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STUDENTS' THINKING PROCESS IN SOLVING HOTS PROBLEM IN DERIVATIVE APPLICATION TOPIC

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ABSTRACT

In every mathematics learning process, it is crucial to identify students' thinking processes to observe and assess their mathematical thinking abilities. One way to comprehend students' thinking processes is by examining their work or their responses to problem-solving test questions. This research utilized Polya's framework, which comprises the four stages of problem-solving. One of the efforts to measure and improve students' problem-solving skills is by giving them High Order Thinking Skills (HOTS) questions. In this study, the researcher employed a qualitative approach, specifically the case study research type, to explore the thinking processes of students who make mistakes in solving higher-order thinking skills (HOTS) problems. Subjects in this study were collected by submitting HOTS-type questions to eleven 12^{th}-grade students. The researcher chose one student with incorrect answers and with more complete writing than others to be the subjects. The results revealed that the subject engaged in the stages of understanding the problem, planning the solution, and executing the plan, but did not undertake the "looking back" stage. Overall, this study provides insight into the subject's thought process in solving HOTS problems related to derivative application material using Polya's framework.

Keywords: Thinking Process, Problem Solving, Derivative Applications

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PRELIMINARY

It is important to identify students' thinking processes in every mathematics learning process to see or assess their mathematical thinking skills. The thinking process is the mental activity of students in solving a given problem, which can be seen when students understand the problem, plan the solution, carry out the plan, and re-examine the answer in writing or orally (Muyassaroh et al., 2021). Students' thinking process in solving problems is an essential aspect because the learning process between one individual and another is different (Farib et al., 2019). Examining students' cognitive processes during each mathematics learning session is crucial for evaluating their proficiency in mathematical thinking. One way to see students' thinking process is by identifying students' work or responses to problem-solving test questions (Lailiyah et al., 2020).

Problem-solving is an essential cognitive process with profound implications in various fields, namely science, engineering, and especially in learning mathematics (Gurat & Melanie, 2018). One of the efforts to measure and improve students' problem-solving skills is by giving them High Order Thinking Skills (HOTS) questions (Dinni, 2018). High Order Thinking Skill (HOTS) is an individual's capacity to connect, reorganize, extend, and apply existing knowledge to achieve specific goals or solve non-routine problems (Bai et al., 2023). HOTS problems in mathematics require students to use their critical thinking skills to analyze, evaluate, and create solutions (Indriyana & Kuswandono, 2019).

Students often face difficulties in solving HOTS problems, especially problems involving the application of derivatives. For example students experienced difficulty in determining the optimum point of the function given ($f(x) = x(x-2)^2$) using the concept of derivatives so that students only answered the part of the question that the students could do (Meiliasari et al., 2021). This difficulty can be caused by several factors, such as difficulty finding the information listed in the problem, difficulty writing conclusions from the numerical solution obtained, and difficulty converting the context written in the problem into a mathematical expression of the corresponding function (Fatmanissa et al., 2019). The application of derivatives in everyday life can be used in determining the maximum and minimum area or volume of an object, the maximum and minimum profit in selling goods, and so on (Roudlo & Dwijanto, 2021), so students need to understand how to solve derivative problems.

Several studies on HOTS problem-solving have been conducted previously. Puspa et al., (2019) examined the HOTS problem solving ability process in statistics material for 12th grade vocational students with high, medium, and low abilities. The results showed that high-ability students could complete all stages of Polya's problem-solving, and medium-ability students could understand the problem. However, they were less able to make plans, implement plans and, look back at results, and low-ability students were less able to do all stages of Polya's problem-solving well. Based on the results of this study, each subject with different abilities has a different thinking process (Polya's four stages), so the researcher wants to use Polya's four stages of the thinking process to see how the thinking process is carried out by the subject in this study. (Leonisa & Soebagyo, 2022) examined students' strategies for solving HOTS-based mathematical problems. Based on the results of their research, it was found that students used two mathematical problem-solving strategies, namely working backward and intelligent guessing and testing strategies on the answer sheets of grade XI students and several stages of problem-solving proposed by Polya (1973).

