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Tracing the Roots of Error: A Polya Method Analysis on Student Problem Solving in Curved Surface Solids

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Abstract

When participating in this activity, students were tasked with recording and evaluating their responses to problems related to curved surfaces' geometry. The following difficulties were included in the scope of the investigation: spheres, cones, and cylinders. The researchers followed a four-step methodology developed by Polya to investigate the approaches and viewpoints of the students. This process included identifying the problem, developing a strategy, putting the strategy into action, and evaluating the results. According to the findings, it appears that the majority of errors occur when attempting to determine the nature of the issue. Using the appropriate formulas and procedures becomes quite difficult if the problem is misunderstood or not fully grasped. In the interest of assisting teachers in better assisting their students in developing stronger mathematical reasoning and understanding skills, this study will investigate real-life examples of students making improper mathematical applications. According to the research findings, it is suggested that mathematics education should incorporate more guided practice and conversation to assist students in developing their ability to solve problems. It is also highlighted throughout the study that it is necessary to have a complete comprehension of the problem statements.

Keywords: Curved; Methode analysis; Mathematical problem-solving; Polya steps.

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1. Introduction

In order to address difficulties methodically, George Polya developed a procedure consisting of four steps known as the Polya Method. (Kania, 2018; Nasir & Syartina, 2021). Identifying the problem, formulating a plan to tackle the problem, implementing that strategy, and evaluating whether or not the solution is complete are the steps that make up this process. These steps can serve as a framework for people to employ in order to solve mathematical issues more effectively. Vitoria & Monawati (2016) These are only a few studies that have demonstrated the significance of Polya's four-step technique for enhancing students' problem-solving abilities. According to Vitoria & Monawati (2016)Polya's method assists students in developing a strategic and organized approach to problem-solving by emphasizing problem analysis, the formation of a plan, the execution of the plan, and reflection on the response. Polya has many uses for students, such as helping them choose materials, identify problems, build strategies, and reduce errors through comprehensive step-checking (Nurwahid et al., 2022).

Understanding and solving problems with solids with curved surfaces presents students with several challenges. Students struggle to understand and solve problems involving solids with curved surfaces due to the intricacy of these shapes. The reason behind this is that these shapes have curves. Students need a more thorough grasp of the material to avoid making procedural mistakes when solving problems involving curved surface solids (Adelia et al., 2022; Angraini et al., 2024). Accurately calculating volumes and surface areas, understanding the geometric features of curved surfaces, and applying the appropriate formulas and methods to address related issues are all challenging tasks. Furthermore, difficulties arise when all of these tasks must be completed together. A thorough familiarity with the mathematical concepts and methods related to curved surfaces will greatly assist students in satisfactorily handling these challenges.

A strong grasp of the concept of curvature is crucial for competently dealing with solids having curved surfaces. In the creation of curved surfaces and the properties they exhibit, curvature—the distance a curve travels from a straight line—is a crucial component. In both of these respects, curvature plays an essential role. The degree of curvature of a surface determines how its surface area and volume are calculated for several distinct curved surfaces, including spheres, cylinders, cones, and ellipsoids. This is because every surface has its unique degree of curvature. In order to analyze and solve issues involving curved solids appropriately, students must have a thorough grasp of curvature and its effects. The reason behind this is that curvature does have consequences.

The discrepancy between the end product and the initial assignment could be due to Polya omitting important steps in the problem-solving process (Arumanita et al., 2018). When students apply Polya's analysis to solids with curved surfaces, it is important to be familiar with his problem-solving methods so that you can evaluate their work more precisely. This area of study is to help students recognize and correct mathematical mistakes. In addition, research by Gopinath & Lertlit (2022) Shows that using Polya's paradigm improves students' problem-solving skills in geometry, among other mathematical domains.

