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Variation of Vocational Students' Difficulties in Solving System Linear Inequality Problem Based on Polya's Theory

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Abstract:
Contextual problem-solving ability is a crucial skill that students, particularly those in vocational schools, must possess, as they will immediately enter the workforce. To optimize students' abilities, research was conducted on the variation of students' difficulties in solving problems. This study aims to identify variations in vocational high school students' difficulties in solving contextual problems of the system of linear inequalities in two variables based on Polya's theory and to offer alternative solutions that can be used to overcome these difficulties. The type of research used is qualitative with a descriptive approach. The study subjects were 3 students of 36 students of the grade XI vocational high school, who had received the material. These students were selected based on the category of abilities they had, namely high, medium, and low, as well as considerations of communication of teacher recommendation results. Data collection was carried out through tests and interviews. Based on the results of the study, it was found that 1) Low Ability Students (LAS) experienced many variation in difficulties at all stages in solving problems according to Polya's theory, 2) Medium Ability Students (MAS) at the stage of understanding the problem experienced fewer variations in difficulties compared to the other three stages, 3) High Ability Students (HAS) at the stage of understanding the problem and making plans experienced fewer variation in difficulties compared to the other two stages. Apart from being based on Polya's theory, students also experience other variations of difficulty, namely the difficulty in defining variables, constants, and coefficients correctly.

Abstrak:
Kemampuan penyelesaian masalah kontekstual adalah kemampuan penting yang harus dimiliki oleh siswa khususnya siswa sekolah kejuruan karena mereka akan langsung terjun ke dunia kerja. Untuk mengoptimalkan kemampuan siswa maka dilakukan penelitian terkait variasi kesulitan siswa dalam menyelesaikan masalah kontekstual. Penelitian ini bertujuan untuk mengidentifikasi variasi kesulitan siswa SMK dalam menyelesaikan masalah kontekstual sistem pertidaksamaan linear dua variabel berdasarkan teori Polya dan menawarkan solusi alternatif yang bisa digunakan untuk mengatasi kesulitan tersebut. Jenis penelitian yang digunakan adalah kualitatif dengan pendekatan deskriptif. Subjek penelitian sebanyak tiga siswa dari 36 siswa kelas XI SMK yang telah mendapatkan materi tersebut. Siswa ini dipilih berdasarkan kategori kemampuan yang dimiliki yaitu tinggi, sedang, dan rendah serta

pertimbangan komunikasi hasil rekomendasi guru. Pengumpulan data dilakukan melalui tes dan wawancara. Berdasarkan hasil penelitian didapatkan bahwa: 1) Siswa Kemampuan Rendah (LAS) mengalami banyak variasi kesulitan pada seluruh tahapan dalam penyelesaian masalah menurut teori Polya; 2) Siswa Kemampuan Sedang (MAS) pada tahapan memahami masalah mengalami variasi kesulitan lebih sedikit dibandingkan dengan tiga tahap lainnya; 3) Siswa Kemampuan Tinggi (HAS) pada tahapan memahami masalah dan membuat rencana mengalami variasi kesulitan lebih sedikit dibandingkan dua tahapan lainnya. Selain berdasarkan teori Polya, variasi kesulitan lainnya yaitu kesulitan untuk mendefinisikan variabel, konstanta, dan koefisien secara tepat juga dialami oleh siswa.

Keywords:
Difficulty, Problem-Solving, Contextual Problems, System of Linear Inequalities in Two variables

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INTRODUCTION

Contextual mathematics problems have become a frequently researched topic in mathematics in the last five years. This is indicated by the presence of 20,900 studies related to contextual mathematics problems in Google Scholar. Research related to contextual problems is interesting to study because one of the goals of learning mathematics is to be able to apply it to solve everyday problems. According to Rosyada and Wibowo (2023), everyday problem-solving skills are one of the mathematics learning goals. Contextual problems in mathematics are an important means for students to develop everyday problem-solving competencies because, with this, students will be trained to formulate and solve their problems based on the information presented. The existence of contextual problem-solving skills will enable students to think analytically, which will make it easier for students to make daily decisions according to conditions.

