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Computational Thinking Process of Prospective Mathematics Teachers in Solving PISA Model Problems

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Abstract: The research outlines the computational thinking process that prospective mathematics teachers use to solve PISA model problems. The Department of Mathematics Education conducted the research on 32 students in the Basic Mathematics course. This qualitative approach research used research instrument such as a computational thinking skill test and interview guidelines. The researchers grouped students into low, medium, and high ability categories based on previous tests. The researchers took as many informants as possible from each category using purposive sampling techniques. The applied technical data analysis included data reduction, presentation, and conclusions. The computational thinking process consisted of orientation, abstraction, decomposition, algorithms, and evaluation. The study provided several results, including high- and medium-category students being able to write information at the orientation and algorithm stages. The difference between the computational thinking processes of low- and medium-category students lies in the orientation stage and algorithms. Low-category students had to be more detailed in recording every step of the problem-solving process, as they could not write down all the primary information and problems. Those three lied in the orientation stage, the process of identifying information, and the key problems at the orientation stage as an early and important aspect of the computational thinking process. This research facilitates teachers improve students' computational thinking in solving high-level problems.

Keywords: computational thinking process, PISA model problems, problem-solving

▪ INTRODUCTION

Computational thinking is one of the essential abilities in education included in the curriculum, starting from primary, secondary, and further education (Qualls & Sherrell, 2010). In addition to reading, writing, and arithmetic, students are required to possess CT. Wing (2006) explain that computational thinking involves problem-solving, system design, and system understanding. When it comes to problem-solving, computational thinking (CT) serves as a technique for developing a solution. ISTE (2015) explains that Computational Thinking (CT) is a general ability that enhances creativity. In creativity, a creative thinking process refers to understanding the information and the provided problems (Sitorus, 2016). Kalelioglu et al. (2016) define processes in computational thinking as consisting of problem identification, data representation, designing solutions, implementation of solutions, and evaluation and follow-up. Concerning problem identification, cognitive activity includes identifying information, understanding the main problem, and focusing on it. Kallia et al. (2021) explain the integration of mathematics and computational thinking for the expansion of mathematical problem-solving through computational thinking, with a focus on problem formulation and solutions. This highlights the significance of problem orientation in computational thinking for the development of problem solutions.

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Computer use only occasionally relates to computational thinking. In the 21st-century digitalization era, educators need to equip themselves with computational skills, enabling students at both primary and secondary education levels to apply them effectively. Selby and Woollard (2013) explain computational thinking as a cognitive activity focused on work and not limited to problem-solving. The explanation of computational thinking includes stages such as abstracting, detailing, algorithmic thinking, evaluating, and generalizing. Denning (2009) explains the notion of computational thinking as a systematic or algorithmic thought to obtain results based on initial conditions. Wing (2006) conveys an understanding that involves problem solving and system design using computer science. Cuny et al. (2010) assert that the formulation of problems and the resolution of ideas require computational thinking. Aminah et al. (2022) define the computational thinking process in solving mathematical problems to consist of abstraction, algorithmic, decomposition, and evaluation. Abstraction thinking has the notion of the ability to explain mathematical problems through models or images (Kallia et al., 2021; Wing, 2010). Yadaf et al. (2014) explain algorithmic thinking involves a meticulous process of completion at each step. The applied term is step by step; decomposition has the notion of the ability to cut complex problems into several small parts to solve in order (Sute et al., 2017); and evaluation is defined as the process of validating problem-solving solutions (Repenning et al., 2017). Harnett (2015) explains that computational thinking is an alternative to developing students' numeracy skills, by giving PISA model questions.

Context, content, and competency level are characteristics of PISA model problems (Ahyan et al., 2014; Jailani et al., 2020; OECD, 2018). A given problem in everyday life, such as social life and community work, is understanding context. The content encompasses concepts such as shape and space, change and relationship, quantity, and uncertainty. The development of competencies involves the ability to identify, plan, implement, and develop ideas within the problem-solving space. Research on the topic of change and relationships is particularly intriguing. Jurnaidi and Zulkardi (2014) prove that change and relationship content positively impact students' reasoning skills and fosters connections between their written responses. Zulkardi and Kohar's (2018) research elucidated that introducing PISA-based questions enhances students' fundamental skills in mathematical computations. This relates to the essence of students' computational problem-solving ability.

Aminah et al. (2022) defines the computational thinking process of prospective mathematics teachers in solving Diophantine linear equation problems. This process involves reflective abstraction thinking, algorithmic thinking, decomposition, and evaluation. The difference between this research and previous research lies in reflective abstraction thinking. Reflective abstraction is the process of building new knowledge from concrete to abstract thinking. This process requires a high level of thinking. Korkmaz et al. (2017) define competencies in computational thinking, such as algorithmic thinking, cooperativity, creativity, critical thinking, and problem solving. Creativity is a real step in formulating creative ideas or solutions. Sitorus (2016) defines the orientation stage as the initial force in generating creative ideas in computational thinking. Students can discover an idea when they have a comprehensive understanding of the information and the core of the problem. Kallia et al. (2021) explain two different findings related to computational thinking in mathematics education: the characteristics and essential aspects of computational thinking. Their findings explain three critical aspects of computational thinking: problem-solving, cognitive processes, and transposition. Researchers assume that the process of thinking in problem-solving has similar characteristics to mathematical and computational thinking. Students' mistakes in solving PISA problems are the main factor in obtaining low Indonesian PISA assessment scores. Computational thinking ability is an important aspect of solving problems with the measurement character of PISA questions. Therefore, this research is crucial understand how students use computational thinking to solve PISA model problems.

Based on this background explanation, the researcher uses five stages of computational thinking processes, namely orientation, abstraction, decomposition, algorithm, and evaluation. The difference with previous research lies in the problem orientation stage and its application to problem solving in the PISA model. This research aims to explore the characteristics of students' computational thinking processes as they solve PISA model problems.