In addition to pupils, teachers can use Polya's methods to help their students become better problem solvers in mathematics. Therefore, educators can aid students in creating more robust strategies for tackling problems (Pradiarti & Subanji, 2022). The following actions can be used to achieve this goal: recognize the issue, think of possible solutions, formulate an action plan, and assess the outcomes. Moreover, the overarching goal of the research is to catalog the many sorts of student mistakes and the factors that contribute to them with curved solids and problems requiring HOTS. According to Anugrah and Pujiastuti (2020), teachers can gain valuable insight into their students' abilities, weaknesses, and motivations for making mistakes.

Analyzing people's mistakes when trying to grasp and resolve mathematical problems with curved surface solids using Polya's approach could teach us a lot about their struggles. As a last step, we look into students' problem-solving mistakes using curved surface solids. Teachers may be better equipped to help their students build stronger problem-solving skills in mathematics if they are aware of the most prevalent errors and what causes them.

2. Methods

This study employs a qualitative research approach to examine students' challenges when solving mathematical issues. The research commenced by administering a Problem Solving Test to 32 MTSN 8 Majalengka pupils, focusing on the geometry of geometric shapes located on the periphery of a circle. Three children were selected as research participants based on their high, medium, and low talents. The researcher interviewed three subjects, focusing on their responses to investigate the outcomes of their thought processes.

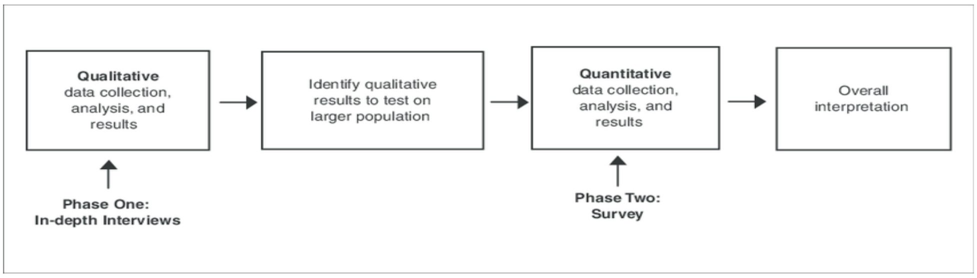


Figure 1 Qualitative research steps

The following presents the findings from analyzing the Problem-Solving Test responses and interview outcomes. These findings provide a detailed account of the mistakes made in solving problems related to the geometry of curved-sided shapes. Triangulation is a method used to determine the position of a point by measuring the angles between it and other known points. The research methodology employed in this study is triangulation, specifically comparing outcomes. Subsequently, the student's task involving the analysis of interview results is conducted using Polya's sequential approach.

The data collection methods employed were examinations, interviews, and documentation. The test is utilized to assess students' problem-solving proficiency. The interview utilized in this study is a structured interview. The interview approach is employed to gather data on students' proficiency in completing the researcher's mathematical problem-solving ability exam. Documentation refers to crucial information about the circumstances and functioning of research objects, such as archives. The documentation method is employed to enhance the data collected by researchers during observations.

3. Results and Discussion

3.1. Results

The research undertaken in class IX MTS 8 Majalengka focused on the properties of curved-sided geometric materials. The researchers utilize indicators to assess problem-solving skills, employing the Polya technique, which encompasses comprehension of problems, formulation of solutions, execution of resolution plans, and subsequent re-evaluation. For this study, a total of 3 research volunteers were chosen. The ability categories are classified as high, medium, and poor. The selection of analysis subjects was determined based on quartiles. The subject is determined based on the results of the work. Students are then rectified and classified according to their problem-solving abilities, from smallest to largest. After that, quartiles are calculated using a statistical method. As indicated in Table 1 below.

Table 1 Student categories based on ability

Subject	Category	Score
S1	High	23
S2	Middle	16
S3	Low	10

Problem Out of the three chosen research subjects, many persons are still experiencing errors throughout this stage of the research. The participants who committed errors during this phase were S3.

