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An Analysis of Students' Errors in Solving Systems of Linear Equations in Two Variables (SPLDV) Based on Polya's Steps

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Abstract

Mathematics is one of the subjects that students find difficult. This is due to the abstract and systematic nature of mathematics, the use of complex formulas, and its logical nature. The perception that mathematics is difficult can make it hard for students to understand mathematical concepts. These difficulties become apparent when students solve problems. This study aims to determine the types of errors students make when solving systems of linear equations with two variables (SPLDV) as viewed through Polya's steps. Polya's problem-solving steps consist of understanding the problem, making a plan, carrying out the plan, and checking the solution. This study employs a qualitative descriptive approach with a sample of 25 eighth-grade students at a public junior high school in Depok, Yogyakarta. Data were collected by administering a diagnostic test. The research instrument consisted of a written test comprising two problems covering the topic of two-variable linear systems of equations. The findings indicate that students' errors were distributed across all of Polya's steps, with the following percentages: understanding the problem (46%), planning (52%), implementing the plan (66%), and checking the results (82%). The types of errors made by students included errors in writing down known and unknown information, errors in algebraic calculations, incomplete solution steps, and a tendency not to check their answers.

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Introduction

Education is a planned effort to achieve a goal. One of the goals to be achieved is to create a bright future. A key factor in this is high-quality human resources. Therefore, education plays a vital role in developing people's ability to think logically, so that they can use this ability to find solutions to problems(Susanti & Lestari, 2019). The ability to think logically can be acquired, in part, through the study of mathematics. Mathematics is an exact science that deals with numbers and operational procedures for solving numerical problems. The application of mathematics is deeply embedded in daily life, so it is not merely a subject taught in school. This means students are expected to possess critical, creative, logical, and meticulous thinking skills when solving mathematical problems(Meika et al., 2022). According to Law No. 20 of 2003, education in Indonesia is implemented to foster a culture of writing, reading, and arithmetic among the entire population. This underscores the vital role of mathematics in daily life, making its teaching in schools essential. One of the objectives of mathematics education is for students to be able to solve various types of mathematical problem(Putri & Fuadiah, 2019).

As a foundational discipline, mathematics plays a crucial role in the development of science and technology. Therefore, instilling an understanding of mathematics in everyone must begin at an early

age. Learning mathematics involves not only following operational procedures but also understanding the mathematical concepts underlying each topic (Yuliani, 2016). Students' difficulty in transforming word problems into mathematical models—due to the abstract nature of mathematics—is one reason why mathematics is considered a difficult subject. In addition to being difficult, mathematics is also perceived as confusing by students. This is due to the logical and systematic nature of mathematics, as well as the use of complex symbols and formulas(Auliya, 2016). This situation can cause students to feel anxious even before they begin learning. Once the belief that mathematics is difficult becomes ingrained in students, they may face obstacles in learning the subject. Students will struggle to understand the concepts and theorems they are studying(Susanti & Lestari, 2019).

Learning difficulties experienced by students are generally caused by two factors: internal factors (related to the student's personal characteristics) and external factors (related to the environment outside the student). Internal factors include, for example, health, ability, student interest, motivation to learn, intelligence, and so on. Meanwhile, external factors include the school environment, family support, and social interactions with the community. Difficulties in mathematics are often dominated by weak conceptual understanding, which is influenced by perception, interpretation, and extrapolation. Therefore, the learning process that takes place in the classroom greatly influences students' success in understanding the material (Jamal, 2014). Students' difficulties are often evident when they are solving problems. These difficulties manifest as students' inability to understand the problem, selecting the wrong formula, performing incorrect calculations, and making errors in writing the final answer. Such difficulties are frequently encountered in word problems. Word problems that require a high degree of precision are often considered difficult by students. Therefore, to overcome these difficulties, students must possess the ability to understand the problem, devise a solution strategy, and solve the problem presented in the question (Fauziyah & Pujiastuti, 2020). There are five reasons why students make mistakes: they do not understand the concept behind the problem; they are unable to understand the meaning of mathematical symbols or notations; they do not understand the underlying principles; they are not proficient in arithmetic operations and the application of procedures; and they lack knowledge (Yuliani, 2016). These errors are one of the obstacles students face in mathematics. This is due to their difficulty in solving mathematical problems (Bahir & Mampouw, 2020).