▪ METHOD

Partisipants

The researchers took students enrolled in Basic Mathematics courses of Universitas Muhammadiyah Purwokerto as research participants. The number of participants involved was 32 people. The researchers grouped participants into low, medium, and high-ability categories based on the results of previous tests. All students attended this test before the research implementation. Table 1 explains the categorization of students' cognitive groups and their numbers:

Table 1. Student cognitive categorization

Criteria	Category	Number of Students
$x > 75.33$	High	2
$57.109 \leq x \leq 75.33$	Medium	25
$x < 57.109$	Low	5

Description: x : score, average value = 66.22 and standard deviation values = 9.11

The next step involves administering a computational thinking ability test to all students. Based on the assessment of the test results, the researchers selected one student by purposive sampling as an informant for each group (Sukestiyarno, 2020). D1, D2, and D3 symbolize high, medium, and low-category informants. This technique is based on specific considerations, including verbal communication skills, academic grades, attitude, and completeness of the answer. Table 1 describes the profile of each informant based on these criteria. The next step involves administering a computational thinking ability test to all students. Based on the assessment of the test results, the researchers selected one student by purposive sampling as an informant for each group (Sukestiyarno, 2020). D1, D2, and D3 symbolize high, medium, and low-category informants. This technique is based on specific considerations, including verbal communication skills, academic grades, attitude, and completeness of the answer. Table 2 describes the profile of each informant based on these criteria.

Table 2. Personal information of informants

Informants	Gender	Verbal Communication	Academic Grades	Attitude	Completeness of the Answer
D1	Male	Excellent	Excellent	Excellent	Detailed, Clear
D2	Female	Excellent	Excellent	Excellent	Less Detailed
D3	Male	Excellent	Excellent	Excellent	Not Detailed

Research Design and Procedures

This study employed qualitative methods to elucidate the computational thinking process students while solving PISA model problems. This case study has a qualitative research type. The research focuses on a small group of students to explore and explain a current case or problem and review its findings (Arikunto, 2019). The research clarifies and sees students' computational thinking processes during the learning process. The researchers conducted the research over a period of 3 months. Figure 1 below describes the qualitative research design.

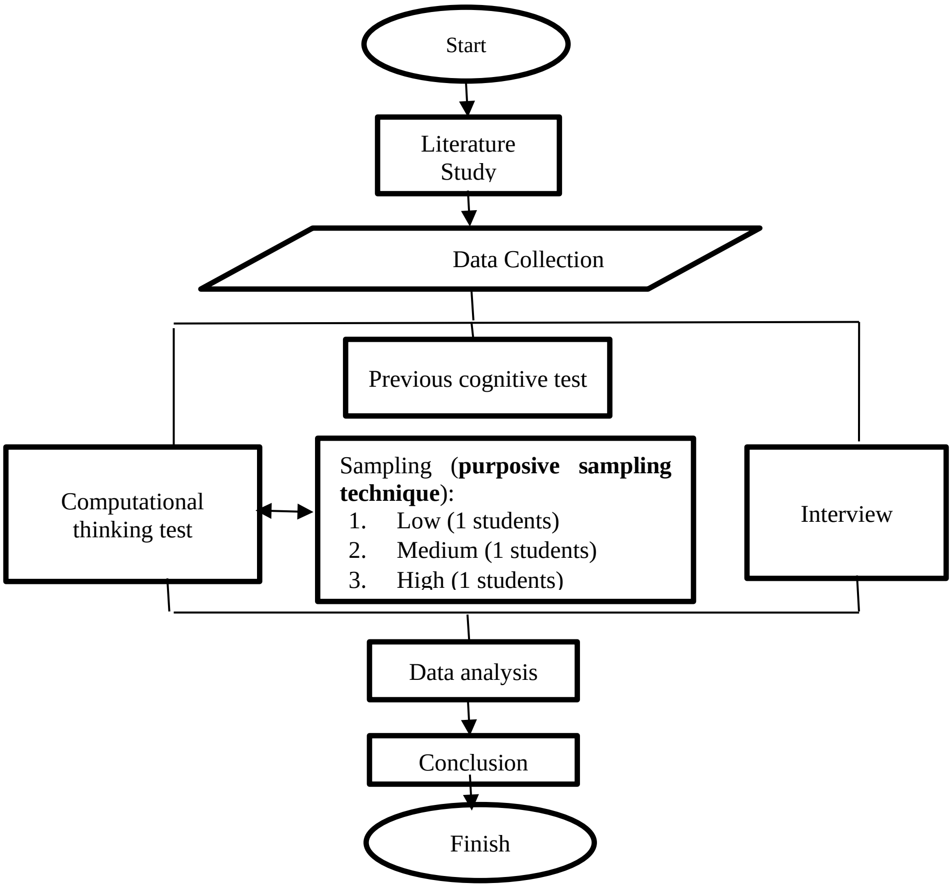


Figure 1. Qualitative research design

Instruments

Tests and interviews were our main data collection methods. The researchers considered context, substance, and competency while writing exam questions using the PISA problem model. The PISA problem has content, context, and competence (Ahyan et al., 2014; Jailani, 2020; OECD, 2018). Content matches school themes. Real-life context covers mathematical problems and student mathematical reasoning. Students used social, work, and personal contexts to overcome arithmetic problems. Competence refers to the student's ability to formulate, apply, and interpret mathematical ideas to solve problems. Figure 2 shows the computational thinking test instrument utilized in the study. The following products were tested:

City A has a square-shaped city park with a size of 100×100 m. To beautify the city park, the regent intends to plant ornamental grass throughout its parts, but there are two circular ponds of different sizes in the city park. The first larger pond is 10 m from the park's south side. The second smaller pool is 10 m from the park's north side. The distance between the first and second pools is also 10 m. The ratio of the diameter of the first pool to the second pool is 3:2. If it is known that the price of grass every 1 m^2 is IDR 50.000 and the budget owned is IDR 400.000.000, then how much is the remaining budget used?