Contextual problem solving certainly requires understanding the existing situation so that it is not only focused on the results. This is supported by Daulay and Ruhaimah (2019), which states that in problem solving, students must understand the situation and the means that can be used to solve the problem. When someone solves a problem of course, they must carry out several stages and choose the right strategy as explained by Polya in Conway (2004) that four stages must be passed to use the appropriate strategy to solve the problem, namely understanding the problem, making a solution plan, implementing the solution plan and rechecking the answer. This shows that the steps of the solution are important because if the steps are carried out correctly, it makes it easier to choose the right strategy in many fields. This shows that the steps of the solution are important because if the steps are done correctly, it makes it easier to choose the right strategy in many areas. According to Rojas, Nussbaum, Chiuminatto, Guerrero, Greiff, Krieger, and Westhuizen (2021), problem-solving skills are important in many fields. Therefore, for someone to be able to solve everyday problems, they must have good contextual problem-solving skills.

One of the mathematical fields that plays a role in solving everyday problems is algebra. The system of linear inequalities in two variables is one of the algebraic materials that has benefits for solving problems in other fields. This is explained by Bowers, Anderson, and Beckhard (2024) that one of the main objectives of mathematics lessons is to provide opportunities for students to be able to relate the activities and contexts of mathematics learned to other fields. Given the role of solving contextual mathematical problems in other fields, a person must continue to hone their abilities to maximize their abilities. This means that students' ability to solve contextual problems is one indicator of the success of learning mathematics. This is in line with the explanation of Septian, Widodo, Afifah, Nisa, Putri, Tyas, Nisa, and Andriani (2022) that problem-solving skills are one of the important things because they are one of the indicators of success in learning mathematics. According to Daulay and Ruhaimah (2019), contextual problems in mathematics can also be used as a basis for connecting formal and informal mathematical knowledge, so that it can help students understand formal mathematics better. It is hoped that after studying mathematics, students can also use the knowledge they gain to solve everyday problems.

However, the reality is that several studies show that students still have difficulties when faced with contextual problems. First, Sopudin and Aminah (2024) explained that students with high, medium, and low abilities tend to have different differences in problem-solving ability scores, which indicates varying problem-solving abilities. The first study focused on student scores to see variations in problem-solving abilities.

Second, Nurhayati and Ratnaningsih (2023) explained that based on Kastolan's theory, students still experience misconceptions in the system of linear inequalities in two variables, namely applying formulas, creating mathematical models, and carrying out solution procedures. The second study focused on conceptual errors in terms of Kastolan's theory.

Third, Anggraini, Yohanie, and Nurfahrudianto (2024) also explained that students included in the relational understanding category, namely high and medium ability students, could explain their answers, while low ability students were included in the instrumental understanding category, where they could not explain their answers. Based on SKEMP theory, the third study focused on student difficulties according to their understanding category.

Fourth, Buyung, Angkotasan, and Jalal (2023) explained that Students with visual, auditory, and kinesthetic learning styles often experience challenges in several key aspects of solving mathematical problems, particularly in constructing mathematical models, determining the Solution Set Region (SDP), and verifying the correctness of their answers. These difficulties suggest that differences in learning styles may influence how students process and apply mathematical concepts. The fourth study specifically explored these challenges by examining the nature and extent of students' difficulties in relation to their individual learning styles, aiming to identify patterns that could inform more personalized and effective instructional strategies in mathematics education.

Fifth, Kumalasari, Winarni, Rohati, Marlina, and Aulia (2022) added that students with introverted and extroverted personality types have different thinking processes when solving problems. Where introverts need a lot of time to read, while extroverts are faster, but at the problem-solving stage, introverts carry out all stages correctly and completely, while extroverts do not write down all the processes completely. The fifth study focuses on the personality type used to see students' thinking processes in solving Myers-Briggs indicator-type problems.

Furthermore, to see students' ability to solve contextual problems related to the system of linear inequality in two variables from a different perspective. Therefore, the researcher will conduct research related to the pattern of students' difficulties with low, medium, and high ability categories in solving contextual problems of the system of linear inequalities in two variables based on Polya's theory. Polya's theory consists of four stages: understanding the problem, making the plan, implementing the plan, and re-checking. The stages were then formulated into six indicators as presented in table 1. The selection of vocational school students is because there has not been much research conducted on vocational high school students related to the difficulty in solving mathematical problems. Vocational high school students need to have good problem-solving skills because they are directed directly to the world of work. Polya's theory is very effective for vocational students because it provides a systematic structure, enhances understanding of the problem, allows for measurable planning, effective implementation, and comprehensive review. This model also helps address gaps that may exist in vocational learning and offers greater flexibility and adaptability than other models. The purpose of this study is to identify the variations of difficulties vocational high school students face in solving contextual problems of the system linear of inequality in two variables based on Polya's theory and to find alternative solutions that can be used to overcome these difficulties.

