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Understanding common errors in solving math problems on systems of linear equations with two variables: A study of 8th grade students

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Abstract: This study aimed to identify the types of mistakes students made in solving SPLDV problems based on the Kastolan technique and why they made these mistakes. This study used a descriptive qualitative approach which was carried out at SMP Negeri 4 Sewon. The research subjects were 2 students of eighth grade who were selected based on the completeness of the answers and the answers were then examined and analyzed. Data was collected using documentation, interviews, observations, and tests. The instruments used were observation sheets, tests, unstructured interview guidelines. The data were then analyzed descriptively. The results of this study are that there are two categories of errors that are mostly made by students when solving SPLDV problems, namely conceptual and technical errors. This research is expected to be a reference for further research related to errors in solving SPLDV problems.

Keywords: *8th grade students, Problem solving errors, Systems of linear equations with two variables*

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INTRODUCTION

A person's future is greatly affected by their education. One cannot be innovative, creative, or live a fulfilling life without a quality education. Education plays an important role in human life, bringing various changes to individuals, including changes in social strata, where access to education must be equal and equitable (Simatupang & Yuhertiana, 2021; Sulistyowati et al., 2019a). However, it cannot be denied that there are many differences in access to education in Indonesia, especially education in underdeveloped and remote areas. This is due to a lack of human resources, poor teacher quality, and inadequate infrastructure and facilities for education. Some of these factors certainly have a negative impact on learning outcomes, including in learning mathematics.

Learning mathematics is a process that aims to develop the ability to calculate, measure, conclude, and apply mathematical formulas to solve problems in everyday life, resulting in relatively stable changes in behavior, both observable and non-observable, that occur as the

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result of training or experience in interacting with the environment (Fajrina et al., 2022; Istiqomah & Sulistyowati, 2021; Juli et al., 2021; Nuraini & Laksono, 2019; Rejeki et al., 2021). Students who study mathematics must be able to apply what they have learned to solve problems in everyday life. This prepares them to tackle challenges that arise in their environment. This ability is known as problem-solving.

Problem-solving is a process of solving problems in everyday life (Irfan et al., 2023; Sulistyowati et al., 2017; Widodo et al., 2021). Every problem has the right solution. Students can solve every problem that arises if they have problem-solving skills. Problem-solving skills are needed to understand and solve problems (Sulistyowati & Harini, 2021). There are still many students who have difficulty solving systems of linear equations with two variables (SPLDV) problems. This is due to procedural errors, lack of understanding in making mathematical models from contextual problems, operational errors, and other errors (Al-Mutawah et al., 2019; Baysal & Sevinc, 2022; Makonye & Fakude, 2016). Therefore, further analysis is needed regarding student errors in solving SPLDV problems.

There are various methods for analyzing student errors in solving problems, one of which is using the Kastolan method. Kastolan said that researching the procedures students use to solve problems can help accurately identify mistakes made by students (Hendriyanto et al., 2022). The components or categories of errors in identifying errors in solving problems accurately are (1) conceptual errors; (2) procedural errors; (3) technical errors (Kartini & Alawiyah, 2023). Students with conceptual errors cannot choose the correct formula. Even if they chose the correct formula, they couldn't use it. The characteristics of students with procedural errors are: (1) there is a difference between the suggested completion steps given in the problem and the completion steps carried out by the students; (2) students cannot simplify the problem to its most basic form. Students with technical errors make mistakes in arithmetic operations, for example, students make mistakes when writing constants or variables.

Based on interviews with students at SMPN 4 Sewon, it was found that students were less able to hold on to mathematical calculations but were interested in the SPLDV topic. This is because SPLDV is taught consistently and the concept of the solution is often found in everyday life. However, there was one student who said it was difficult to solve contextual problems related to SPLDV. On the other hand, observations during SPLDV learning show that the teaching methods used by teachers are centered on textbooks. According to the students, this was less interesting and reduced their interest in SPLDV material. In interviews, students also said they lacked confidence in mathematical calculations, especially when dealing with positive and negative signs in SPLDV. This shows that there are several problems that occur to students at SMPN 4 Sewon in solving SPLDV problems, so further studies are needed to identify errors made by students. The errors found can be used to improve learning so that students' problem-solving abilities also increase.

METHOD

The research design used in this study is qualitative descriptive. Qualitative research is an approach that reveals specific social situations by accurately describing the reality formed by words based on relevant data collection and analysis techniques obtained from natural situations (Istiqomah & Sulistyowati, 2023; Nahlati & Sulistyowati, 2023; Rukmana & Sulistyowati, 2023). Using a descriptive method means that the researcher analyzes data collected in the form of words, images, and not numbers (Moleong, 2012; Sulistyowati et al., 2019b).