Figure 2. PISA Model computational thinking test items

The PISA model includes the test questions in Figure 2. The aspect of the applied content is the width of the circle. The question's context pertains to the daily life conditions, which in turn influence the state of the city park and its activities. In the competency aspect, the researchers required cognitive activities such as identification, analysis, concept implementation, and result interpretation. Figure 2 employs question instruments to measure each reflective abstract indicator, decomposition, algorithm, and evaluation. The student test answer sheet clearly presents information about the four indicators. Multiple questions present the test answer sheet, each measuring a different indicator. Interview techniques will explore the answer sheet in depth if the informant cannot write clearly and in detail. Figure 3 depicts layout of the test answer sheet in use.

Answer Sheet

Name :
Class :
Write down your answers to each question according to the instructions below.

<u>Question No.1</u>

a. Write down the information you know and ask in question number 1. (**Orientation)**
......
b. Illustrate the problem in question number 1 with a picture or another. **(Abstraction)**
…..
c. Write down your completion in detail and clearly. **(Dekomposition and Algorithm)**
…..
d. Give a conclusion from the above problem. **(Evaluation)**

Figure 3. Test answer sheet design

Questions a, b, c, and d measure computational thinking initiators, such as orientation, abstraction, decomposition, algorithms, and evaluation. The non-test instrument is in the form of interview guidelines.

For the interview activity, the main focus is the computational thinking process, and researchers transfer in-depth information about the stages of computational thinking in solving PISA model problems. Table 3 presents information on the interview guidelines used in the study.

Table 3. Interview guidelines

Indicators	Questions
Orientation	1. What is the first thing you do after reading a given math problem?
	2. What information did you get from the question?
	3. What is the main question in the item?
	4. What was the first concept you remember after understanding the problem?
Abstraction	1. What did you do after obtaining information and understanding the core of the problem?
	2. In what form did you present the information obtained?
	3. What mathematical symbols or notations did you use?
	4. How do you visualize the main situation/problem in the question?
Dekomposition	What steps are taken to solve the problem?
Algorithm	1. Do you think the answers written are detailed and systematic?
	2. What concept did you use in solving this problem?
	3. What are your reasons for using the concept? Can you explain?
Evaluation	1. Did you double-check the results of the work before they are collected?
	2. If you found a mistake, then was it corrected?
	3. What conclusions did you obtain?
	4. Do you usually re-check the results of your work?

In table 3, the orientation and abstraction indicator consist of three questions that delve into the preliminary information and clarity of the problem. The decomposition aspect's trigger question concentrates on the necessary steps to reach a solution. The algorithm extracts information from the indicators regarding the application of mathematical concepts and the thoroughness of answer writing. Three different questions facilitated uncovering this information. The researchers delved into the evaluation indicators by asking two questions that focused on the interpretation of the solution as a final conclusion and the accuracy of the answers provided.

Experts first corrected and validated the instruments used in collecting research data. The researcher collaborated with a validator who specializes in mathematics education evaluations. In addition, experts publish their research results in reputable international journals, focus their research on computational thinking, and have attended several national and international seminars. The results showed that computational thinking skills tests and interview guidelines met valid and reliable aspects.

Data Analysis

Researchers collect data, conducted data analysis, including the data reduction stage, presented data related to the main topic, and draw conclusions (Sugiyono, 2015). Before carrying out the data reduction stage, the researcher categorized students into three cognitive categories (high, medium, and low), corrected and analyzed the written test results based on this categorization, and conducted in-depth interviews to explore in-depth information related to computational thinking skills. The reduction stage selected data based on the analysis focus. Furthermore, the researchers present the data as tables and figures to elucidate the research findings. The conclusion section explains findings about computational thinking processes based on test results and in-depth interviews with students. The researchers conveyed before the test that all activities in this study would not affect the assessment, either individually or in groups. The researcher exclusively utilized the research results for scientific endeavours. The researcher conducted a triangulation test to test the validity of the data, such as triangulating sources, techniques, and time. The researcher used multiple subjects as the data source. The research data collection techniques were observations, written tests, and interviews. The researchers conducted the research multiple times, initially observing the students' initial conditions in class before directly administering a written test.

▪ RESULT AND DISSCUSSION

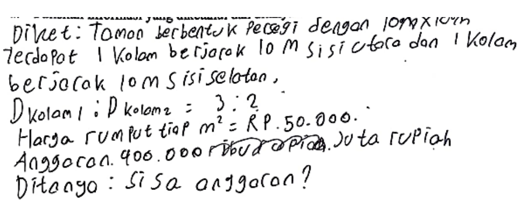
Table 4 describes the characteristics of the stages of the mathematical computational thinking process in solving PISA model problems. The stages of computational thinking consist of orientation, abstraction, decomposition, algorithms, and evaluation. The following is an explanation of each stage.

Table 4. Computational thinking process in solving PISA problems

No	Stage	Characteristics
1	Orientation	Understanding the available information, write down the primary data and questions, explain the initial information related to the problem, and explain the initial resolution plan.
2	Abstraction	Identifying information and problems in mathematical sentences, using mathematical notation or symbols to explain news or issues.
3	Decomposition	Writing down the settlement in several interconnected sections, explaining the completion flow used.
4	Algorithm	Writing answers systematically and in detail, using mathematical concepts correctly.
5	Evaluation	Rechecking answers and write down simple conclusions.