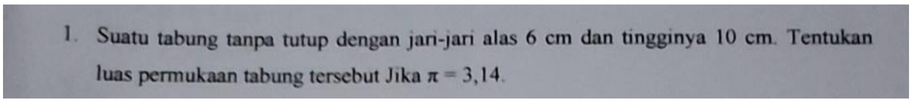

1. Suatu tabung tanpa tutup dengan jari-jari alas 6 cm dan tingginya 10 cm. Tentukan luas permukaan tabung tersebut Jika π = 3,14.

Figure 2 Question number 1

To begin with, let us solve each problem by applying the four-step technique developed by George Polya, beginning with problem number 1. Assuming the following 6 equals the radius: cm r equals 6 cm, height *X* equals 10 cm t, and $\pi \approx 3.14$. Perform the calculation to determine the lateral surface area of a cylinder, which appears to be the desired result given the utilized parameters and formula.

Acquiring an Understanding of the Issue Calculating the lateral surface area of a cylinder needs to be done. For calculating the lateral surface area, the formula utilized is $L = 2\pi r h$, where r represents the radius, and *h* represents the height of the cylinder. Making a plan is the second step. We will use the formula provided to get the lateral surface area and then insert the numbers provided for *r* and *h*. Putting the plan into action: To determine the lateral surface area, let us use the following formula: the equation $L = 2\pi r h$. Revisiting the past after reviewing the calculations, we will ensure they are accurate and check if the outcome is consistent with the provided data.

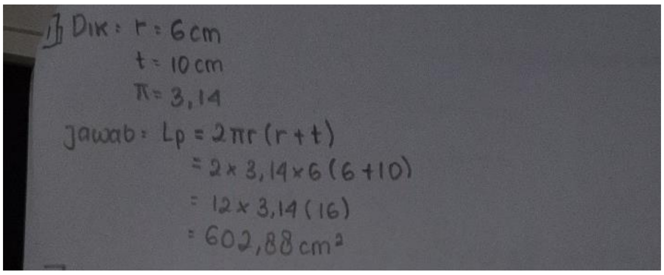


Figure 3 Student answer number 1

Based on Polya's steps for handling mathematical problems, the student's comprehension of the questions and the formula choices is lacking. Before Polya can find a solution to an issue, she must first understand the problem. Considering that the question is enquiring about the surface area of an open cylinder, it is reasonable to expect that pupils will be able to determine this. Despite this, students often use the formula for the total surface area of a cylinder with a lid and a base. This formula is L=πr(r+s), considering the entire cylinder, including the lid.

In the second stage of the process, Polya will develop a strategy. When the computation is restricted to the side walls of the cylinder, it is recommended that students apply the formula for the surface area of a cylinder that does not have a lid, which is Lp=2πrh. The fact that students made this error demonstrates that they may not know when to apply which formula to describe the many types of cylinder surfaces.

In the third section of the plan, the students will use the formula they selected to carry out the calculations appropriately. However, the formula is not appropriate for the question that was asked. This demonstrates how important it is to thoroughly comprehend the question's overall purpose in the initial stage. Because of this, the final product has some problems.

When Polya's method is finished, the final step is to examine the gathered results. The student might recognize that he mistakenly selected the formula during the review by comparing the formula with the particular problem conditions associated with a cylinder without a lid.

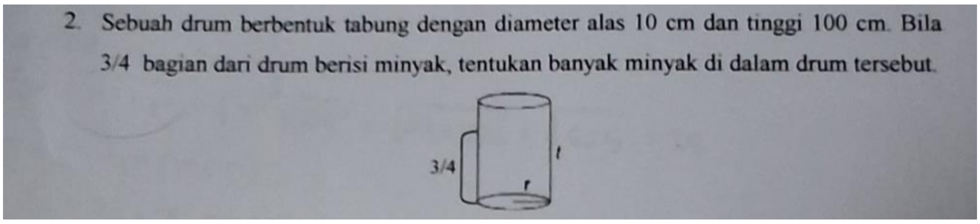

2. Sebuah drum berbentuk tabung dengan diameter alas 10 cm dan tinggi 100 cm. Bila 3/4 bagian dari drum berisi minyak, tentukan banyak minyak di dalam drum tersebut.

