examination. In the following, research data related to S5 and S6 computational thinking processes are presented in order to solve PISA questions.

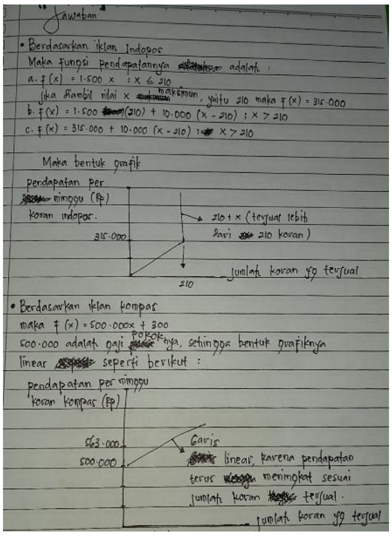

Figure 6. S5 Work

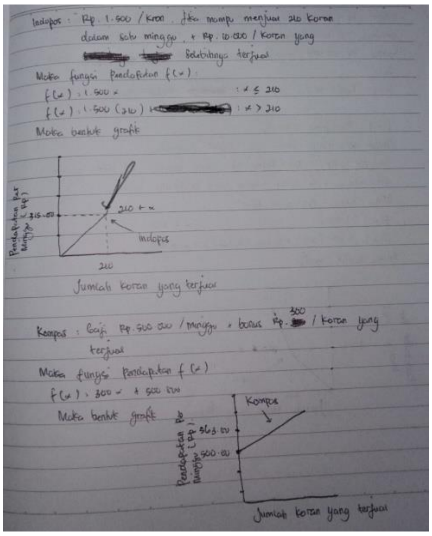

Figure 7. S6 Work

Through pictures 6 and 7, we learn that in the step of understanding the problem, S5 and S6 were able to simplify the problem into several parts. S5 can describe the income of workers at Indopos and Kompas. This is supported by interviews and oral expressions in S5. S6 is also able to describe the problem by mentioning important information related to salaries and bonuses for workers' income, both at Indopos and Kompas. Thus, the simplification of the problem carried out by S5 and S6 on the problem is included in the decomposition skills of computational thinking ability.

Furthermore, in formulating strategies, S5 and S6 can integrate problems with mathematical concepts, namely linear programming material. S5 and S6 assume that f(x) is the worker's income, with x being the number of newspapers sold. S5 generates two functions that describe the earnings of Indopos employees: f(x) = 1,500x and f(x) = 315,000 + 10,000 (x-210).However, the S5 made a mistake in drawing a line on the chart. It can be seen that the line that describes the sale of more than 210 newspapers is made vertically. In addition, S5 also made an error in the income function of Kompas, namely 500,000x + 300. Meanwhile, S6 experienced an error in making the second Indopos worker income function, where the functions found by S6 were f(x) = 1,500x and f(x) = 315,000 . However, even though S5 and S6 made mistakes, the examples proved that the two subjects had the appropriate prior knowledge, so they were able to perform pattern recognition on the given problem.

As for the stage of implementing the plan, S5 and S6 experienced errors. This is due to previous mistakes in applying mathematical procedures when creating functions and graphs that describe the incomes of Indopos and Kompas workers. The two subjects also did not solve the problem completely because they did not draw conclusions regarding the solutions they found. So, S5 and S6 have not been able to achieve abstraction indicators and think algorithms in solving problems on PISA questions.

Discussions

Computational thinking is defined as the process of solving problems using logic gradually and systematically (Weintrop et al., 2016; Wing, 2014). Computational thinking has four operational skills, including decomposition, pattern recognition, abstraction, and algorithms, which are not only important in the computer programming process but are also needed by students in various disciplines (Supiarmo, 2021).

Computational thinking is part of problem solving and is one way to solve problems through logical thinking. Of course, computational thinking ability is different from problem solving in general, because computational thinking focuses more on the reasoning process followed by problem solving (Jose, 2017; Supiarmo, Turmudi, 2021).

In this study, the computational thinking process was revealed by looking at the problem solving abilities of students in solving PISA questions on linear programming material. Whether student’s problem solving abilities can affect their computational thinking skills remains to be seen. Through the research results that have been presented, it is evident that there are differences in the achievement of the computational thinking processes of students with low, medium, and high problem solving abilities. The differences in the achievement of student’s computational thinking processes can be seen in table 2.

Table 2. Differences in Student’s Computational Thinking Process Achievements Based on Problem Solving Ability

Student Problem Solving Ability	**Achievement of Student's Computational Thinking Process**			
	Decomposition	Pattern Recognition	Abstraction	Algorithms
Low	✓	-	-	-
Medium	✓	✓	-	-
Height	✓	✓	-	-

Based on table 2, it can be seen that the computational thinking process of students who have low problem solving abilities only reaches the decomposition stage. This is because students can simplify problems even though they are incomplete, but are unable to connect mathematical concepts or material to build solutions to problems. This is per the problem solving categorization expressed by Samo (2017), that students with low problem solving abilities are in the sufficient category in understanding the problem and lacking in developing strategies because they cannot recognize characteristics or patterns to build solutions. It's just that in computational thinking, what students do is included in decomposition skills but they cannot do pattern recognition (Wing, 2014).

Furthermore, the achievement of the computational thinking process of students who have moderate problem solving abilities is limited to pattern recognition indicators. This is because students can simplify problems and develop strategies, but make mistakes in using patterns, do not conclude answers, and have incomplete steps. This is supported by the problem solving categorization expressed by Samo (2017), who argues that students with moderate problem solving abilities can understand problems and develop strategies. Simplifying the problem and formulating a strategy for the problem are referred to as decomposition and pattern recognition in algorithms (Supiarmo, Turmudi, 2021).

The achievement of the computational thinking processes of students who have high problem solving abilities is not much different from that of students with moderate problem solving abilities. Students with high problem solving abilities only arrive at pattern recognition indicators. This is because students can simplify problems and develop strategies, but still make mistakes and do not draw conclusions about the solutions found. This is contrary to what was expressed by Samo (2017), who said that students with high problem solving abilities can understand problems, develop strategies, and carry out plans well. However, in this study, it was found that the computational thinking processes of students with high problem solving abilities had not yet reached the indicators of abstraction and algorithms.

CONCLUSION

Based on the results of data analysis and discussion related to student’s computational thinking processes in solving PISA questions in terms of problem solving abilities, it can be concluded as follows:

a. The computational thinking process of students who have low problem solving abilities only reaches the decomposition stage. This is because students can simplify problems even though they are incomplete, but are unable to connect mathematical concepts or material to build solutions to problems.

b. The computational thinking process of students who have moderate problem solving abilities is limited to pattern recognition. This is because students can simplify problems and develop strategies, but make mistakes in using patterns, do not conclude answers, and have incomplete steps.

c. The computational thinking process of students who have high problem solving abilities only comes down to pattern recognition indicators. This is because students can simplify problems and develop strategies, but still make mistakes and do not draw conclusions about the solutions found.

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