Based on the test results, the researchers describe the students' computational thinking process in soving mathematical problems of the PISA model. The report begins with students with high, medium, and low cognitive abilities. The focus of the description of computational thinking processes includes the stages of orientation, abstraction, decomposition, algorithms, and evaluation.

High Ability Student Category



Translation:
Given: The garden is square, 10m x 10m.
There is 1 pool 10m away on the north side and 1 pool 10m away on the south side.
$D_{pool\ 1} : D_{pool\ 2} = 3 : 2$
The price of grass per m^2 = IDR 50.000.
Budget IDR 400.000.000
Asked: What is the remaining budget?

Figure 4. D1 Response at the orientation stage

The orientation stage began with looking at the problem and then identifying information that can be retrieved. The informant wrote down known data and the context of the situation in question. Based on Figure 4, the informant wrote down the size of the garden, the comparison of two different ponds, and the core of the problem. This shows that the informant is focused on a given situation. The results of the interview also illustrate the same thing as above.

R: Do you understand the given problem?
I: Yes, sir, I understand that the question is the remaining budget.
R: Have you written all the information?
I: Already, sir.
R: What plan did you use to solve the problem?
I: I will start by drawing the conditions according to the size and shape of the problem, and then I will try to connect the information that can be used.

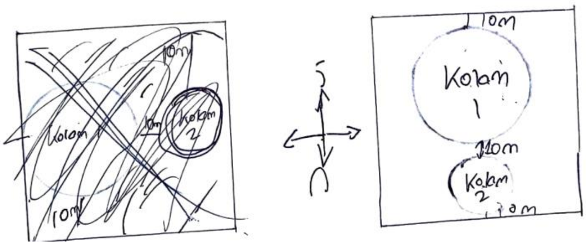
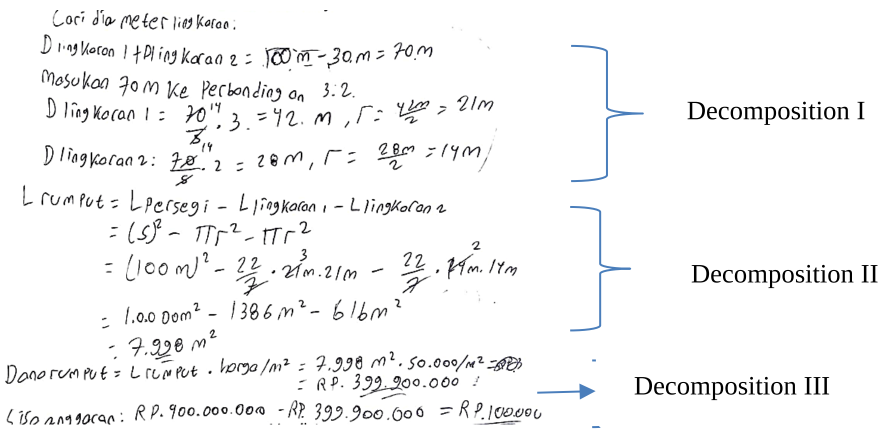


Figure 5. D1 Response at the abstraction stage

In solving problems, informants described the given information through pictures and mathematical symbols. In Figure 5, the informant described two pools, including their respective sizes, by writing "Pool 1" and "Pool 2" on each circle. Additionally, the informant used mathematical symbols to compare the two pools. According to the informant interviewed, this process aimed to condense a large amount of information into a concise form, adhering to the rules of mathematical writing. Informants commonly carried out this process each time they solved mathematical problems. Here are the results of interviews with informants related to the abstraction stage.

R: What do you use to describe the entirety of the known information?
I: I pour in the form of pictures and mathematical symbols.
R: Can this process help you find a solution?
I: Yes, sir, this can help me find an initial solution. I can shorten that much information into another mathematical form.
R: Is this process normal or not?
I: Yes, sir, I usually do it when doing math problems, especially problems in the form of stories.

The next step broke down the problem into its component parts. Figure 6 shows informant breaks down the problem-solving process into three key components: determining the diameter of the circle, determining the area of grass, and calculating the remaining budget. These three components become crucial and must be completed



Translation:
Find the diameter of the circle.
$D_{circle\ 1} + D_{circle\ 2} = 100m - 30m = 70m$
Put 70m to a rasio 3:2
$D_{circle\ 1} = \frac{70}{5}.3 = 42m, r = \frac{42m}{2} = 21m$
$D_{circle\ 2} = \frac{70}{5}.2 = 28m, r = \frac{28m}{2} = 14m$
$L_{grass} = L_{square} - L_{circle\ 1} - L_{circle\ 2}$
$= s^2 - \pi r^2 - \pi r^2 = 100^2 - \frac{22}{7}.21.21 - \frac{22}{7}.14.14 = 10.000 - 1386 - 616 = 7.998m^2$
Grass fund = L_{grass} . price $1m^2$ = 7.998 – 50.000
= IDR 399.900.000
Remaining budget = IDR 400.000.000 – IDR 399.900.000 = IDR 100.000

Figure 6. D1 Response at the decomposition stage

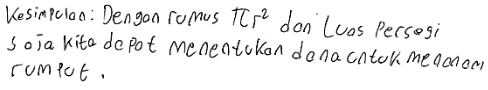
sequentially. In other words, the students had to first pass the three parts to determine the remaining budget. The interview results also support this explanation.

R: What did you do in resolving the above issue?
I: I determined the circle's diameter and then calculate the grass area. Finally, I figured out the remaining budget based on the size of the grass obtained.
R: Are the sections sequential?
I: Yes, sir, to get the remaining nominal budget, all three had to be done. Based on my answer like that, sir.

