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ANALYSIS OF MATHEMATICAL PROBLEM-SOLVING SKILLS OF INDONESIAN HIGH SCHOOL STUDENTS OF LINEAR PROGRAMME MATERIAL

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Abstract

Mathematical Problem-Solving Ability is an important competency that students must have in the process of learning mathematics. KPMM is a crucial aspect because it can help students in solving various problems faced, both inside and outside the learning context. This study aims to describe students' KPMM, especially in linear programme material, using a descriptive approach. The subjects in this study were 23 students of class XI Accounting of SMK Keuangan Pekanbaru in the academic year 2024/2025. The instrument used was a written test consisting of two items and four indicators of KPMM that refer to the steps of problem solving according to Polya. The results showed that in the indicator of understanding the problem, the average student achievement was 47.10% and was in the insufficient category. In the indicator of planning the solution, the average achievement was 75% in the good category. The indicator of implementing the solution plan obtained an average of 65.94% and was included in the sufficient category. Meanwhile, the indicator of rechecking showed the lowest achievement with an average of 51.09% which was included in the very poor category. Overall, the average KPMM of students is 59.78% which is in the sufficient category. Based on these findings, it is suggested that students should be given more practice with non-routine problems to improve their overall mathematical problem-solving skills.

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INTRODUCTION

Education is an effort that aims to prepare students to face various challenges in the future. Therefore, the education system implemented must be able to equip students to have relevant competencies in facing the demands of the global community. The rapid and dynamic development of the world emphasises the importance of mastering 21st century skills, one of which is problem-solving ability. Based on Permendikbud Number 20 of 2016, this ability is one of the essential competencies that students need to have. Problem-solving skills require logical, critical, and systematic thinking processes, which ideally can be developed through mathematics learning (Dwita Imannia et al., 2022).

Mathematics is a very important discipline in education because it is able to train how to think and solve problems rationally. Therefore, by studying mathematics, it is expected that students' problem-solving skills can improve. The National Council of Teachers of Mathematics (NCTM, 2000) states that problem solving is the core of learning mathematics. This process involves complex thinking patterns that are not only useful in solving mathematical problems, but also in everyday life. This is in line with Russeifendi's opinion in Zakiyah et al. (2018) which emphasises that problem solving skills are not only important in mathematics, but also in other disciplines and their implementation in real life.

KPMM is a basic skill in learning mathematics (Badrulaini et al., 2020). This ability is needed so that students can solve various problems effectively. Branca in Akbar et al. (2018) asserted that KPMM is the core of the curriculum and the main goal of learning mathematics. KPMM is a cognitive activity that involves strategic thinking processes in solving problems (Harahap et al., 2017). According to Riza et al. (2020), students are said to have problem solving skills if they are able to understand the problem, plan and implement solutions, and double-check the solutions found. Siregar and Syafari (2017) stated that KPMM is the ability of students to find answers to mathematical problems in the form of stories or texts, by following the steps of problem solving.

According to Nuraini et al. (2019), there are four indicators of KPMM, namely: (1) understanding the problem, (2) planning the solution, (3) implementing the plan, and (4) rechecking the solution. Problem understanding is shown by the ability to mention known and questionable information. The planning stage includes the making of memorisation, mathematical modelling, and determining the steps of the solution. The implementation stage is done by describing the plan that has been made. Meanwhile, rechecking is done by making a conclusion from the solution obtained. These four steps are interrelated with each other; without understanding the problem, the solution plan cannot be made, and without proper planning, the solution cannot be obtained properly (Damayanti and Kartini, 2022).

Problem solving skills are often part of the basic competencies and competency standards. However, conditions in the field show that many students have not mastered this ability well. PISA results in 2022 showed that Indonesia ranked 70th out of 80 countries with an average score of 366 in mathematics, far below the OECD average of 472 (OECD, 2023). This shows that Indonesian students' mathematics skills are still low and have not reached the RPJMN 2024 target. Therefore, it is necessary to improve the national education system to match international standards. Previous research shows that students' KPMM is low (Osman et al.,

2018; Hadi et al., 2018; Suparman et al., 2021). Observations and interviews conducted by Ratna and Yahya (2022) to grade XI mathematics teachers at Tinambung State Senior High School showed that 60% of students had not completed the KKM, which reflected the low KPMM. Research by Andayani and Lathifah (2019) also found that many students have difficulty in understanding problems, so contextual problems are needed to train their abilities.