According to the National Council of Teachers of Mathematics (NCTM), students must master five skills in mathematics learning, namely problem solving, reasoning and proof, making connections between concepts, mathematical communication, and representing ideas (NCTM, 2000).. Problem-solving requires students to actively participate and exercise creativity. Additionally, students are trained to use logical and critical thinking, as well as higher-order thinking skills, to articulate their ideas in order to solve problems (Kania & Ratnawulan, 2022). Problem-solving typically takes the form of word problems that depict real-life situations. This type of mathematical problem generally requires a complex solution process. Word problems demand precise calculations and a high degree of attention to detail, which is why most students find them difficult(Fauziyah & Pujiastuti, 2020). Polya argues

that solving mathematical problems consists of four steps: understanding the problem, devising a solution strategy, carrying out the plan, and reflecting on the results (Polya, 2004).These stages are outlined more systematically as follows: understanding the problem—at this stage, students need to identify the information provided in the problem; next, devising a plan—students are expected to be able to determine the variables, formulate a mathematical model, and decide on the solution strategy to use; the third stage is carrying out the plan— students implement the predetermined strategy; and the final stage is reflecting on the results obtained (Looking back). At this stage, students need to review the information, examine the calculation process, and ensure that the solution obtained answers the question in the problem. To solve problems, students must also possess the ability to understand the concepts presented in the problem as well as the computational skills needed to solve it (Fauziyah & Pujiastuti, 2020).

Related research on error analysis based on Polya's problem-solving steps has been applied in several previous studies, including a study by Ratna Sari et al. (2025) titled "Analysis of Students' Errors in Line and Angle Problems Based on Polya's Stages." Furthermore, there is a study by Humayatun et al. (2021) titled "Analysis of Students' Errors in Solving Ratio Problems Based on Polya's Steps." Although both studies successfully identified the sources of students' errors, the characteristics of lines, angles, and ratios are certainly different from those of algebra. Therefore, this study aims to expand on that research by focusing on "Analysis of Students' Errors in Solving Systems of Linear Equations in Two Variables (SPLDV) Based on Polya's Problem-Solving Steps." The topic of two-variable linear systems of equations was chosen because it presents a unique level of complexity that requires students to be skilled not only in reasoning but also in transforming narrative language into abstract algebraic models.

Based on the above discussion, the researcher was interested in examining the types of errors students make when solving problems involving systems of linear equations with two variables (SPLDV) as viewed through Polya's steps. This study was conducted to address the research question regarding the types of errors students make when solving problems involving systems of linear equations with two variables (SPLDV) as viewed through Polya's steps.

Method

This study is a descriptive qualitative study that aims to identify the errors students make when solving problems, as analyzed using Polya's steps. This approach was chosen to provide an in-depth and comprehensive understanding of the types of errors students make when solving problems. This study was conducted during the even semester of the 2025/2026 academic year at a public junior high school in Depok, Yogyakarta. The study was carried out during mathematics class with the permission of the school administration and the relevant subject teacher. This study was conducted during the even semester of the 2025/2026 academic year at a public junior high school in Depok, Yogyakarta. This

study was conducted during mathematics class with the permission of the school administration and the relevant subject teacher.

The population in this study consisted of all eighth-grade students at a public junior high school in Depok, Yogyakarta, during the 2025/2026 academic year. Sampling was performed using the cluster random sampling technique (random sampling based on groups or classes). This technique was chosen because the students were already organized into existing classes. Based on this technique, Class VIII A was selected as the research sample, consisting of 25 students. The data analysis method employs qualitative data analysis techniques, which consist of three stages: data reduction, data presentation, and drawing conclusions.

Results and Discussion

The students' work was then analyzed to identify and map the types of errors they made. These types of errors refer to the stages of problem-solving according to Polya, namely understanding the problem, devising a plan, carrying out the plan, and reflecting on the results obtained.

Research Findings

The indicators of types of errors in problem-solving according to Polya, which will be examined in this study, are presented in Table 1.