METHODS

The method used in this study is qualitative with a descriptive approach. The descriptive approach was chosen because this approach can make it easier for researchers to describe the variation of vocational students' difficulties in more detail and depth in solving contextual problems of the system of linear inequalities in two variables based on Polya's theory. The study subjects were 3 of the 36 students of grade XI vocational students who had received the material. These students were selected based on the category of their abilities, namely high, medium, and low, as well as considerations of communication of the teacher's recommendation results.

Data collection was carried out through tests related to contextual problems of the system of linear inequalities in two variables and semi-structured interviews. Tests were conducted to explore students' understanding of the contextual problems, and semi-structured interviews were conducted to explore the difficulties they found. Data were analyzed by categorizing students with high, medium, and low abilities.

Analysis was conducted using triangulation techniques to be more comprehensive. The test results from the subjects were explored using interviews based on the indicator formulation guidelines of Polya's theory as presented in table 1.

Table 1. Polya's Theory Indicators

Number	Steps	Indicators
1.	Understanding the Problem	Able to identify known information accurately.
		Able to explain the meaning of the question correctly.
2.	Making a Plan	Able to choose the right solution strategy
3.	Implementing a Plan	Able to carry out steps based on the chosen strategy systematically.
4.	Re-Checking	Able to check the accuracy of the results.
		Able to make conclusions about solutions correctly

RESULTS AND DISCUSSION

The results of the research on the variation of vocational students' difficulties based on Polya's theory are presented in table 2.

Table 2. Variation of Vocational Students' Difficulties

Number	Steps	Variation of Vocational Students' Difficulties
1.	Understanding the Problem	LAS only understands the information presented in the question, but does not understand the meaning of the question properly.
		MAS had a little difficulty at this stage. MAS was able to understand the meaning of the contextual problem presented and was able to understand the information presented correctly.
		HAS had a little difficulty in the stage. HAS can understand the meaning of the contextual problem presented, namely the problem presented involving two variables (pencil and eraser) and two limitations (money and stock), and know the information presented by HAS
2.	Making the Plan	LAS just guessed
		MAS has not been able to make a systematic problem-solving plan according to the procedure due to a lack of understanding of the concept of the system

Number	Steps	Variation of Vocational Students' Difficulties
		of linear inequalities in two variables and its application.
		HAS had a little difficulty in the stage. HAS created two inequalities. This shows that HAS have tried to model the problem in mathematical form. However, HAS did not clearly explain the purpose of selecting variables x and y
3.	Implementing the Plan	LAS just guessed
		MAS had difficulty applying the appropriate solution procedure, including modeling the problem in mathematical form.
		HAS had difficulty choosing an effective strategy and its application in finding a solution due to a lack of understanding of the concept of the system of linear inequalities in two variables and its application, so HAS only made substitutions using two pairs (x,y).
4.	Re-checking	LAS's work was unsystematic and wrong because the procedural steps were not carried out optimally.
		MAS also had difficulty in the re-checking stage because the answers were not checked thoroughly due to the less-than-optimal previous stages.
		HAS was less careful because he wrote an equation instead of an inequality on his answer sheet, even though, after being confirmed through an interview, what was meant was an inequality.

The results of the research on Low Ability Students (LAS), Medium Ability Students (MAS), and High Ability Students (HAS) based on Polya's theory are presented in figures 1 to 3.