Based on the results of this study, some HOTS questions require a look back stage to see the answers that have been written in accordance with what is asked in the question. The looking back stage is found in Polya's thinking stages that will used in this research. Several other studies examined the difficulties faced by students in solving HOTS problems (Ernawati & Sutiarso, 2020; Fiqih & Winarso, 2022; Utami & Andriani, 2023). The results of these studies are used as a reference for possible HOTS problem solving errors that might be occur in this study.

In order to understand more deeply how students solve mathematical problems, it is necessary to analyze through a more detailed approach. One approach that can be used is Polya's problem-solving model. George Polya is a mathematician famous for his problem-solving approach, which consists of four stages: understanding the problem, planning the solution, implementing the plan, and evaluating the results (Polya, 1973). Therefore, it is essential to understand the stages of students' Polya solution in solving HOTS problems on derivative application material.

The purpose of this study is to describe students' process in solving HOTS problems using Polya's problem-solving stages framework. This research will include an in-depth analysis of how students solve HOTS problems using Polya's stages of problem-solving framework. The results of this study are expected to positively contribute to the development of mathematics curriculum and teaching approaches that are more effective in improving students' understanding and mathematical problem-solving skills.

METHODS

In this research, the form of research is case study research. This research aims to see how students think with wrong answers in solving HOTS problems. The subjects solved the questions systematically by using the right concepts to solve the problem but did not provide the final answer correctly, therefore the researcher used a case study approach to explore the phenomena that occurred by looking at the students' thinking processes. Arikunto, (2006) states that case study research is conducted intensively in detail and in-depth on a particular symptom. By looking in detail at students' thinking processes, researchers aim to find out the reasons that can explain the phenomena that occur.

The results of this study are presented in descriptive form in the form of written words from the results of answers and interviews with subjects. The research was implemented in the odd semester of the 2023/2024 school year at one of the tutoring institutions located in Klojen District, Malang City, East Java 65113. The research time was conducted in

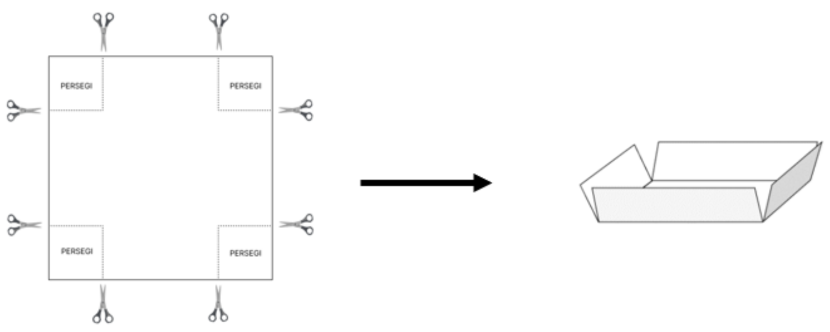
November 2023. Subjects in this study were collected by submitting HOTS-type questions to eleven 12^{th}-grade students. The subject's grade level selection is based on most of the mathematics subject matter studied by 12^{th} grade students so that students already have some prior knowledge of mathematics related to the mathematical problems to be tested. The subject selection technique used was purposive sampling, a data source sampling technique with certain considerations. Of the eleven students, there were two correct and nine incorrect answers. The researcher took one of the incorrect answers. Students with more complete writing than others were chosen to be the subject.

The researcher then conducted interviews to explore students' thought processes in solving HOTS problems further. Interviews were conducted face-to-face to observe in detail how students explained their answers. The researcher asked each point written by the students to get details about the students' process in working on their answers. The researcher then divided the interview answers into 4 parts of the thinking process according to Polya. In the analysis process, the researcher compares students' answers with the results of interviews and then explains them based on previous research sources. The observation results of the answers given by the students and the interview results are presented in a descriptive form to see how the students process solving the problems given.