Figure 4 Question number 2

Answer number 2 using the formula for the volume of a cylinder, we can calculate the amount of oil contained within a drum that is formed like a cylinder and has a base diameter of 10 centimeters and a height of 100 centimeters. The drum is three-quarters filled. In the equation $V = \pi r 2 h$, the radius of the base of the cylinder is denoted by the symbol r, while the symbol height denotes the height of the cylinder. Because the diameter of the base is 10 centimeters, the radius is equal to 10 centimeters divided by two, which equals five centimeters.

In other words, the height of the cylinder that is filled with oil is three-quarters of its full height. Three times four times one hundred equals seventy-five centimeters, $h = \frac{3}{4} \times 100 = 75\ cm$. By substituting the values of r and isi h into the formula for cylinder volume, we can achieve the following results: V=π(5)2(75). To simplify the calculation, we employ the equation $\pi \approx 3.14$, $V = 3.14 \times 25 \times 75 = 5887{,}5\ cm^3$. A total of approximately $5887{,}5\ cm^3$ of oil is contained within the drum.

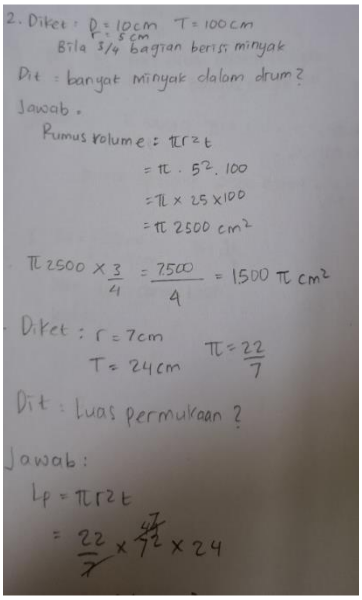
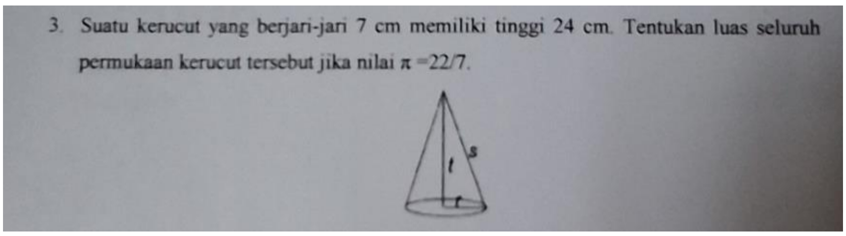


Figure 5 Student answer number 3

One of the formulas utilized in the provided paper is erroneous. The student mistakenly substitutes the term "area" for "volume" while explaining the formula $\pi r^2 t$, which is specifically used to calculate the volume of a cylinder. Using π as $\frac{22}{7}$ Instead of the more commonly accepted value of π as 3.14 in everyday calculations, it demonstrates an inconsistency. However, the student's mistake in converting and applying units may not be a significant problem in a classroom environment.

The primary error lies in employing incorrect numerical values and units during the calculation. The student should understand that the π multiplied by 25×100 calculation yields a result of 2500 cm^2, representing volume, not area. The intended aim is to calculate volume, not area. When computing volume, there is no requirement to convert square centimeters (cm^2) to cubic centimeters (cm^3). Therefore, multiplying this quantity by $\frac{3}{4}$ results in 1500 π cm^2, which is theoretically incorrect. This mistake serves as an illustration of the intricate relationship between volume and surface area. Upon completing the initial stage of the Polya technique, "Understand the Problem," pupils will grasp that the inquiry pertains to the quantity of oil rather than its surface area. In the second level, known as "Make a Plan," you must choose a suitable formula. The volume formula for a cylinder is given by $V=\pi r^2 h$, where *h* denotes the liquid's height, not the cylinder's total height. This misinterpretation results in errors in stages three and four.