This study aimed to identify the types of mistakes students made in solving Systems of Linear Equations with Two Variables (SPLDV) problems based on the Kastolan technique and why they made these mistakes. This research has been carried out at SMPN 4 Sewon, Yogyakarta, Indonesia in 2022. In this study, the researcher is the main instrument, while the SPLDV problems test, interview guide and observation sheets are the secondary instruments. The research subjects were 2 students of eighth grade who were selected based on the completeness of the answers and the answers (purposive sampling). The most commonly used sampling techniques in qualitative research are purposive sampling and snowball sampling (Naderifar et al., 2017; Taylor et al., 2015). Purposive sampling is a technique for selecting data sources based on specific considerations, such as individuals who are considered to be most knowledgeable about what is expected, and those who make the most errors in solving math problems (Ames et al., 2019; Campbell et al., 2020). In this study, purposive sampling was used to identify the types of errors made by students when solving SPLDV problems. The researcher selected two students, identified as students K and M, for analysis. This was done to observe the variety of errors made by students in solving SPLDV problems. Therefore, the sample size in this study is 2 students.

The data collection techniques used in this study are observation, tests, and interviews. Observations are used to see the learning that has been carried out so far and to see the characteristics of students when solving SPLDV problems. Interviews were conducted to find out more about how students made mistakes when solving SPLDV problems. Tests are used to obtain student data in solving SPLDV problems. During interviews, researchers use indirect communication via instant messaging (eg, WhatsApp) to ask open questions and collect detailed, in-depth, and relevant information related to student errors in solving SPLDV problems.

The error analysis used in this study refers to Kastolan. Kastolan said that researching the procedures students use to solve problems can help accurately identify mistakes made by students (Hendriyanto et al., 2022). The components or categories of errors in identifying errors in solving problems accurately are (1) conceptual errors; (2) procedural errors; (3) technical errors (Kartini & Alawiyah, 2023). Students with conceptual errors cannot choose the correct formula. Even if they chose the correct formula, they couldn't use it. The characteristics of students with procedural errors are: (1) there is a difference between the suggested completion steps given in the problem and the completion steps carried out by the students; (2) students cannot simplify the problem to its most basic form. Students with technical errors make mistakes in arithmetic operations, for example, students make mistakes when writing constants or variables. In this study, the answers of 32 students who solved the SPLDV problem were reduced to 2 students (K and M) who were the research subjects. Answers K and M are the answers that have the most errors, and the mistakes are obvious. The errors that appear are then analyzed, namely by relating them to the actual answers. After that, further interviews were conducted to find out the causes of the mistakes made. The results of the interviews obtained were used as guidelines for obtaining conclusions in this study.

RESULTS AND DISCUSSION

Following are the results and analysis of student errors in solving SPLDV problems according to Kastolan which are categorized into three types of errors, namely conceptual errors, procedural errors, and technical errors. Student errors will be analyzed to determine the most common types of errors. The researcher chose 2 students (K and M) to be analyzed, because their problem solving approach was unique and the mistakes were obvious.

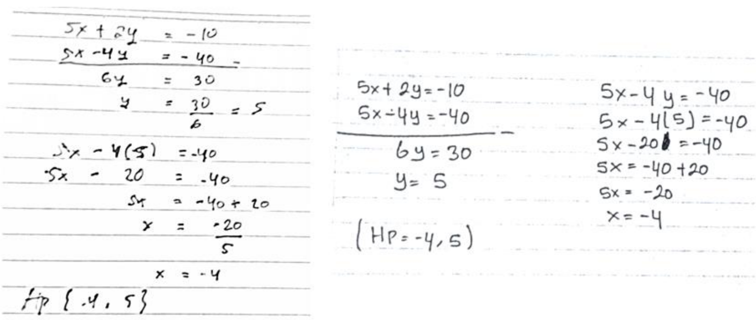

Figure 1. Subject's answer when solving the first SPLDV problem

Results

The K and M strategy in solving the first SPLDV problem can be seen in Figure 1. Figure 1 shows two pictures left and right, the left picture is a problem-solving step of K and the right picture is a problem-solving step of M. In the first SPLDV problem, K and M were able to solve it without making any mistakes. Both of them accurately choose the suitable formula and were able to use it correctly. The solution steps used by the students were in accordance with the instructed solution steps. The solution steps are as follows: step (1) - Using the elimination method to eliminate variable x and obtain the value of y. After obtaining the value of y, proceed to step (2) - Substituting the value of y into one of the equations, as shown in the work of student K and student M, substituting y = 5 into equation and resulting in the value of x = -4. In solving the given problem, K and M did not make any calculation errors and were accurate in writing the constants and variables. The students were able to solve the problem until they obtained the solution of the given system of equations. During the interview, the subjects stated that they enjoyed learning about SPLDV because it is always being taught. The students are capable of solving advanced SPLDV problems if they continue to practice solving similar model problems like the first SPLDV problem.