Tabel 1. Types of Errors

No	Polya Step's	Error Indicator
1	Understanding the Problem	a) The student incorrectly wrote down the given information in the problem
		b) The student incorrectly wrote down the given information in the problem
		c) The student did not write down the given information in the problem
		d) The student did not write down the question in the problem
2	Develop a Plan	a) Students immediately write down the equation without any example.
		b) The student made a mistake in writing the mathematical model
		c) The student did not write down the mathematical model
		d) The student made a mistake in choosing the method to use
3	Carrying out the Planning	a) The student completed the steps outlined in the plan but made a mistake.
		b) The student did not complete the steps for solving the problem as planned
		c) The student did not write down the steps for solving the problem as planned
		d) The student made a mistake in performing the mathematical calculation

		e)	The student did not perform the given math problem but got it wrong
4	Looking Back	a)	Students did not re-examine the results they found
		b)	b) The student made a mistake in the
		c)	calculations when rechecking the solution
		d)	c) Students do not adjust the values of x and y to fit the context of the problem
		e)	d) The student did not write a conclusion based on the results obtained

Meanwhile, the percentages of each type of student error based on the problem-solving indicators outlined in Table 1 are presented in detail in Table 2.

Tabel 2. Percentage of Error

Polya Step's	Questions 1	Questions 2	Mean
Understanding Problem	56%	36%	46%
Devising a Plan	64%	40%	52%
Carrying out the Plan	72%	60%	66%
Looking Back	100%	64%	82%

Discussion

Based on the results of the data analysis that has been conducted, the following is a discussion of the types of errors made by students when completing the test:

Errors in the problem-understanding stage, to understand a problem, students must first understand the language and terminology used in the problem and identify the given information. Students need to ensure that this information is sufficient to solve the problem in the question(Polya, 2004). Based on Table 4, it can be seen that 46% of students made errors in understanding the problem. This stage falls into the low category. At this stage, errors were identified based on how students wrote down the given information and the question posed in the problem. Based on these results, it was found that a number of students did not write the information from the questions on their answer sheets. Students also made mistakes in identifying and writing down what was given and what was asked. This may have occurred because students preferred short answers. In Question 1, a student wrote the component being asked about as follows: "How many points are there for one question?" This demonstrates a misunderstanding of the question. The question asked students to identify two different values (multiple-choice points and fill-in-the-blank points), not a single general score for the question. In another sample answer, a student neatly wrote down the number of questions but forgot to include the final score. Meanwhile, in Question 2, students immediately jumped to writing down the variables (Saturday: x = 1, y = 2 = 14 minutes). Here, students did not define the conceptual meaning of the symbols x and y. In fact, students did not write down any information first. Errors at this stage will confuse students in the next stage, because the information obtained is incomplete. This error generally

stems from students feeling that there is no need to write down what is known and what is being asked because they already understand the content of the question. This aligns with the findings(Amelia et al., 2024) which reveal that one of the factors causing students to have difficulty understanding word problems is that they are not accustomed to writing down the steps for solving them, particularly the parts containing the given information and the question being asked.

Errors in Formulating a Plan, students can formulate a plan once they have a clear understanding of the arithmetic operations, the steps for solving the problem, the formulas to be used, and the constructions needed to arrive at a solution. Polya emphasizes that success in problem-solving lies in a person's ability to formulate a plan to solve the problem(Polya, 2004). At this stage, students are asked to examine the relationship between the data and the unknowns in order to formulate ideas, select strategies, or construct relevant mathematical models. The analysis results show that the error rate in planning was 52%. These errors are among those with a relatively high frequency. The analysis also revealed that most students were incomplete and inaccurate in writing down formulas and modeling problems in mathematical form. Students had also planned an elimination strategy for the right-hand side, but the analysis of the first step showed that this approach is often used by students because it relies on mechanically following procedural steps, rather than on their understanding of the relationships involved. Students immediately wrote down the values in terms of x and y simply because they recalled patterns from previously given problems. Several factors contributing to students' errors in this step include a lack of attention to detail and a lack of understanding of the prerequisite material relevant to the problem. Additionally, students still have limitations in their ability to process known and requested information to formulate a plan for solving the problem in the next step (Rofi'ah et al., 2019).