Figure 3 also shows the informant's systematic and precise answers related to the algorithm stage. The informant used the formula of the diameter of a circle correctly, the area of a square, and the area of a process precisely and performed algebraic operations excellently and clearly. In addition, the informant wrote entirely and correctly on units of diameter, area, and rupiah notes. In the interview, the subjects explained the conceptual flow used in writing the solution.

R: What concepts are used in solving problems?
I: The diameter of a circle, the area of a square, the size of a process, and simple algebraic rules.
R: Try to explain again the completion flow you wrote.

I: At first, I used the circle diameter formula to determine the diameter of ponds 1 and 2, respectively, then used the square area and circle to find out the location of grass and used the multiplication rule to calculate the turf fund based on the grass area and grass fund per m2.
R: Is your answer detailed and precise?
I: Already, sir.



Translation:
Conclusion: With the formula πr^2 and square footage, we can find the funds to plant grass.

Figure 7. D1 Response at the evaluation stage

In the final stage, known as evaluation, the informant presented conclusions drawn from the final results. Based on Figure 7, the informant provided an easy-to-understand decision, which involved determining the remaining funds using the circle and square formula. The researchers concluded by synthesizing the activities involved in problem-solving. Additionally, the researchers collected information from informants during interviews, such as the initial steps of correction and the final outcomes. Here's an excerpt of the interview.

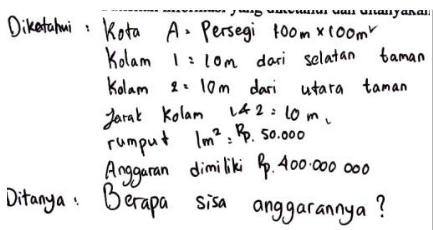
R: What can you conclude from that answer?
I: The conditions are enough to determine the remaining funds, namely the square and circle area concept.
R: Did you correct the entire answer?
I: Yes, sir, I re-corrected the steps and the suitability of the final result.

A crucial aspect that sets apart research findings from earlier studies is the orientation stage. Students thoroughly comprehended the problem and pinpointed all the crucial information required to generate potential solutions. Supiarmo et al. (2022) and Suntaryati et al. (2023) demonstrated that the PISA model problem could enhance computational thinking skills. The characteristics of the PISA model problem correlated with the core computational thinking process used to solve mathematical problems. The researchers could not separate computational thinking from the problem-solving space, making it an integral part of the problem-solving process. Harangus (2018) clarifies that the PISA problem does not solely measure education quality, but also encompasses problem-solving, including computational thinking.

Students with high academic ability could demonstrate the computational thinking process in solving PISA model problems, starting from the orientation, abstraction, decomposition, algorithm, and evaluation stages. In the orientation stage, students could understand the situation excellently. The ability to write down all known information and the core of the problem demonstrates this. In the completion process, students wrote down the steps systematically, clearly, and correctly. Suntaryati et al. (2023) revealed that students with high abilities to meet the algorithm aspect, namely using mathematical rules correctly and solving steps written sequentially and in detail. Additionally, during the evaluation stage, students logically wrote the conclusion in their language and verified all the answers, including the completion steps.

The high-category computational thinking profile is evident in cognitive activity at the algorithm stage. The process involves accurately and precisely writing down the steps and applying the concept. Students with excellent computational thinking will be able to analyze and apply a concept to a problem appropriately; this is related to algorithmic thinking. Doleck et al. (2017) demonstrated a direct proportional correlation between computational thinking and algorithmic thinking. Note that the activity at the orientation stage influenced the success or failure of the algorithm stage. The high student category did the orientation stage excellently and in detail to facilitate students find main problem solutions. Thus, the orientation stage has an important role in the emergence of creative ideas. Sitorus (2016) explain that the problem orientation stage plays a crucial role in generating creative ideas, while computational thinking incorporates creative thinking to formulate solutions (Snalune 2015; Voskoglou and Buckley 2012).

Medium Ability Student Category



Translation:
Given: City A = square 100m x 100m
Pool 1 = 10m from the south of the park
Pool 2 = 10m from the north of the park
Distance between pools 1 & 2 = 10m
$1m^2$ grass = IDR 50.000
Budget owned = IDR 400.000.000
Asked: How much is the remaining budget?

Figure 8. D2 Response at the orientation stage

Figure 8 demonstrates that the informant successfully documented all known information and the essence of the problem at hand. In the information identification section, the informant wrote the area of city A, the location of each pool 1 and 2, and the amount of funds owned. At the core of the problem, the informant writes down the amount of the remaining budget held. When the informant was asked about the initial knowledge he remembered, he immediately answered the concept of square area, namely the length of the side multiplied by the side. The following is an excerpt from an interview with the informer.

R: Do you understand the given problem?
I: I understand, sir.
R: Try to explain it briefly.
I: I write down information ranging from the city's shape and area to the budget you have. According to my understanding, the main question is your remaining budget.
R: What do you first remember after looking at the problem?
I: I remembered the square area formula.

Figure 9 shows the cognitive activity of the informant at the abstraction stage. The informant translates the problem into a more mathematical visual form. The informant used the obtained information to create pictures that visually represent the entire