RESULT AND DISCUSSION

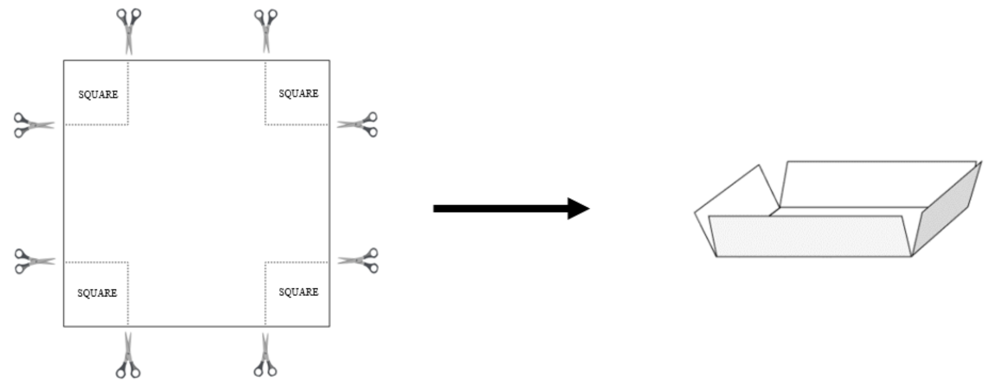
Results

The questions used in this research are as follows.



Budi memiliki selembar karton berukuran 50 cm x 50 cm. Budi ingin membuat kotak tanpa tutup atas dari karton tadi sebagai wadah alat tulis dengan cara melipat seperti pada gambar. Budi membuat kotak dengan cara memotong karton berbentuk persegi yang sama di tiap-tiap sudut karton. Tentukan panjang sisi persegi yang harus dipotong agar volume kotak yang terbentuk maksimal.

English Version



Budi has a piece of cardboard measuring 50 cm x 50 cm. Budi wants to make a box without a top lid from the cardboard as a stationery container by folding it as shown in the picture. Budi made the box by cutting the same square-shaped cardboard at each corner of the cardboard. Determine the length of the side of the square that must be cut so that the volume of the box formed is maximized.

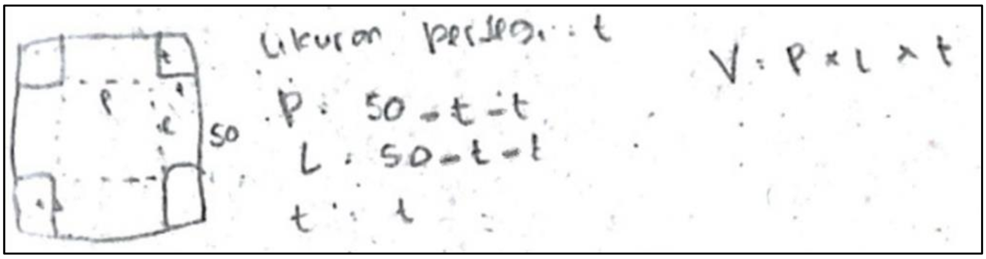
Figure 1. The HOTS Problem

In the given problem, the subject was asked to find the size of the square cut at the corners of a piece of paper to maximize the volume of the box made. In this problem, the length, width, and height of the box formed are unknown. One way to solve this problem is to assume the dimensions of the box in the form of a variable that represents the length of the cut square. Using the concept of the volume of a rectangular prism, a function for the volume of the box can be derived. By applying the concept of the derivative, the maximum volume of the box can be determined.

The description of the subject's answers will consist of a description of the stages of understanding the problem, the stages of planning problem solving, and the stages of carrying out the solution plan. There is no description for the looking backstage because the subject did not perform the looking backstage.