Fatmala et al. (2020) stated that the KPMM of seventh grade students at one of the junior high schools in Purwakarta Regency was low. Many student errors occur in the aspects of understanding the problem, performing calculations, and double-checking. Yustianingsih et al. (2017) added that the low KPMM was due to students not being used to working on non-routine problems. The problems given by the teacher are generally similar to the examples they have learnt, so students have difficulty if the problems are different from what they are used to.

Another factor that causes weak KPMM is the learning process that does not support the development of these skills. Teachers still use traditional methods and do not relate the material to real life (Amam, 2017). One of the materials that are closely related to story problems is linear programmes. Research by Nuryana and Rosyana (2019) showed that only 19.23% of students were able to solve linear programme problems well. Many students do not understand how to build mathematical models in the form of inequality systems. This is reinforced by Suci's findings in Andriyani and Ratu (2018), which show that many students make mistakes in determining the optimum value, especially in making mathematical models and determining corner points.

Based on the low KPMM found in various studies, it is necessary to analyse this ability, especially in solving linear programme problems. This study aims to describe students' KPMM in doing linear programme problems, so that teachers and students can understand the mistakes that often occur and find solutions to overcome them.

METHODS

This research uses descriptive method with the aim to describe students' Mathematical Problem Solving Ability (KPMM) on linear programme material. The subjects in this study were 23 students of class XI Accounting of SMK Keuangan Pekanbaru in the odd semester of the 2024/2025 academic year. The object of this research is students' KPMM on linear program material, especially on the aspect of the optimum value of objective functions based on KPMM indicators.

Data collection techniques in this study used two instruments, namely tests in the form of story problems and interviews. The test instrument used consisted of two story items designed to measure students' KPMM. The data obtained were analysed using the data analysis model according to Miles and Huberman in Fitri et al. (2021), which includes three stages: (1) data reduction, namely by collecting and filtering important information from the results of student assignments and interviews; (2) data display, namely presenting relevant data for further analysis; and (3) conclusion drawing and verification, namely interpreting the data that has been collected and then formulated into a final conclusion.

The KPMM data was obtained from the results of the test with the scoring guidelines based on the KPMM indicators according to Polya in Table 1_in (Fitri and Kartini, 2022) .

Table 1.

CAR Scoring Guidelines

Indicators	Description	Score
Understanding the Problem	Does not identify what is being asked.	0
	Identifies only what is known or only what is asked, but not both.	1
	Identifies both what is known and what is asked, but they are not appropriately matched.	2
	Clearly identifies and appropriately matches what is known and what is asked.	3
Planning the Solution	Does not develop a plan to solve the problem.	0
	Develops a plan by analysing the mathematical model or formula, but does not match it to the problem.	1
	Develops a plan using appropriate mathematical methods to translate the problem into a solution.	2
Implementing the Plan	Does not attempt to solve the problem.	0
	Provides a partial or incorrect solution.	1
	Explains the solution process but lacks clarity or completeness.	2
	Clearly and concisely explains the solution process and the final answer.	3
Rechecking the Solution	Does not provide a conclusion.	0
	Writes a conclusion that is unrelated or unclear.	1
	Provides a clear and accurate conclusion based on the solution obtained.	2

Figure 1

KPMM Test Instrument

1. Bread A requires 150g of flour and 50g of butter, while bread B requires 75g of flour and 75g of butter. The profit from the sale of bread A and bread B is Rp400 and Rp500 respectively. Determine each type of bread that must be made for maximum profit and determine the maximum profit.
2. To treat patients, a hospital needs at least 225,000 units of calories and 195,000 units of protein every day. Each 1kg of beef contains 750 units of calories and 300 units of protein, while each 1kg of fresh fish contains 450 units of calories and 600 units of protein. The price per kg of beef and fresh fish is Rp90,000 and Rp60,000 respectively. Determine the amount of beef and fresh fish in kg that the hospital must provide so that the costs incurred are as small as possible.

