

## Mathematical Representation of Students in Solving Linear Program Problems

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### Abstract

The purpose of this study is to describe mathematics representation of vocational high school students in solving linear program problem. The representation that will be seen is pictorial representation, symbolic representation and verbal representation of students with varying abilities. The research subjects were 3 students of class XII from one of the Vocational High Schools in Jambi with a variety of high, medium and low ability levels. The data was collected by giving two linear program problems that the students would work on, then conducting interviews based on each student's answer sheet to strengthen the test result data. Answer sheet data and interview results were analyzed and presented in narrative text. Students with high abilities implement the three forms of representation accurately and are able to change the form of one representation to another representation. Students with moderate abilities do not implement pictorial representation and symbolic representation accurately. Low ability students do not implement pictorial representation in problem solving.

*Keywords:* Mathematical Representation; Solving Problems; Linear Program

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### 1. Introduction

Representation is one of the five mathematical process standards established by the National Council of Teachers of Mathematics (NCTM). According to NCTM, the standard of representation in mathematics learning is that students can choose, implement and translate between representations in solving a problem (Rahmawati et al. 2017). Representation is a form of expressing ideas to define, visualize and communicate mathematical information in various ways such as spoken language, pictures, graphs, symbols, diagrams and tables (Villegas et al. 2009). Villegas et al., (2009) categorizes representations into three forms of representation, namely: 1) pictorial representations in the form of tables, graphs, diagrams, or pictures; 2) symbolic representation in the form of numbers, algebraic symbols and connection signs; and 3) verbal representation in the form of spoken or written language.

In the world of mathematics education representation is an important process (Villegas et al. 2009; Sanwidi 2018b). Representations can help students understand mathematical concepts (Moreno-Armella et al. 2008; Krawec 2015), improve students' thinking skills (Villegas et al. 2009; Dündar 2015; Rahmawati et al. 2017), to improve reasoning abilities (Debrenti 2015). In solving math problems, students are required to

be able to translate abstract mathematics into concrete and vice versa (Sanwidi 2018b). That is, students are expected to be able to translate one form of representation into another form of representation. Through representation, students can make mathematical ideas more concrete (Noto et al. 2016). The fluency of students in selecting and implementing representations will help students understand and solve problems better. The results of the study (Bal 2014) found that the use of different forms of representation helped pre-service teacher understand the problem better. (Jupri et al. 2020) in his research also found that the use of representation helped reduce student errors in the process of operating algebraic forms. In addition, from the results of the study (Anwar & Rahmawati 2017) it was found that verbal representations and symbol representations were widely used by students at the stage of understanding problems in the problem solving process. Also, (Krawec 2015) also found that accurate visual (pictorial) representation has a positive correlation with accurate problem solving.

The amount of the influence of representation in learning mathematics makes the ability of representation to be an ability that must be developed in students and cannot be ignored. The National Council of Teachers of Mathematics (NCTM) states that representation is at the core of learning mathematics and defines representation as one of the five standard mathematical processes. As a standard for mathematical processes, NCTM sets 3 standards for representational abilities, namely: 1) creating and using representations to organize, record, and communicate mathematical ideas; 2) selecting, applying, and translating various forms of mathematical representation to solve problems; 3) using representations to model and interpret physical, social, and mathematical phenomena. Several studies on the ability of representation shows that many Indonesian students do not meet the standards set out the process representation of the NCTM. Some research found that students are able to choose the appropriate form of representation to communicate mathematical ideas (Jupri et al. 2020) but the students are unable to translate various representations (Sanwidi 2018b). Based on the results of research conducted, (Noto et al., 2016) concluded that the ability of the student representation is still low. Therefore, it is necessary to study the mathematical representation of students in solving problems so that the representation process is more concerned and can be developed for students in the future. This study examines the mathematical representation of students in solving linear program problems.