3. Suatu kerucut yang berjari-jari 7 cm memiliki tinggi 24 cm. Tentukan luas seluruh permukaan kerucut tersebut jika nilai π =22/7.

Figure 6 Question number 3

In order to get the surface area of the full cone with a radius of 7 centimeters and a height of 24 centimeters, we need to determine the base area and the curved surface area of the cone. Using the equations π as $\frac{22}{7}$, It is possible to follow these procedures. A circle with a radius of seven centimeters is used as the base of the cone to determine the area of the base of the cone. The formula for calculating the square of the base's area is 154 centimeters, equal to 22.7 multiplied by seven and then multiplied by 49. We may calculate the area of the base by using the formula πr^2, which is $\frac{22}{7} \times 7^2$= 154 cm^2.

Get an estimate of the number of lines that the painter will use: To calculate the surface area of the cone, we need to know the length of the painter's line, which is equal to s. This can be accomplished by using the Pythagorean theorem to the triangle formed by the painter's line, the cone's height, and the cone's radius. The equation $s = \sqrt{r^2 + h^2} = \sqrt{7^2 + 24^2} = \sqrt{625} = 25$ centimeters. The formula is s = r squared plus h squared plus twenty-four squared. 625, equivalent to 25 centimeters, is the result of adding 50 and 576.

Determine the size of the cone-like this: the surface area of the cone can be calculated using the following formula: A surface area of 550 cm, which is indicated by the symbol, is equal to $\frac{22}{7} \times 7 \times 25$ = 550 cm^2.

To determine the cone's total surface area, the cone is total surface area can be calculated by adding the cone's surface area to the cone's base area. By adding the surface area, which is 550 cm squared, to the total area, which is 704 cm squared, the total area equals 154 cm^2. The total area, including the base area, is 154 cm. 550 cm^2 in addition to 704 square centimeters. Thus, the overall area of the cone is 704 cm^2.

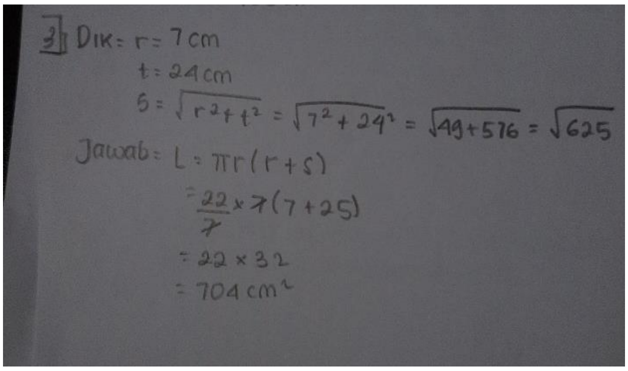


Figure 7 Student answer number 3

Students successfully tackled the second task, which involved estimating the lateral surface area of a cone. Initially, it is vital to ascertain the vertical measurement of the incline, subsequently incorporating this numerical value into the prescribed mathematical equation. The equation is expressed as *L=πr(r+s)*. By applying the Pythagorean theorem, the students accurately determined the height of the slope, demonstrating their proficiency in Steps 1 and 2. Furthermore, there were no discernible problems in the ultimate submission of Step 3. To summarise, it is worth noting that students committed substantial mistakes when initially attempting to solve Problem 1 by making unwarranted assumptions or employing erroneous formulas. The anticipated outcome may not be attained due to this error, as there is a discrepancy between the application and the resulting output. The student's proficiency in each stage of the second question indicates a greater comprehension of the topic than the first. In order to enhance our skills, it is imperative that we thoroughly examine the relevant formulas for each specific geometric shape and ensure a comprehensive understanding of the formula prior to attempting to solve the problem at hand. Receiving this critique may drive students to think critically about their work from Step 4, which can help them remember and apply effective mathematical approaches and principles.