Note. Figure above shows the KPMM instrument that was tested on students.

The data were analyzed by reviewing students' test results, followed by analyzing their Mathematical Problem-Solving Ability (KPMM). Students' KPMM scores were calculated using the following formula:

$$\text{Value} = \frac{student's\ score}{ideal\ score} \text{ x } 100\%$$

The scores obtained were then classified according to Table 2 (Fitri et al., 2023) below.

Table 2.

Student KPMM Criteria

Value (%)	Criteria
$85.00 - 100$	Very good
$70.00 - 84.99$	Good
$55.00 - 69.99$	Fair
$40.00 - 54.99$	Poor
$0 - 39{,}99.$	Very Poor

FINDINGS AND DISCUSSION

This study aims to describe the Mathematical Problem-Solving Ability (KPMM) of students on linear program material, especially related to the optimum value of the objective function. The KPMM indicators analysed in this study include: (1) understanding the problem, which is shown by the ability to write down known and questionable information; (2) planning the solution; (3) implementing the solution plan; and (4) rechecking the solution obtained. Table 3 below presents the percentage of students' KPMM scores based on each aspect of KPMM.

Table 3.

Percentage of Students' KPMM Score by Aspect

No.	Aspect of KPMM	Percentage	Category
1	Understanding the Problem	47.10%	Poor
2	Planning the Solution	75.00%	Good
3	Implementing the Plan	65.94%	Fair
4	Rechecking the Solution	51.09%	Poor

The average score of the Mathematical Problem-Solving Ability (KPMM) of students in Class XI Accounting at SMK Keuangan Pekanbaru was 59.78%, which falls into the fair category. The KPMM of the accounting students was further analyzed and is described in detail as follows:

Aspect 1: Understanding the Problem

The aspect of understanding the problem was assessed by evaluating students' ability to write down the known information and what is being asked in the problem. In Table 3, the aspect of understanding the problem falls under the **poor** category with a score of 47.10%, indicating that students still have difficulty understanding the problem. Many students made mistakes in interpreting the questions, as illustrated in Figures 2 and 3 below:

Figure 2.

First mistake in understanding the problem

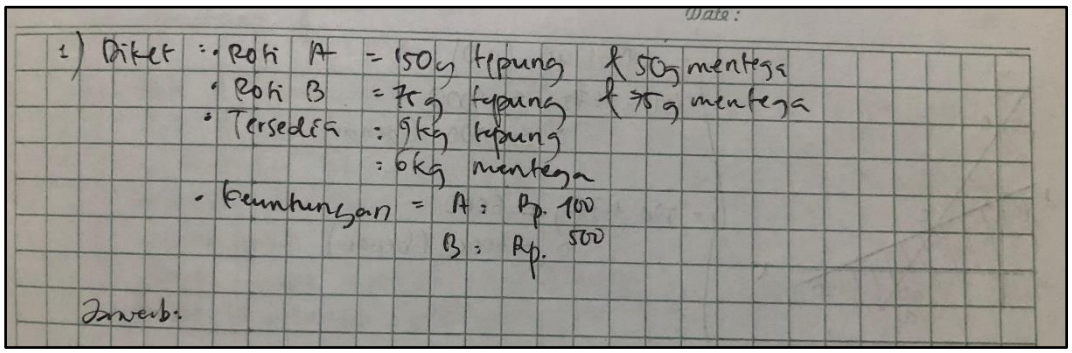
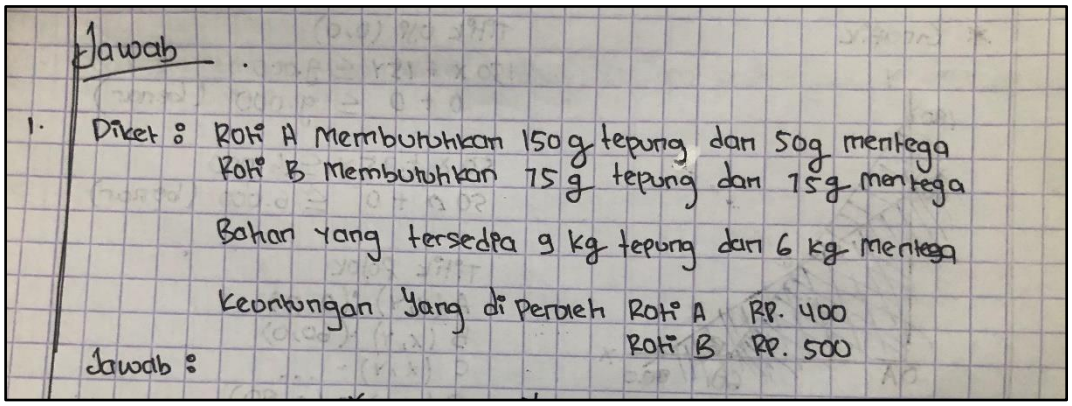