The K and M strategy in solving the second SPLDV problem can be seen in Figure 2.

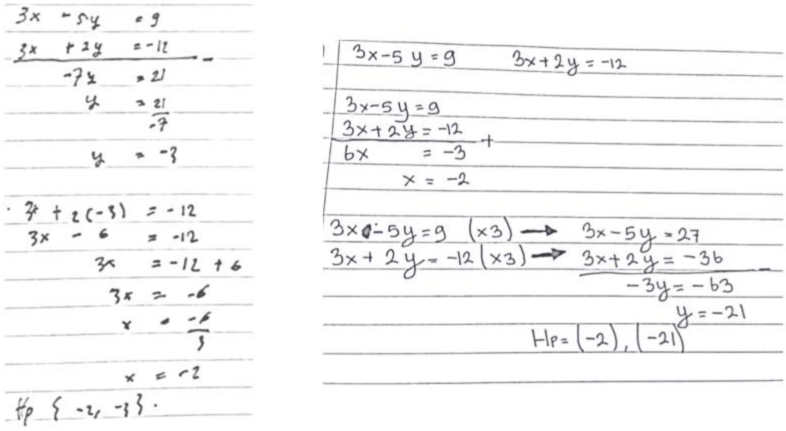

Figure 2. Subject's answer when solving the second SPLDV problem

Figure 2 shows two pictures left and right, the left picture is a problem-solving step of K and the right picture is a problem-solving step of M. Student K, in solving problem number 2, did not make any of the three types of errors mentioned by Kastolan, which are conceptual errors, procedural errors, and technical errors. The solution to problem number 2 was done using the elimination method. The student eliminated the variable x to obtain the value of y. After obtaining the value of y, they proceeded to Step (2), which involved substituting the value of y into one of the equations. Student K choose to substitute y = -3 into the second equation, resulting in the value of x as -2. Student K correctly wrote the constants and variables when answering the problem and performed mathematical operations without errors. They were able to find the solution to the given system of equations and solve the problem. Based on the interview with student K, they mentioned that they didn't make any mistakes because the solution method was similar to the first problem.

Unlike the solution to the first problem, M made many errors in solving the second problem. However, if we observe the solution method, it is the same as solving in the first problem. Based on the analysis of the student's work, there are two types of errors observed: conceptual errors and technical errors. However, the student correctly chose the procedural technique to solve the problem. According to the interview results, the student mentioned feeling confused about how to solve the problem, which led them to copy the previous work. The concept error made by M can be seen in Figure 3. In this figure, the method used by M is the elimination method, by eliminating the variable x to obtain the value of y. After obtaining the value of y, substitute it into one of the given equations to obtain the solution set. However, M has made a conceptual error which can be seen in the blue column shown in Figure 3. The error made by the student in the conceptual error is selecting the correct solution method but not being able to use it correctly. M correctly choose the elimination method but used it to eliminate y without first equating the coefficients of the y variable. The second part of the conceptual error is that the subject made a mistake in creating the multiplication formula, resulting in an incorrect result. The conceptual error continues with the subject attempting to equate the coefficients of the x variable, even though the coefficients of the x variable were already the same. Although the subject's solution steps are accurate and follow the prescribed solution procedure in the problem, the subject was unable to apply it properly.

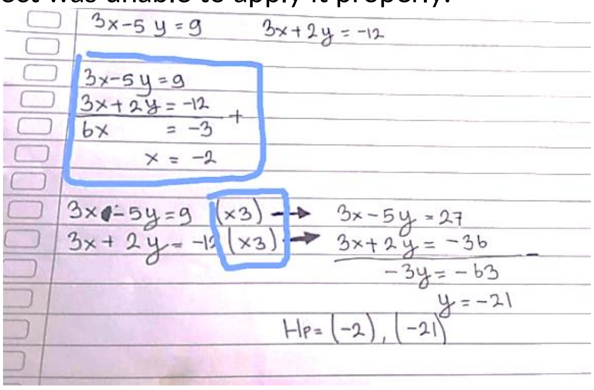

Figure 3. Student M's conceptual error in the second problem

Apart from conceptual errors, M also made technical errors which can be seen in Figure 4.