1. Stages of Understanding the Problem

The stage of understanding the problem consists of several indicators: mentioning what is known precisely, what is asked precisely, and checking the adequacy of information. The subject can mention any important information in the problem by writing or mentioning it. Figure 1 is the answer given by the subject in the stage of understanding the problem.



English Version

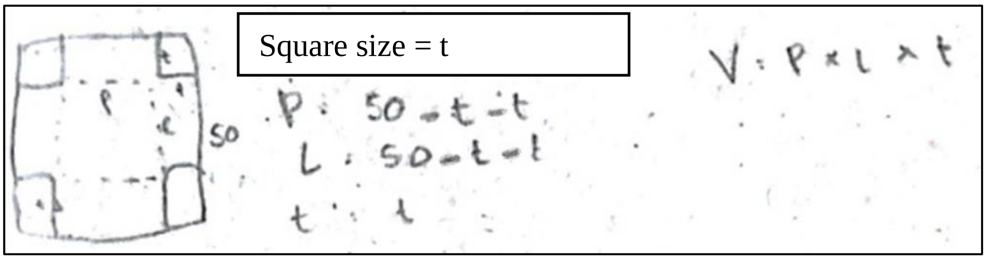


Figure 2. Subject's Answer in The Stage of Understanding The Problem

Based on Figure 2, some information is written on the subject's answer sheet, namely the picture of the paper to be cut and the size written on the right side of the picture. On the answer sheet, the subject redraws the illustration of the paper to be cut, then adds the symbols p, l, and t to the picture. The subject then used the letters to formalize the length, width, and height of the beam formed. It was clarified by an interview by the researcher (P) with the subject (S).

P: *What information can you get from the problem?*

S: *The paper to be cut is square, and the side length is 50. The paper is cut and then folded into a box.*

P: *This square picture (Pointing to the square picture on the subject's answer) did you take from the problem?*

S: *Yes, sir.*

P: *Why did you write the letters p, l, and t in this picture?*

S: *Because later, when folded, p will be the length, l will be the width, and t will be the height of the box.*

Next to the drawing made, the subject formalized p and l in the form of t and did it correctly. It was done because the subject wanted to normalize the length of the side of the square with the symbol t and related to what was asked in the problem. At this stage, the subject understands what is asked in the problem. The subject understands that it is necessary to find the length of the side of the square that must be cut so that the volume of the box formed is maximum. The purpose of the subject to formalize this is clarified in the interview with the subject.

P: *Why did you write beside it p=50-t-t?*

S: *That means the length p is from the initial size of the paper, which is 50, and then reduced by t twice.*

P: *Why should it be reduced by t?*

S: *It means that the length p is from the initial length of the paper, which is 50, and then cut into a square whose length is t.*

P: *Does that mean the length is t?*

S: *The length of the side of the square, which is cut.*

P: *Then what will you do with the equation?*

S: *I put it into the volume formula.*

P: *Why do you put it into the volume formula? Isn't there a value yet?*

S: *It doesn't exist yet, but later, it will form a volume function. Later, we will find out when the volume is maximum.*

P: *Okay, is that enough information?*

S: *God willing, it's enough.*

The subject used the equation to form a volume function, which will be found when the equation is at its maximum. The subject also stated that the information collected was sufficient to answer the question. Collecting what is known, the subject first thinks about what can be done with the information.

2. Stages of Planning Problem Solving

At the stage of planning the problem, the researcher needs to question the subject directly to find out how the subject plans to solve the problem. The following is an interview with the subject:

P: *Earlier, you said you wanted to find when the volume function was at its maximum value.*

S: *Yes, sir.*

P: *Okay, can you explain how you planned the solution after gathering information?*

S: *So, I put the values of p, l, and t that I wrote earlier into the beam volume formula, it will form a volume function, then I look for the derivative function.*

P: *Why did you look for the derivative?*

S: *As I recall, if you look for the maximum value of a function, you can find it using the function's derivative and then look for the maker of the 0 derivative.*

P: Then the next step?