Figure 3.
Second mistake in understanding the problem



In Figures 1 and 2, students only stated the information they knew from the question but did not identify what was being asked. Their focus was solely on the known elements of the problem. In fact, some students did not write down either the known or the asked components at all and proceeded directly to the solution. This indicates that the students lacked analytical skills and were not careful in reading the questions.

Similar findings were reported by Arista et al. (2022) and Syahril et al. (2021), who found that some students skipped identifying the known and asked components and went straight to solving the problem. Hidayah (2016), as well as Andayani and Lathifah (2019), also reported that students made errors in the "understanding the problem" indicator due to a lack of attentiveness and thoroughness when reading the question. The students appeared to rush

through the task, which resulted in their failure to properly analyze the information presented in the problem.

Aspect 2: Planning the Solution

The percentage score for the second indicator is 75%, which falls into the **good** category. This percentage indicates that students were generally able to select appropriate problem-solving strategies by correctly constructing mathematical models. However, errors at this stage were still found, as illustrated in Figures 4 and 5 below:

Figure 4.

First mistake in planning problem solving

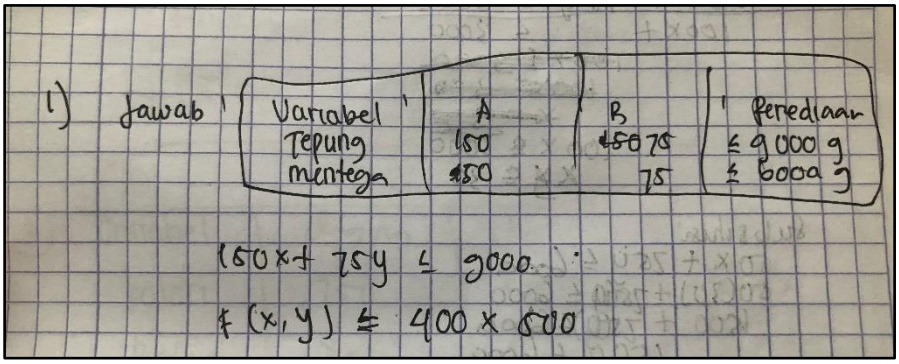
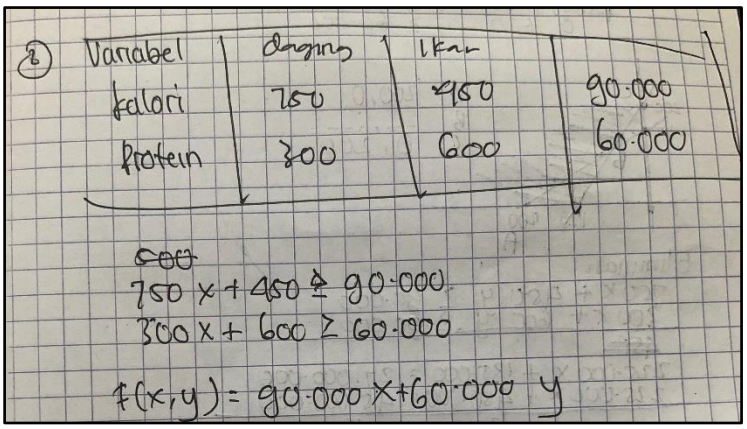


Figure 5.