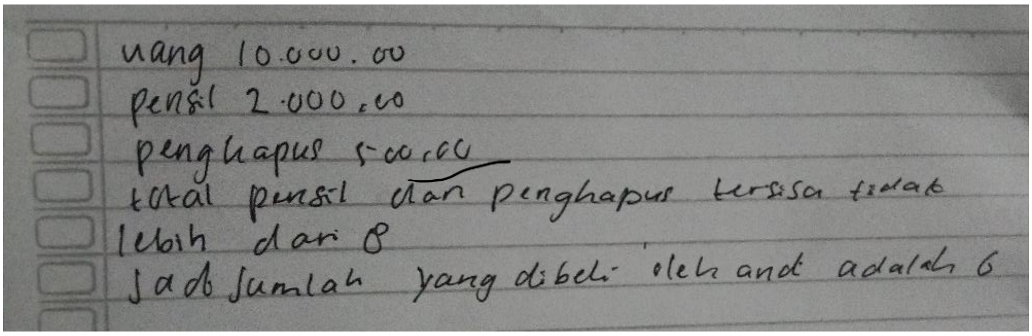

Figure 1. LAS' Answer

Interview with LAS about The Stage of Understanding the Problem.

R : Do you understand from the question?
LAS : asked to find many pencils and erasers
R : What information is given in the question?
LAS : I understand that Andi has 10,000, the price of the pencil is 2,000, and the price of the eraser is 500, but in the canteen, the number of pencils and erasers is no more than 8.

Based on figure 1 and the results of the interview with LAS, it shows that LAS experienced many variations of difficulties at all stages in solving problems according to Polya's theory. In the stage of understanding the problem, LAS has not been able to understand the problem optimally because LAS only understands the information presented in the question, namely the money that Andi brought was only 10,000 and the remaining stock of pencils and erasers was 8, but did not understand the meaning of the question properly. Understanding the problem is one of the most important stages in solving a problem. Due to the lack of understanding of the problem, LAS cannot find the right solution. This is explained to Bowers, Anderson, and Beckhard (2024)) that after students try to understand the meaning of the contextual problem, they will know how to find a solution to the problem by applying a concept that is connected to the context of the problem.

Interview with LAS about The Stage of Making the Plan.

R : Where did you get the answer 8 from?
LAS : I just guessed because you can't buy more than 8
R : Any planning to finish?
LAS : No, because I don't know about the procedure.

Interview with LAS about The Stage of Implementing the Plan

R : Do you know the maximum number of pencils and erasers that can be purchased?

LAS : No, because I know that the number of pencils and erasers in the canteen is no more than 8, so of course, 8 can be purchased.

R : Do you implement a procedure?

LAS : No, I just guessed.

The stages of making plans and implementing the plans are not visible from LAS's answers because LAS immediately provides conclusions without using procedural steps. The steps taken by LAS contradict the explanation of Stewart and Ball (2023), namely that in solving problems, students must be able to choose, interpret, formulate, model, and understand a problem so that they can apply appropriate procedures in problem situations. The cause of the emergence of confusion LAS is confused about contextual problems related to the system of linear inequalities in two variables due to a lack of understanding of the mathematical concepts contained in the problems presented, so LAS has difficulty determining and applying the appropriate solution procedures. In fact, according to Santos-Trigo (2024), the foundation for solving mathematical problems is knowing the terms, concepts, language used, and approaches used in solving problems.

Interview with LAS about The Stage of Re-Checking

R : Did you re-check your answers?

LAS : No, because I don't know how to solve that problem.

The re-checking stage was also not carried out by LAS, resulting in LAS's work being unsystematic and wrong because the procedural steps were not carried out optimally. The difficulty in the re-checking stage was that previously, LAS had not carried out the stages of making plans and carrying out plans to solve contextual problems. LAS had difficulty re-checking because they did not understand the concept of the system of linear inequalities in two variables, resulting in difficulty in carrying out these stages. The variation in difficulties experienced by LAS is in line with (Astuti, Sari, & Wirawan, 2023) who explained that when given contextual problems, students were still not right in compiling and implementing problem-solving plans using Polya's stages.