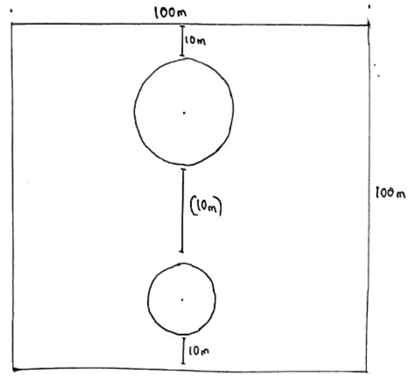


Figure 9. D2 Response at the abstraction stage

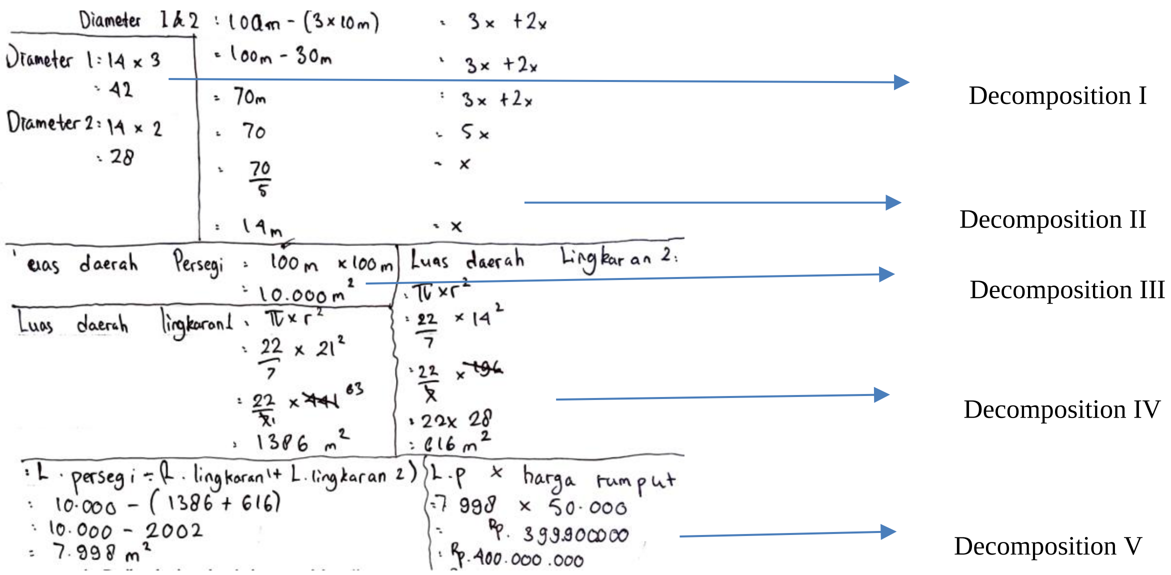
information. The informant created a box with two distinct circles, each representing a different pond. The distance between the two pools is marked with a line segment and honored with several 10 m. The figure shows the distance between the two pools. The interview results also provide insights into the abstraction of the problem.

R: Do you use mathematical symbols or sentences to explain information?

I: Yes, sir, I use mathematical sentences such as "diameter 1, diameter 2, L. Square, and grass 1 m2. I use it to explain information to make it more concise and mathematical.

R: What do you do next to find a solution?

I: I present all the information in the form of pictures. This makes it easier for me not to read the questions repeatedly.



Translation:
Diameter 1 = 14x3= 42, diamater 2 = 14x2 = 28
Diameter 1&2:
$100m - (3x10m) = 3x + 2x$
$100m - 30m = 3x + 2x$
$70m = 5x$
$\frac{70}{5} = x$
$14m = x$
Square area =100m x 100m = 10.000m^2.
Area of circle 1 = $\pi x r^2 = \frac{22}{7} x 21^2 = 1.386m^2$
Area of circle 2 = $\pi x r^2 = \frac{22}{7} x 14^2 = 616m^2$
Area = square area– area of circle 1 + area of circle 1
= 10.000-(1386+616)= 10.000-2002= 7.998m^2.
Area x price of grass = 7.998 x 50.000 = IDR 399.900.000= IDR 400.000.000

Figure 10. D2 Response at the decomposition stage

In solving the problem, the informant carried out the calculation in stages. Figure 10 illustrates that the informant starts by calculating the diameters 1 and 2, the square area, and the circle area 1 and 2, before determining the remaining budget based on the obtained site. This proves that the informant divides problem-solving into several interrelated small parts. This stage also enhances the informant's ability to solve problems mathematically. The following is an excerpt from an interview with the subject.

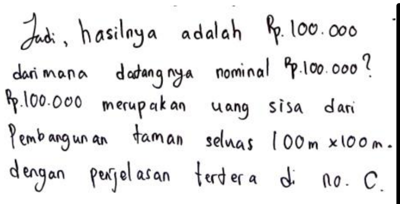
R: Can you describe the troubleshooting flow?
I: In solving the problem, I divide the solution into parts and mark them in small boxes. I am starting by calculating the diameter area of each pool to calculate the remaining budget based on the size of the site.
R: Are you used to it that way?
I: Yes, sir. If the problem is contextual and complex, it is easier to solve in that way and more convenient, sir.

The calculation process solved the aforementioned small parts correctly and in detail using precise mathematical rules. For instance, the informant accurately applied the formula to calculate the area of circles 1 and 2, ensuring a clear understanding of the calculation. Similarly, the informant meticulously completed the remaining parts. In this case, the systematic, factual, and correct calculation process enabled the informant to reach the algorithm stage. The informant also provided an explanation of the algorithm stage when questioned during the interview.

R: What are some mathematical rules or formulas used in solving problems?
I: The diameter rule of a circle, the area formula of a square, and a process, the power of simple algebra.
R: Are you familiar with the rules?
I: Yes, sir, I understand.
R: Do you think the answers written are detailed and precise?

I: Already, sir.

The informant's last stage is to re-examine the answers and provide conclusions and is referred to as evaluation. Figure 11 describes the activities carried out by subjects in giving findings based on the obtained solutions.



Translation:
So, the result is IDR 100.000
Where did the nominal amount of IDR 100.000 come from?
Rp. 100,000 is the remaining money from constructing a 100m x 100m park with an explanation stated in number C.