Second mistake in planning problem solving



Figures 4 and 5 show that students had attempted to create a table as an initial step in problem planning and as a tool to assist in constructing a mathematical model. However, the tables created were inaccurate and incomplete. Students made errors in inputting the numerical values that should have appeared in the table. As a result, these errors led to incorrect formulation of the mathematical model.

To correctly construct the table, students should have first defined and visualized the variables involved. For example, in Figure 4, x should represent Bread A and y should represent Bread B. Similarly, in Figure 5, x could represent the kilograms of beef, while y could represent the kilograms of fresh fish. However, students failed to identify or write down the variables based on the context of the problem.

In Figures 4 and 5, students were expected to model the constraint functions using the variables that had been previously defined. Although the student in Figure 5 attempted to write a mathematical inequality as a constraint function, the use of incorrect variables resulted in an inaccurate model. These errors at the planning stage had a cascading effect, leading to further mistakes in subsequent steps.

Similar findings were reported by Hidayah (2016) and Syahril et al. (2021), who observed that students made errors in planning problem solutions, particularly because many of them failed to formulate appropriate mathematical models. This difficulty was attributed to students' unfamiliarity with defining and using variables effectively. Utami and Wutsqa (2017) further explained that students' errors in constructing mathematical models were often due to challenges in linking relevant mathematical concepts with the analysis of facts presented in the problem.

Aspect 3: Implementing the Plan

In the third aspect, implementing the plan, students' performance was classified as **fair**. This indicates that their ability to carry out the planned solution was moderate. Examples of students' errors in this aspect are illustrated in **Figures 6 and 7** below:

Figure 6.

First mistake in solving the problem

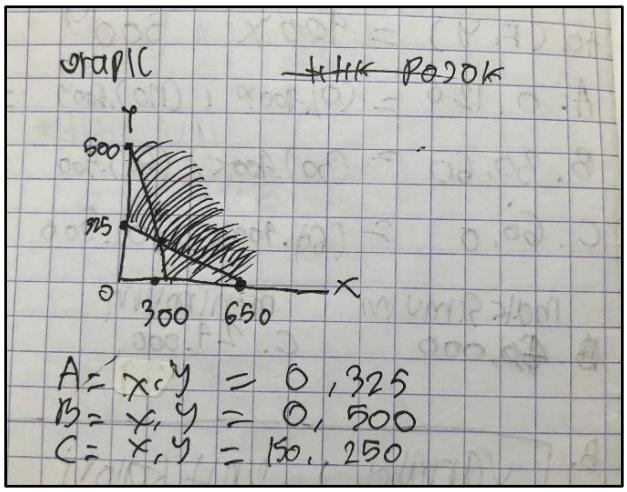
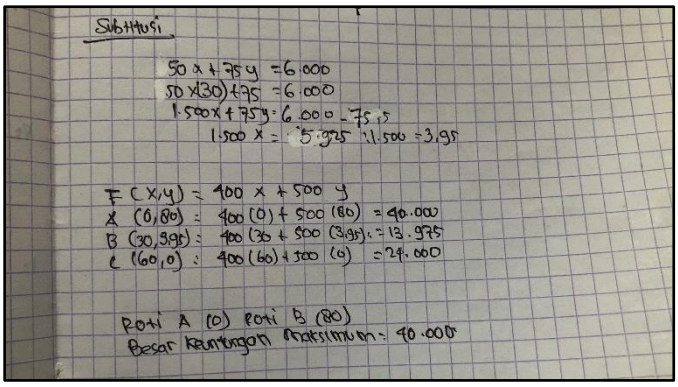


Figure 7.