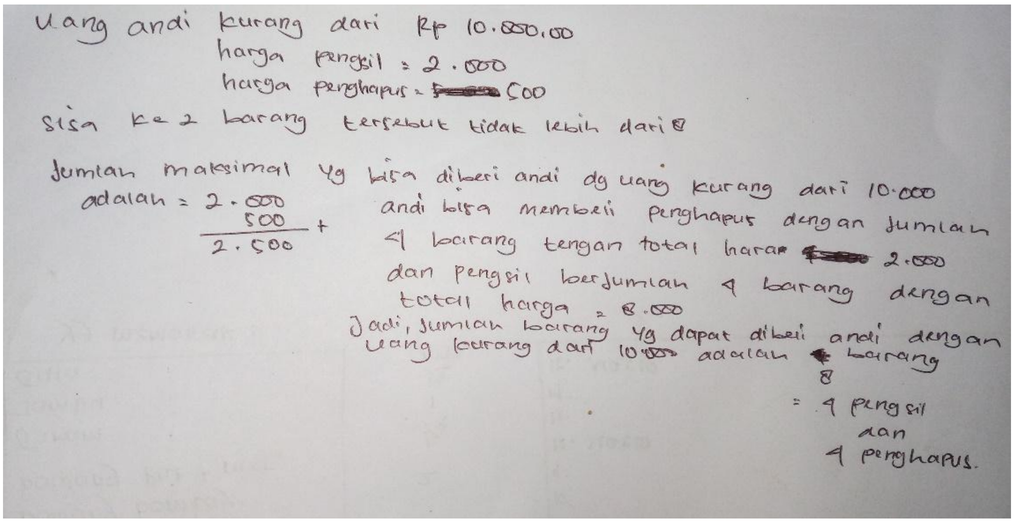

Figure 2. MAS' Answer

Interview with MAS about The Stage of Understanding the Problem.

R : *Do you understand the question?*

MAS : *Asked to determine the maximum amount that can be purchased using 10,000 with a maximum stock of pencils and erasers of 8, with a pencil price is 2,000 and an eraser price is 500*

Figure 2 and the interview results with MAS show that MAS experienced a variety of difficulties in the problem-solving stages, according to Polya's theory. The greatest variation in difficulties occurred in three stages: making a plan, implementing the plan, and re-checking. At the stage of understanding the problem, MAS was able to understand the meaning of the contextual problem presented and was able to understand the information presented correctly, so at this stage, MAS experienced little difficulty.

Interview with MAS about The Stage of Making the Plan

R : *How do you solve the problem?*

MAS : *Determine the variables, determine the equation, determine the solution, and count the number of pencils and erasers.*

Stages of making plans. In the second stage, MAS experienced more difficulties than in the first stage because even though MAS tried to calculate the total purchase price, the problem boundaries were not fully considered, so only estimates were made to determine the appropriate number of pencils and erasers without using procedural methods. This is in line with Ani and Rosyidi (2022), who explained that students' planning abilities are still lacking at the planning stage, especially when modeling or interpreting information into symbols. The cause of this is a lack of understanding of the concept of the system of linear inequalities in two variables and its application.

Interview with MAS about The Stage of Implementing the Plan

R : Which is included in the variable, coefficient, and constant?

MAS : The variables are the number of pencils and erasers, the coefficients are the price of pencils and erasers, and the constants are 10,000 and 8.

R : Is it true that only 4 pencils and 4 erasers can be purchased?

MAS : Yes, it is.

The stages of implementing the plan carried out by MAS were less than optimal because the plan was less systematic, so MAS was only able to find one possibility that could be purchased within the limitations. This is because the previous stage, namely making a plan, was not carried out according to the procedure; as a result, MAS experienced many difficulties when applying the appropriate solution procedure, including modeling the problem into mathematical form.

Interview with MAS about The Stage of Re-Checking

R : Did you re-check your answers?

MAS : No, because only 4 pencils and 4 erasers can solve the problem.

MAS also experienced many difficulties at the re-checking stage because this difficulty was seen when MAS did not carry out the re-checking stage systematically to ensure the correctness of the answer; the less-than-optimal previous stages also caused this. This is in line with Stewart and Ball (2023), namely that in solving problems, students must be able to choose, interpret, formulate, model, and understand a problem so that they can apply the appropriate procedure in the problem situation.

The emergence of more variations in difficulty at stages two to four indicates that MAS understands the contextual problems presented but is unable to solve the problems correctly. This is in line with Erni (2021), who explained that students do not understand the steps to be taken even though they understand the questions. Students' inability to solve these contextual problems is due to their lack of understanding of the context of the problem. This happens because MAS does not understand the concept of the system of linear inequalities in two variables and its application in contextual problems, and has difficulty creating mathematical models because they are not used to translating contextual problems into mathematical forms. The strategies used are still less systematic, and the answers are not checked thoroughly.