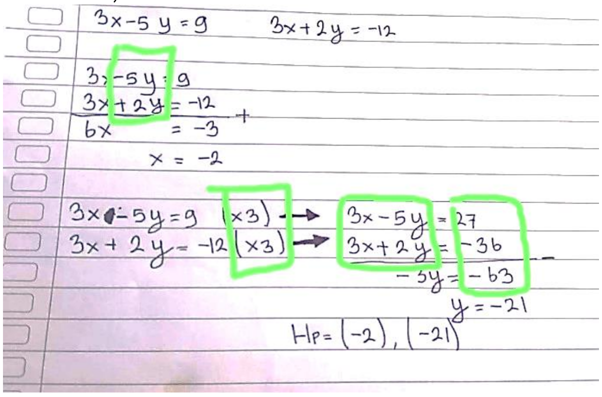

Figure 4. Student M's technical error in the second problem

A technical error made by M involves an error in arithmetic operations, which can be seen in the green column. Basic arithmetic operations, such as addition and subtraction of integers, should be mastered by elementary school students from an early age. However, in practice, children often make mistakes when solving problems. The first technical error made by student M is a mistake in addition (-5y + 2y), where student M fails to record the result correctly, making it appear as if the sum is 0. This error continues with the multiplication operation used to equate the x variable, resulting in errors in arithmetic operations. Another mistake is not paying attention to the mathematical symbols in the subtraction operation, such as 27 - (-36), resulting in an incorrect result of -63. The impact of the errors made by the subject in both conceptual and technical aspects will lead to faulty outcomes in the final result.

Discussion

Based on the analysis, several things need further analysis, namely K who can solve all the problems, and M who makes mistakes only when solving the second problem. It is clear that K can use the right solution and can determine a suitable strategy even though given different problems. That is, K has a strong understanding of the basic concepts and executes the solution steps accurately, indicating proficiency in applying the elimination method (Al-Mutawah et al., 2019; Zhong et al., 2023). What K does is also said to be accurate in selecting and utilizing elimination techniques to translate problems effectively into mathematical representations (Fan & Zhu, 2007; Krawec, 2014). Thus, K can be said to have no errors conceptually, procedurally, or technically. Students with these characteristics have the potential to solve problems accurately and structurally (Mares et al., 2015). In addition, these students have the potential to develop other mathematical abilities, for example, the ability to understand concepts. This is because K can understand basic concepts in problem-solving and can easily represent mathematical models from contextual problems (Smith et al., 2018).

On the other hand, the errors found in M's answer indicated that it was difficult for M to apply the chosen problem-solving approach correctly. A deeper analysis of M's errors is obtained by M making conceptual and technical errors. M's conceptual errors indicate the need for further emphasis on understanding the basic principles in solving systems of linear equations (Brown et al., 2020; Geller et al., 2017). By overcoming these conceptual errors, students can make connections between mathematical concepts and their real-world applications (Karakoç & Alacaci, 2015). This can be achieved through explicit instruction and guided practice that supports deep conceptual understanding (Duschl & Grandy, 2013). The technical mistakes made by M students show the importance of developing computational skills and arithmetic precision. Skills in basic arithmetic operations, such as addition and subtraction of integers, are essential to perform mathematical calculations accurately (Cragg & Gilmore, 2014). Therefore, it is very important to strengthen students' computational skills, perhaps through targeted exercises and remedies (Fuchs et al., 2020).

The difference between K and M in problem-solving shows the importance of metacognitive skills and problem-solving strategies. While student K successfully applied the elimination method, student M had difficulty translating mathematical procedures into correct calculations. Therefore, it is necessary to develop metacognitive in students to enable students to monitor their thinking processes and identify potential errors (Schoenfeld, 2014). Additionally, instructional interventions should focus on providing multiple opportunities for guided practice, explicit instruction, and meaningful feedback (Thurlings et al., 2013). By combining real-world applications and contextual problem-solving assignments, teachers can increase student engagement and motivation, enabling them to relate mathematical concepts to practical situations.

CONCLUSION

Based on the analysis and discussion, the findings in this study are: (1) K shows a strong understanding of the concepts and procedures needed to solve all SPLDV problems; (2) M has conceptual and technical errors when solving the second SPLDV problem. K's application of the elimination method shows a high level of proficiency in solving SPLDV problems. On the other hand, M requires an emphasis on conceptual understanding, computational skills, and metacognitive awareness to be used in solving problems. The results of this study can be used as a guide for teachers to develop learning that can facilitate students to improve their skills in solving problems. Further research is needed to explore the effectiveness of special instructional strategies designed by teachers (based on this research) in improving students' problem-solving skills, especially in SPLDV material.

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