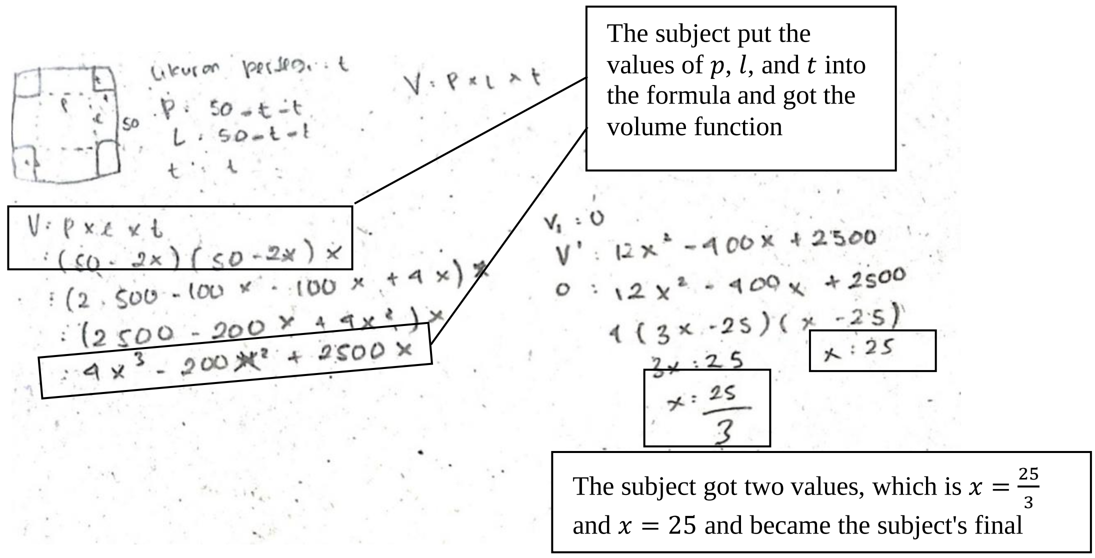
S: Later, we will find the t-value when the derivative equals 0.

P: Okay, then what will the value of t be?

S: It is the size of the square that was cut.

Based on the interview with the subject, the subject explained that his plan after collecting information about the beam's length, width, and volume was to put it into the beam volume formula. Then, the subject explained that by entering the values into the beam volume formula, the subject would get the beam volume function. From the function formed, the subject then looked for the derivative of the function and looked for the maker 0 of the derivative of the function. The value of maker 0, according to the subject, is the length of the side of the square that needs to be cut so that the volume is maximized.

3. Stages of Planning



English Version

Square size = t

V= $p \times l \times t$ (length × width × height)

p (length of the paper) $= 50 - t - t$

l (width of the paper) $= 50 - t - t$

$$
\begin{aligned}
V &= p \times l \times t \text{ (length × width × height)} \\
&= (50 - 2x)(50 - 2x)x \\
&= (2500 - 100x - 100x + 4x)x \\
&= (2500 - 200x + 4x^2)x \\
&= 4x^3 - 200x^2 + 2500x
\end{aligned}
$$

$$
\begin{aligned}
V_{,} &= 0 \\
V' &= 12x^2 - 400x + 2500 \\
0 &= 12x^2 - 400x + 2500 \\
0 &= 4(3x - 25)(x - 25)
\end{aligned}
$$