3.2. Discussions

Teachers frequently encounter students who struggle to understand mathematical topics. These problems manifest in more sophisticated problems and in problems that appear to be basic. We have seen how a lack of early understanding can affect problem-solving in the three situations we discussed. These cases include the surface area of an open cylinder, the volume of oil in a drum, and the surface area of a cone (Rahaju et al., 2019; Sari et al., 2020; Silva, 2013)According to the National Council for Teachers of Mathematics, to address these issues, teachers must place a primary emphasis on developing students' problem-solving skills in mathematics. Bentayao (2023) stated that using problem-solving assignments can potentially improve students' mathematical education. Teachers need to have a role in assisting pupils in finding solutions to difficulties. They can employ strategies such as helping students identify the known and unknown aspects of a problem, translating problems into symbols, and then solving them by employing the appropriate mathematical processes (Angraini et al., 2023; Soesanto et al., 2022; Syaifuddin et al., 2019). They can apply these strategies.

During the first stage of Polya's approach, "Understanding the Problem," you must carefully read the problem and then proceed to assess and evaluate all of the information provided. In order to complete this procedure, it is necessary to determine what the problem genuinely desires and what information is lacking. If this stage is skipped, the student is more likely to employ the incorrect formulas or problem-solving processes, increasing the possibility that they will get the answers wrong. If this step is skipped, the student will perform inadequately.

The relevance of this stage extends far beyond the simple act of solving mathematical problems it is also an important and necessary life skill (Madhuri et al., 2012; Nusantara et al., 2021). Accurate and quick situational knowledge is a skill that is vital not just in the classroom but also in the business world when it comes to making judgments on a day-to-day basis and in social connections, all of which require the ability to deal with complex difficulties. Furthermore, analytical reasoning and critical thinking abilities are honed through solving mathematical problems (Palwa et al., 2024; Susilo et al., 2023). The ability to identify patterns and connections, simplify complex problems, and solve them through the application of logical reasoning is a skill that students develop. In addition to being crucial in the classroom, these cognitive abilities are highly sought after in the workplace, where one must assess data, weigh alternatives, and ultimately make judgments.

To assist their students in becoming more adept at finding solutions to problems, teachers may employ various strategies, including the following, to assist pupils in comprehending the distinctions between methods that produce accurate outcomes and those that do not. This demonstrates that there are examples of comparable problems with accurate and incorrect responses. The purpose of this activity is to assist students in developing their analytical skills and strategies for problem-solving by providing them with a variety of scenarios that include problems that need to be solved (Chen & Liu, 2020; Efendi1 & Suastra, 2023; Ratnawulan & Kania, 2020)(Efendi1 & Suastra, 2023). When it comes to problem-solving, one method that might assist students in becoming more self-aware is to have them reflect on their thought processes by explaining the reasons behind the strategy or formula they chose. Establishing a setting where students feel comfortable discussing their ideas and approaches to problem-solving is necessary to improve group and individual comprehension through peer learning. Through these strategies, students can develop their critical thinking skills, which are beneficial in many facets of life, including, but not limited to, their academic endeavors (Barcelos et al., 2018; Kania et al., 2023; Rahman & Manaf, 2017; Saepuzaman et al., 2021).

4. Conclusions

As a result of the discussion of errors that occur when attempting to comprehend mathematical issues by the first stage of the Polya method, it is possible to deduce that an in-depth and accurate grasp of the problem is an essential component of the problem-solving process. It is possible that if this phase is not done correctly, it will start a chain reaction of strategic and technical errors that will result in incorrect or misleading results. Due to the relevance of this stage, it is imperative that training and education be provided that places a focus not just on the ability to apply formulas but also on the ability to comprehend and analyze issues. Using a method that involves discussion, metacognitive tasks, and a range of scenario circumstances, students can enhance their mathematical skills and cultivate their critical thinking talents, which are crucial for success in many aspects of life. Consequently, it is of the utmost importance for educators to incorporate tactics that assist students in developing their solution-finding skills.

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Conflict of Interest
The authors declare no conflicts of interest.

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