Second mistake in solving the problem



In Figure 6, the student correctly identified the feasible region but made an error in determining the values of the corner points. Specifically, the student confused the x-coordinate with the y-coordinate, resulting in incorrect coordinate labeling.

In Figure 7, the student miscalculated the value of the y-variable. The student was expected to state the x-variable value as the result of a substitution from the previous step, and then proceed by multiplying the coefficients with the known y-variable value. However, the student mistakenly recalculated the x-variable that had already been determined, leading to further errors in estimating the value of the y-variable. Consequently, because the x and y values were both incorrect, the next step—substituting the corner point values into the objective function—was also incorrect.

These errors occurred due to students' lack of understanding of the relevant mathematical concepts needed to solve the problem, as well as their unfamiliarity with basic arithmetic operations. This is consistent with the findings of Andriyani and Ratu (2018), who reported that students made errors in calculating corner points, which ultimately led to incorrect final solutions. Similar errors were also found in the form of incorrect graphing, which further impacted the determination of corner points and final values.

Furthermore, research by Andayani and Lathifah (2019) revealed that students often made calculation errors due to a lack of fluency in multiplication and division operations. At this stage, procedural accuracy and mathematical fluency are essential to avoid errors in problem-solving (Novitasari & Wilujeng, 2018).

Aspect 4: Rechecking the Solution

This aspect involves reviewing the results obtained and drawing appropriate conclusions. The percentage score achieved in this aspect was **51.09%**, which falls into the **poor** category. This indicates that many students struggled to evaluate their solutions and formulate proper conclusions. Examples of students' errors in this aspect are illustrated in **Figure 8** below:

Figure 8.

Errors in Rechecking Answers

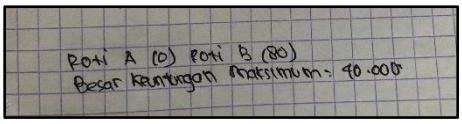


Figure 8 illustrates that students made errors in drawing conclusions. These mistakes occurred because students had previously made calculation errors, which led to incorrect determination of the maximum value requested in the question. Another frequent issue was that some students did not write a conclusion at all, even after completing the problem-solving process.

Similar findings were reported by Syahril et al. (2021), who observed that some students failed to formulate accurate conclusions based on the problems they had solved. Although students completed the problem-solving steps and arrived at a solution, the final answer was often incorrect (Azzahra & Pujiastuti, 2020).

Research by Erfani et al. (2020) also revealed that one contributing factor to students' failure in making appropriate conclusions was their lack of habit in reviewing or evaluating the results they had obtained. This is consistent with the findings of Fatmala et al. (2020), who stated that students often lacked analytical thinking and tended to rush through tasks. As a result, their answers were not reviewed or verified, and although some students had solved the problems correctly, they did not write conclusions because they were in a hurry or overwhelmed by the task.

CONCLUSION

The Mathematical Problem-Solving Ability (KPMM) of students in class XI Accounting of SMK Keuangan Pekanbaru is included in the sufficient category, with an average value of 59.78%. The average achievement on each KPMM indicator is as follows: understanding the problem by 47.10%, planning a solution by 75%, carrying out planning by 65.94%, and checking back by 51.09%. Common mistakes made by students include only writing known information without mentioning what is asked in the problem. Although students had tried to plan the solution, the planning was not fully precise and complete, especially in preparing the mathematical model. In addition, in the planning implementation stage, students showed inaccuracy in performing calculations, which was caused by a lack of accuracy and fluency in performing mathematical operations. At the rechecking stage, most students did not write conclusions. Only a small number of students were able to conclude the results correctly, even after not making mistakes in the previous stages. Based on these results, it is recommended that students be accustomed to working on non-routine problems in order to train their mathematical problem-solving skills. Continuous practice on contextual and varied problems is expected to help students avoid the same mistakes in the future.

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