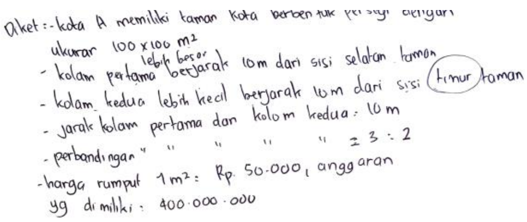
Figure 11. D2 Response at the evaluation stage

The informant provided a comprehensive conclusion sentence, beginning with the results obtained for the area of the park that was built. The sentence naturally came from the informant. In addition, the interview results also explore information related to informant activities in conducting reexaminations. These are the outcomes of the interview conversation.

R: What do you do when you're done working on the problem?
I: I corrected the answer and steps, sir.
R: Was an error found?
I: There is a sir. I miscalculated it, and then I corrected it.
R: Are you used to giving conclusions and recorrecting the results of the work?
I: I often like that, sir, especially the contextual problems.

Students in the high-ability category were similar to those with medium ability; they could correctly and clearly answer PISA model problems. The student's answer shows an excellent computational process, including orientation, abstraction, decomposition, algorithm, and evaluation stages. In explaining known information, students used mathematical symbols or notation to represent it. Students also employed visualization aids to articulate the central questions they need to address. Gravemeijer (2011) explains students in the medium category could present information and problems in visual form with the abstraction process. In order to solve the problem, students in the medium category organize their answers into parts that are interrelated. Students begin by addressing the relatively simple initial question. Students often struggle with decomposition due to the complexity of the problem. However, students in this category could divide the problem into multiple parts for solution (decomposition). For medium-level students, the decomposition stage played a crucial role in achieving a complete solution to the problem. Rich et al. (2018) explain that decomposition plays a crucial role in problem-solving, and while students understand decomposition techniques, they often struggle to apply them effectively. Similar to high ability, students in the medium category at the evaluation stage could apply re-examination of answers and make a final statement as part of the conclusion (Worthen et al., 2019). The evaluation stage represents the final phase of the problem-solving process, where students derive valid final results from their prior experience.

Low Ability Student Category



Translation:
Given:
- City A has a square city park measuring 100 x 100m.
- The first larger pool is 10m from the south side of the park.
- The second smaller pool is 10m from the east side of the park.
- Distance between the first pool and the second pool = 10m.
- The ratio of the first pool to the second pool = 3:2.
- Price of $1m^2$ grass = IDR 50.000, budget = IDR 400.000.000

Figure 12. D3 Response at the orientation stage

Figure 12 illustrates that the informant possesses the ability to record all the information involved in the problem. The information in question includes the size of city A and its dimensions, the differences in size between the two pools, a comparison of the two pools, the price of grass, and the total budget owned. The respondent's answer differs in that it does not address the primary posed problem. However, during the interview, the informant could clarify the central question about the problem. Additionally, the informant acknowledged that he needed to be more thorough in identifying the given situation.

R: Could you understand the problem?
I: Yes, sir, I have looked at it.
R: What do you think is known?
I: The characteristics of city A, the size of two different ponds, the price of the lawn, and the budget you have now.
R: What is asked in the matter?
I: The remaining budget you have.
R: However, I see nothing in your writing. Try to explain.
I: Yes, sir, that's right, I didn't write down the core question because I wasn't careful.

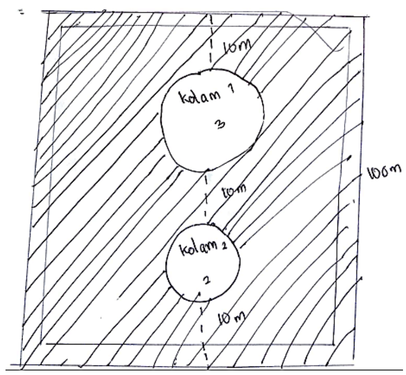
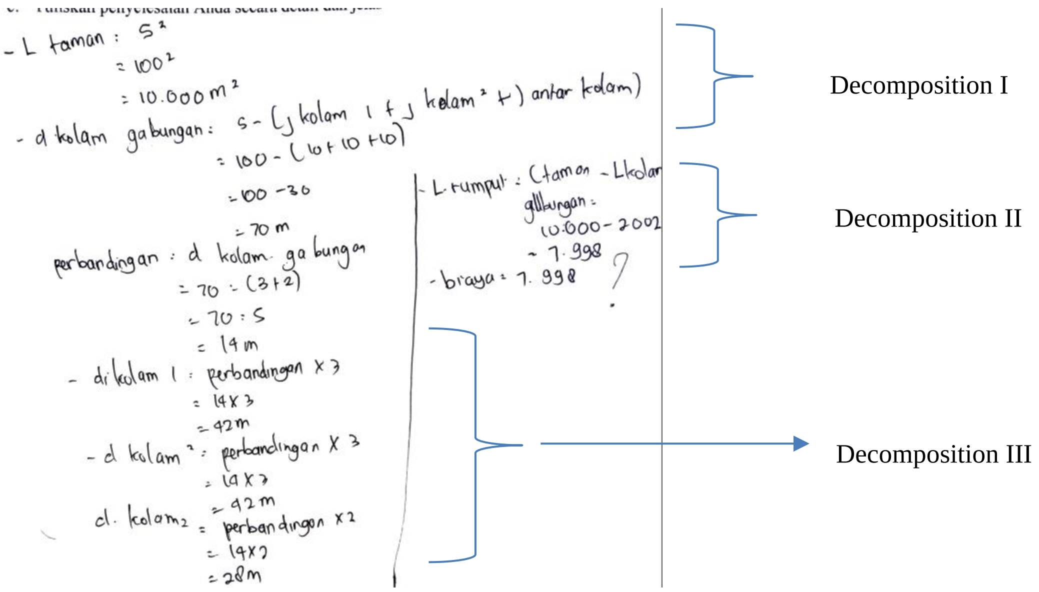


Figure 13. D3 Response at the abstraction stage

The informant also described the entire information in a visualization. This stage is called abstraction. In Figure 13, the informant wrote the distance between Pools 1 and 2, the size of the city park, and the length of each pool to the park's edge. In addition, informants use mathematical symbols to explain the area and diameter of the collection. Examples could each describe the garden's location and the diameter of the pond. Interviews with informants revealed that the use of notation aids in problem-solving and effectively explains long mathematical sentences. The following are the outcomes of the discussion conducted during the abstraction stage.