When students study mathematics, they tend to memorize without understanding the concept's meaning. To understand the context of a problem, students must understand the concepts that can be used to solve the problem, such as the solution procedure and what information must be known to solve it. This is in line with (Kumalasari, Winarni, Rohati, Marlina, & Aulia, 2022), who explained that students' tendency to solve problems theoretically causes them to experience difficulties because they do not know the formula to solve the problem.

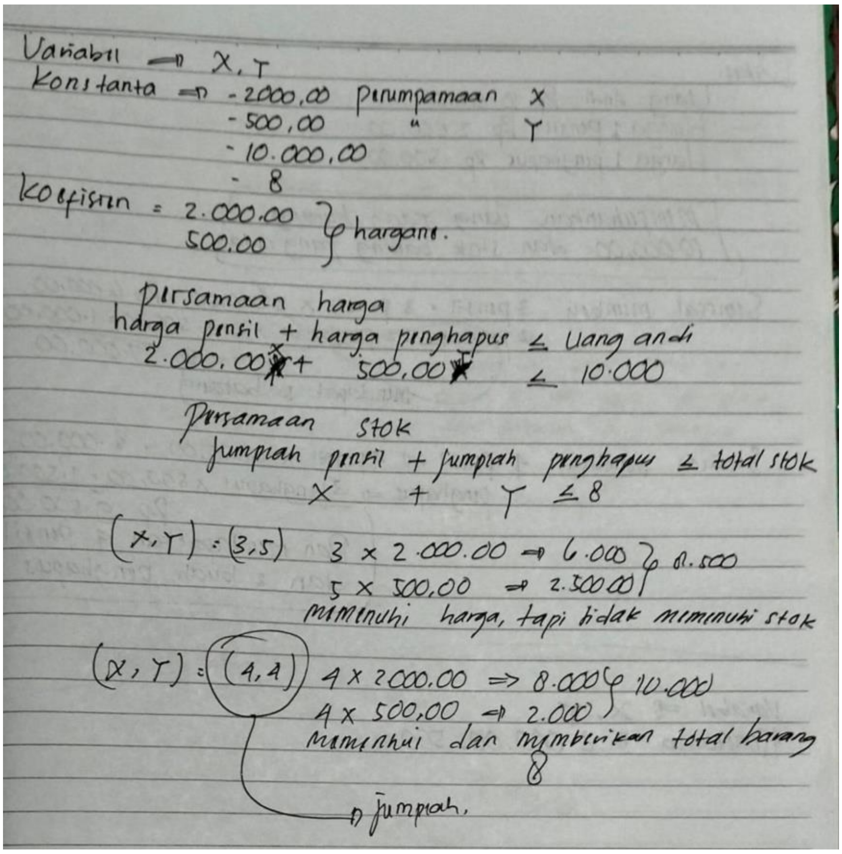

Figure 3. HAS' Answer

Interview with HAS about The Stage of Understanding the Problem.

R : Do you understand the question?

HAS : Asked to determine the maximum number of pencils and erasers that Andi can buy with a maximum of 10,000, but the stock of pencils and erasers is only 8, the price of a pencil is 2,000, and the price of an eraser is 500.

Based on figure 3 and the interview with HAS, it shows that HAS has a variety of difficulties at the Polya stage. The difficulties experienced by HAS at the stages of understanding the problem and making a plan are less than the difficulties that occur at the stages of implementing the plan and re-checking. At the stage of understanding the problem, HAS can understand the meaning of the contextual problem presented, namely the problem presented involving two variables (pencil and eraser) and two limitations (money and stock), and know the information presented by HAS.

Interview with HAS about The Stage of Making the Plan

R : What did you do to solve the problem?
HAS : I first determined the variables, coefficients, and constants.
R : What do the variables and y mean?
HAS : x is a pencil, and y is an eraser.
R : Is the variable an object or a value?
HAS : I think of an object.
R : For constants?
HAS : numbers.
R : What is the difference between a constant and a coefficient?
HAS : I'm still confused about distinguishing

At the making the plan stage, HAS created two inequalities, one to limit the amount of money Andi had and another to limit the total number of items that could be purchased. This shows that students have tried to model the problem in mathematical form. However, HAS did not clearly explain the purpose of selecting variables x and y. In addition, the way HAS selected the values of the variables (x, y) was unclear and did not appear systematic. After conducting an interview, it turned out that the values of the variables (x, y) chosen were the results of limited experiments carried out by HAS until they finally found results that met the limits. This is in line with the results of research by Ani and Rosyidi (2022), which explained that students' planning abilities are still lacking at the planning stage, especially when modeling or interpreting information into symbols.