$3x = 25$ atau $x = 25$

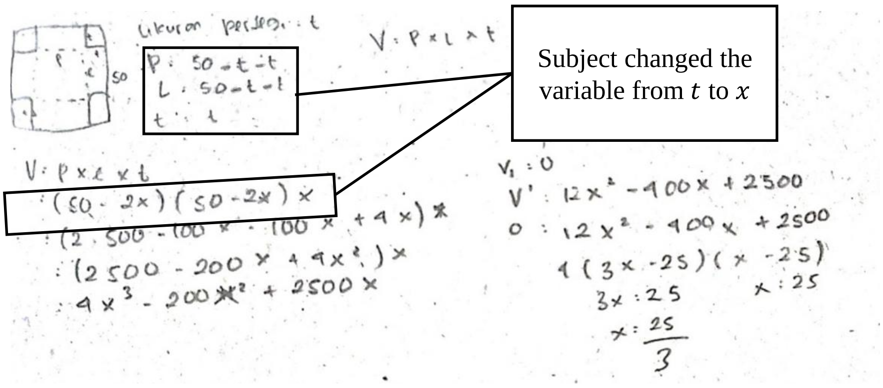
$x = \frac{25}{3}$

Figure 3. Subject's Answer at The Stage of Implementing Planning

At the stage of planning appropriately, there are three indicators: restating the problem into an appropriate mathematical model, writing the mathematical model or formula appropriately, performing calculations appropriately, and writing answers completely, systematically, and accurately.

To see the stages of the subject's planning implementation, researchers need to look at the answers written by the subject after collecting information that can be taken from the problem, as in Figure 2.

In Figure 2, by using the information that had been written previously, the subject entered the values of p, l, and t into the beam volume formula and obtained the beam volume function. However, in Figure 3, the subject changed the previous variable, t, to x.



English Version

Square size = t

V= $p \times l \times t$ (length × width × height)

p (length of the paper) $= 50 - t - t$

l (width of the paper) $= 50 - t - t$

$$
\begin{aligned}
V &= p \times l \times t \text{ (length × width × height)} \\
&= (50 - 2x)(50 - 2x)x \\
&= (2500 - 100x - 100x + 4x)x \\
&= (2500 - 200x + 4x^2)x \\
&= 4x^3 - 200x^2 + 2500x
\end{aligned}
$$

$$
\begin{aligned}
V_{,} &= 0 \\
V' &= 12x^2 - 400x + 2500 \\
0 &= 12x^2 - 400x + 2500 \\
0 &= 4(3x - 25)(x - 25)
\end{aligned}
$$

$3x = 25$ atau $x = 25$

$x = \frac{25}{3}$

Figure 4. The Subject Made A Mistake in Writing The Variable

The researcher asked the subject why the subject decided to change the variables in the p, l, and t values.

P: *Earlier, right p, l, and t, you generalized with the value of t; you also wrote it at the beginning of the answer; why here (pointing to the subject's answer) did you write it using x?*

S: I am used to using the x variable. For the initial one, I used t temporarily to know the form of p, l, and t values first. However, I don't think it affects the answer.

After getting the beam volume function, the subject wrote the function's first derivative. The subject gets the value of the maker 0 for the derivative of the equation, namely $x = \frac{25}{3}$ and $x = 25$.

4. Looking Back Stages

The researcher asked that the two x values were the final answer obtained. The subject believed that the procedure performed was appropriate to find the maximum value of a function. So, the length of the side of the square that needs to be cut is $\frac{25}{3}$ cm and 25 cm. This is as explained by the subject in the interview.

P: Okay, from the answer you wrote, what conclusion did you get?

S: The lengths of the cut sides of the square are 25 cm and 25/3 cm.

P: Does it mean that if the square is cut along that length, the volume of the box formed will be maximum?

S: Yes, because the result is that way using the method earlier.

P: Are you sure about your answer?

S: Already sir.

At this stage, the subject made a mistake because he chose both values as the length of the side of the square that needed to be cut. When the length of the cut square side is 25 cm, the box's volume becomes 0 or has no volume, so the box's volume is not maximized. The researcher asked a trigger question to see if the subject looked backstage, but the subject was sure of his answer. So, it can be concluded that the subject did not do the looking backstage.

Discussion

Based on the research results at the stage of understanding the problem, subject can understand the problems contained in the given problem. Although the student did not get the correct answer, the subject could explain the purpose of the problem given. It is supported by research belonging to (Rahmawatiningrum et al., 2019), mentioning that students with low and high learning achievement can understand the problems given. Based on the findings of this study, learning achievement does not affect the understanding of the problem so that the subject can understand the problem given. According to Inganah et al. (2023), when students can organize the information known in the problem, they will more easily understand what is in the problem.