R: In the process, do you use mathematical symbols?
I: That's right, sir. I use mathematical symbols to explain the area and diameter.
R: How do you find the solution?
I: I used the image to describe the condition of the problem. Because the problem is in the form of a story, it will be easier if presented in pictures. This helped me to find a solution.



Translation:
- Park area = $s^2 = 100^2 = 10.000m^2$
- *d* combined pools = *s* – (j pools 1 + j pools 2 + j between pools
  = 100- (10+10+10) = 100-30 = 70
- Comparison d of combined pool = 70: (3+2) = 70:5 = 14m
- *d* pools 1 = ratio x 3 = 14 x 3 = 42m
- *d* pools 2 = ratio x 2 = 14 x 2 = 28m
- *L* grass = park – combined area = 10.000-2002 = 7.998?

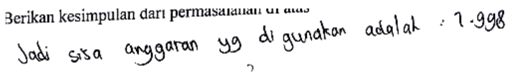
Figure 14. D3 Response at the Decomposition Stage

To simplify the resolution process, the informant broke the problem into several sequential parts. The informant first divided the problem by calculating the overall garden area and the distance between the pond and the garden. The second part compared the two pools and then calculates the distance between pool one and pool two, respectively. The last function calculated the remaining grass area and the costs required. The results of interviews with informants revealed information about the sequence in which the tasks were completed.

R: Describe what you did until you found the result.
I: To solve the problem, I divided it into three core parts. First, I started calculating the area of the garden owned. Second, I processed information about the comparison of distances between pools. Third, I figure the remaining budget based on the remaining area of the park.
R: Does it relieve you in the calculation?
I: Yes, sir.

Figure 14 clearly illustrates the sequence and clarity of the informant's answers. This section outlines the steps the algorithm to solve the problem. The calculation process adheres to the correct rules, the applied units are appropriate, and each part's final result is accurate. However, in the last section, the informant had to complete the final result based on the main question. The informant stopped at the remaining area of the park even though the question was the remaining budget based on the remaining area of the park. The interviewer re-asked the informant about the unresolved issue, to which the informant could provide a correct response.ly.

R: Has your answer been written entirely according to the question?
I: It turns out that there is an incomplete part, sir. After my correction, I did not answer the question.
R: What are the drawbacks?
I: I calculate the remaining area of the garden multiplied by the cost of grass per m2.



Translation:
So, the remaining budget used is 7.998.

Figure 15. D3 Response at the evaluation stage

The lack of answers in the previous stage leads to errors in drawing conclusions. However, after the interview, the informant could provide the correct decision. As in Figure 15, As in Figure 15, the error arises due to the informer's activity in reexamining each step of completion until the final result is obtained. Here is the evaluation stage of the interview follows.

R: Did you check the whole answer?
I: Yes, sir, I finally know where he went wrong.
R: What errors have you found?
I: The calculation in the remaining part of the budget is based on the rest of the grass area.
R: What is the correct conclusion in your opinion?
I: After recalculation, the conclusion is that the remaining budget used is IDR 100,000.00.

The characteristics of the computational thinking process in students in the low ability category differ from the high and medium categories. The difference lies in the orientation stage and the algorithm. High-category students were required to write down all information, including the subject of the question, during the orientation stage. This directly influenced cognitive activity at the algorithm stage. Only partial and perfect writing of the completion steps was possible due to the inability to correctly identify the existing data. Hee et al. (2019) explain that students who comprehend the problem and meticulously record all the necessary information for its solution will discover the correct solution with ease. The research shows the potential position of orientation activities in problem-solving. Under these conditions, orientation activities will significantly influence the algorithm stage. In this stage, the completion steps are written in detail and correctly, but low-category students need help to reach the algorithm stage fully. Paf and Dincer (2021) found students with low cognition tended to exhibit poor algorithmic thinking. The main obstacle that low-category students face is their limited cognitive knowledge. Students' limited knowledge leads to a deficiency in mathematical concepts for problem-solving. De Lange (2003) posited that students could use their knowledge to generate and apply problem-solving ideas during school learning. Stillman (2015) explains says that someone with excellent cognitive knowledge, when given an issue, could understand and detail the problem correctly.

▪ CONCLUSION

Computational thinking is essential to the problem-solving process in current digitalization era, especially when solving complex problems such as the PISA model. Prospective mathematics teachers use a computational thinking process to solve PISA problems, involving five stages: orientation, abstraction, decomposition, algorithms, and evaluation. In the group of high and medium ability, students could write cognitive activities clearly and in detail at each stage of orientation, abstraction, decomposition, algorithms, and evaluation. Students comprehended problems and crucial information for problem-solving, articulated issues using mathematical symbols and visual aids, broke down problems into detailed parts, formulated conclusions based on the central questions, and scrutinized the final outcomes again. Unlike students in the low ability category, students with high and medium ability still had improvement in certain aspects of their answers. For instance, students should meticulously record the problem's question or the entire solution process. This relates to the cognitive activity of students at the orientation and algorithm stage. The PISA model's mathematical problems are the sole focus of the research. It is more intriguing if the other issues presented are open-ended. This is linked to students' capacity for creative thinking when solving open-ended problems, as prospective teachers in the 21st century need to possess creativity in solving mathematical problem. Students' computational thinking process in solving open-ended problems and its correlation with mathematical creative thinking can be the subject of further research.

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