Interview with HAS about The Stage of Implementing the Plan

R : $2000x + 500y \leq 10.000$ and $x + y \leq 8$, is it an equation or inequality?
HAS : I mean inequality.
P : Why are 3 pencils and 5 erasers not sufficient?

HAS : Because it does not meet the stock, it only meets the price.
P : Is it not allowed if it is less than 8?

At the plan's implementation stage, HAS performed calculations to see the values that satisfy both inequalities. However, the method used by HAS was less efficient because it did not comply with the solution procedure. HAS had difficulty in choosing an effective strategy and its application in finding a solution due to a lack of understanding of the concept and its application so HAS only made substitutions using two pairs of (x, y). Although the procedure chosen was less effective, it was one of HAS's efforts to solve the problem. This is in line with Schoenfeld (1992), who explained that when solving problems, students develop ways of thinking to solve problems in various contexts.

Interview with HAS about The Stage of Re-Checking

R : Did you re-check your answers?
HAS : Yes, I re-checked because initially I entered $= 3$ *and was* $y = 5$, *but it was not sufficient stock, finally I replaced* $x = 4$ *and* $y = 4$.

At the re-checking stage, HAS has tried to check whether the solution obtained meets the conditions of the problem, even though it is still limited to two pairs of values (3.5) and (4.4) so that the possibility of a solution has not been maximally found. At the re-checking stage, HAS was also less careful because he wrote an equation instead of an inequality on his answer sheet, even though, after being confirmed through an interview, what was meant was an inequality. In addition to experiencing many difficulties at the two stages, HAS also still has difficulty understanding the meaning of variables, constants, and coefficients because he assumes that variables are objects, and coefficients are all existing numbers. This is in line with Santos-Trigo (2024), who explains that students have different ways of interpreting and applying problem-solving approaches to understand concepts and solve problems.

To anticipate the emergence of increasing variations in student difficulties, efforts that teachers can make to overcome this are by explaining the material conceptually so that students do not only memorize, providing routine and non-routine practice questions, teaching various problem-solving strategies, providing questions to stimulate students to think about the meaning of the results obtained. The existence of these efforts is expected to make students accustomed to solving contextual mathematical problems so that the benefits of mathematics can also be felt optimally by students. According to Wang (2020), teachers should not only explain the definition of a concept but also explain in depth the meaning of the concept and provide examples of good problem-solving so that they can stimulate students to be involved in it. Therefore, according to Engelbrecht, Borba, and Kaiser (2023), the mathematics curriculum must be structured based on the main content and habits of mathematical thinking so that students can understand and interpret real-world problems and solve these problems.

CONCLUSION

Based on research on vocational students, it shows: 1) Low Ability Students (LAS) experienced many variation in difficulties at all stages in solving problems according to Polya's theory, 2) Medium Ability Students (MAS) at the stage of understanding the problem experienced fewer variations in difficulties compared to the other three stages, 3) High Ability Students (HAS) at the stage of understanding the problem and making plans experienced fewer variation in difficulties compared to the other two stages. Apart from being based on Polya's theory, students also experience other variations of difficulty: the difficulty in defining variables, constants, and coefficients correctly. This research shows that vocational students experience many difficulties at the re-checking stage. This occurs due to students' lack of mastery of the concept of a system of linear inequalities in two variables. Efforts that teachers can make to overcome the pattern of student difficulties in solving contextual problems related to the system of linear inequalities in two variables are by explaining the material conceptually so that students do not only memorize, providing routine and non-routine exercises, teaching various problem-solving strategies, providing questions to stimulate students to think about the meaning of the results obtained. The existence of these efforts is expected to make students accustomed to solving contextual mathematical problems so that the benefits of mathematics can also be felt optimally by students. However, it should be noted that conceptual understanding needs to be emphasized before getting students used to solving contextual mathematical problems. For conceptual understanding to be optimal, so that its application in everyday problems can be more optimal, mathematics learning must also be carried out optimally. Therefore, further research is needed regarding didactic obstacles in mathematics learning. This research needs to be carried out as a means of evaluation in mathematics learning to help teachers determine appropriate teaching strategies in mathematics learning so that the results align with the expected learning outcomes.

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