The subject also wrote down what was known and some information that could be processed from subsequent information by the subject on his answer sheet. The box's length, width, and height are unknown values, so the subject uses symbols to express the box's length, width, and height. According to (Lutfianannisak & Sholihah, 2018), mathematical symbols are one of the most effective means of mathematical communication to convey and encode mathematical ideas. Symbol interpretation is important in understanding mathematical problems formulated using various symbols (Rini et al., 2021). According to Roudlo & Dwijanto (2021), most students can express the facts obtained in these problems clearly and logically.

At the stage of planning the solution, the subject explained his plan to find the length of the side of the square so that the volume formed was maximized. According to Delaney et al. (2004), planning the solution results in a better solution and helps write a complete problem solution. The solution plan connects students' imagination with the context of the problem. It connects the prior knowledge needed to solve mathematical modeling problems through questions or statements that do not directly lead to answers (Nuryadi & Hartono, 2021).

Implementing plans that have been made previously is important because the success of problem-solving activities cannot be separated from the initial stage, namely understanding the problem and utilizing existing information, then formulating strategies and representing the strategies made (Wahyuni & Dahlan, 2020). At this stage, the subject wrote the answer following the plan that had been made previously, but there were errors, such as incorrectly writing variables. The mistakes made by the subject do not affect the correctness of the answer. However, it is important to look back at whether the answer obtained is what is needed because the determining factor for successful problem-solving is revising and validating the solution (García et al., 2016; Prabawanto, 2019). Because, in this case, the subject did not look back, the answer given was not correct.

Students (especially students with low abilities) are less able to do all the stages in Polya's problem-solving well, so they rush in solving problems without considering whether the solution obtained has gone through the correct calculation procedure or there are errors in its implementation to get an incorrect answer (Puspa et al., 2019; Wahyuni & Dahlan, 2020). Indeed, employing less meticulous steps and problem-solving approaches leads to incorrect solutions (Sartika et al., 2023). Fatimah et al.'s research (2021) also states that some students struggle to finish the review phase that leads to incorrect solution.

Based on the description of students' thinking process in solving HOTS problems on derivative application, the implication can be stated that students who can understand the problem and apply mathematical concepts well can produce incorrect final answers if they do not perform one of the stages in Polya's thinking process, namely the process of looking back. The implication of this research is based on the results of research using HOTS questions on derivative application material based on Polya's four stages of the thinking process. Research using other types of problems and other research approaches is recommended to see a variety of research results.

CONCLUSION

Students' thought process in solving HOTS problems on derivative application material in this study is seen based on Polya's problem-solving stages, which consist of 4 stages, namely the stages of understanding the problem, the stages of planning the solution, the stages of planning, and the stages of looking back. The subject performed three stages of Polya's solution: the stages of understanding the problem, the stages of planning the problem, and the stages of planning. However, it did not perform the stages of looking back. The subject understood and collected all the information needed in the problem by mentioning and writing down information and drawing illustrations that could be obtained from the problem. The subject planned the solution by using the concept of volume and derivative, where the subject used the box's length, width, and height to get the volume function and find when the volume is maximum by finding when the function's derivative is zero. The subject then performed the solution according to the plan and obtained two values of the length of the side of the square. The subject made some mistakes, but they did not affect the calculation. The subject did not perform the looking backstage because he was sure of the two values obtained as the answer because it was following the method he had learned. It caused the subject's answer to be incorrect.

Non-routine problems or more complex problems (especially HOTS problems) usually require more complex solutions, so it is necessary to emphasize to students to double-check whether the answers they have obtained are in accordance with what is asked in the problem. Future research can more broadly explore about the thought process in Polya's stages of solving when working on various types of more complex problems.

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