Errors in the Planning Phase. In this step, students perform calculations using concepts or theorems appropriate to the given problem. They then substitute the known data into the formula derived during the planning phase. Next, students carry out the solution steps to resolve the problem(Polya, 2004). The analysis results show that the percentage of errors in the planning stage is 66%. The most common error in this stage is that students make mistakes in computational operations due to a lack of precision and a lack of prerequisite skills, such as in multiplication and addition in algebra. However, there are also students who have started the calculations but have not yet completed them. The student did not write the plus sign (+) between the terms 56x and 10y. The student also forgot to include the constant -66 and made a mistake in the calculation 23 – 56. The student also omitted the negative sign (-) when dividing to find the value of x. Meanwhile, in the image on the right, there is a procedural error in the elimination process. In that equation, the coefficients of y are already equal, but the student chose to equalize the coefficients of the variable x. Although the product is correct, this indicates that the student does not yet understand how to analyze the steps of the solution. The calculation process was also incomplete, resulting in errors in the student's work. In addition to errors in arithmetic operations,

the analysis also shows that the student took a long time to understand and select a solution strategy, meaning the allotted time was insufficient to fully solve the problem.

Errors in Rechecking. At this stage, none of the students rechecked their answers. The analysis revealed that students tend not to be in the habit of rechecking their answers. Students assume that once they have found an answer, it is correct, without checking for calculation errors. Some students completed the problem-solving steps and found their answers but did not perform the rechecking step. This aligns with the findings of (Herbianti et al., 2024)that, in the process of solving math problems, students are not accustomed to rechecking the results they obtain. They assume that once an answer is written down, it is most likely correct, without considering the possibility of calculation errors or mistakes in copying numbers. In addition to not being accustomed to checking their answers, the high percentage is also due to incomplete problem-solving behavior in the previous stage.

This study supports Polya's theory of problem-solving. It has demonstrated that errors in the initial phase—that is, understanding the problem—will lead to errors in subsequent steps. The problem-understanding stage is the first step in the process of solving math problems, particularly word problems. A systematic approach significantly influences students' success in solving problems. The results of this study provide teachers with insight into the types of errors students make when solving problem-solving questions. Teachers can use these findings to improve their teaching systems, adopt appropriate teaching methods, and encourage students to solve problems using a systematic approach, rather than merely following procedural steps. Mathematics education is not merely about teaching procedural steps that students simply memorize, but also about developing students' ability to understand concepts. This is essential for students to solve mathematical problems—not only in school within an academic context but also in situations related to daily life. Mathematics is a discipline that requires students to think logically, systematically, creatively, and critically to solve problems. Therefore, conceptual understanding in mathematics education is not merely a set of rules outlined in the curriculum but a fundamental necessity for students to think critically and logically when addressing various problems.

Conclusion

Based on the analysis results, this study revealed that students' errors in solving problems on the topic of Systems of Linear Equations in Two Variables (SPLDV) were spread across all steps of the solution process according to Polya, with the following percentages of errors: understanding the problem (46%), devising a plan (52%), carrying out the plan (66%), and looking back (82%). The types of errors made by students include mistakes in writing down known and unknown information, errors in algebraic calculations, incomplete solution steps, and the habit of not checking their answers. These errors are not only caused by students' lack of understanding of the material but also by other factors such as rushing and a study habit of merely following procedural steps without understanding each one.Teachers can encourage students to write down the information they know and the questions they

are asked, help students plan their problem-solving strategies, train students to be meticulous in their calculations, and encourage students to develop the habit of double-checking their answers. This is done so that students do not merely follow procedural steps, but also engage in the process of understanding a problem and the steps they take to solve it.

Recommendation

Teachers can encourage students to write down the information they know and the questions they are asked, help students plan their problem-solving strategies, train students to be meticulous in their calculations, and encourage students to develop the habit of double-checking their answers. This is done so that students do not merely follow procedural steps, but also engage in the process of understanding a problem and the steps they take to solve it.

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