## **2. Research Method**

The method used in this research is descriptive qualitative which aims to describe the mathematical representation ability of students in solving linear program problems. In qualitative research, which is the main instrument is the researchers themselves. Therefore, in this study, the main research instrument was the researcher assisted with the instruments of each data collection. Data collection techniques used in this study are test and non-test. The test used is a written test in the form of a word problem with two questions. The two problems of the linear program are presented in Table 1. The non-test technique in this study is an interview. The interviews conducted in this study were semi-structured open interviews. The students who were the subjects of this study knew that they were interviewed and understood the purpose of the interview and it was conducted after the students completed the written test. Interviews were conducted

based on interview guidelines which were prepared by adjusting aspects of mathematical representation.

The forms of representation that will be seen in this study are pictorial representation, symbolic representation and verbal representation which are adapted from (Villegas et al. 2009). Representative indicators are presented in Table 2. The research subjects were 3 students of class XII from one of the Vocational High Schools in Jambi with a variety of high, medium and low ability levels. The consideration in choosing the subject is to look at the average grade of students and the recommendations from the math teacher at the school. In this study, students were asked to work on 2 linear program problems related to finding the maximum profit and minimum cost. This test was given to students via online media due to the ongoing pandemic conditions. Furthermore, interviews were conducted with research subjects through online media to strengthen the research data. Furthermore, the data from the test and interview results were analyzed and presented in the form of narrative text. Data analysis was carried out starting from the beginning of data collection. Miles and Huberman (Arifin 2021) suggests qualitative data analysis phase into three stages, namely data reduction, data presentation, and draw conclusions.

Table 1. Linear Program Problem

No	Problems
1	PT Lasin is a housing developer in a new residential area. The PT has a land area of 600 m <sup>2</sup> and plans to build two types of houses, namely the rose type with an area of 60 m <sup>2</sup> and the jasmine type with an area of 20 m <sup>2</sup> . The number of houses to be built is not more than 20 units. The developer plans the profit for each type of house IDR 2,000,000.00 and IDR 1,500,000.00. How many units of rose and jasmine type houses should the developer build to get maximum profit?
2	Look at to the problems below! A pharmaceutical factory produces two types of flu drug capsules named Fluin and Fluon. Each capsule contains three main ingredients with the content levels listed in Table A. According to doctors, a person with the flu will recover in three days (on average) by ingesting a minimum of 12 grains of aspirin and 74 grains of bicarbonate. If the price of Fluin is IDR 500.00 per capsule and Fluon IDR 600.00 per capsule. How many Fluin and Fluon capsules should a patient buy for minimum purchase costs?

Table A. Ingredients (in grain)

Ingredient	Many grains per capsule	
	Fluin	Fluon
Aspirin	2	1
Bicarbonate	5	8

Table 2. Representation Indicators

No	Form of Representation	Indicator
1	Pictorial Representation	Students restate information in the form of pictures or graphics
2	Symbolic Representation	Students represent information in symbol form Students operate symbols
3	Verbal Representation of Word Problem	Students use explanations in the form of words to answer questions

### 3. Result and Discussion

#### 3.1 Result

##### Student with High Ability (S1)

Based on the answer sheet, it can be seen that S1 translates the problem into three forms of representation, namely pictorial representation, symbolic representation and verbal representation. In pictorial representation, S1 draws a graph to find the coordinates of the corner points which will produce the maximum and minimum values. Based on the results of the interview, S1 drew a graph so that the points that would be used to calculate the possible maximum and minimum values became clearer. S1 draws a graph based on the results of equations that have been prepared previously. When solving problem number 2, initially S1 made a mistake in drawing the graph, then S1 reads the problem again and corrects the image that has been made (see Fig. 1).

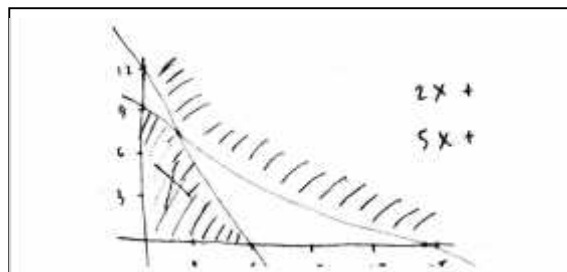
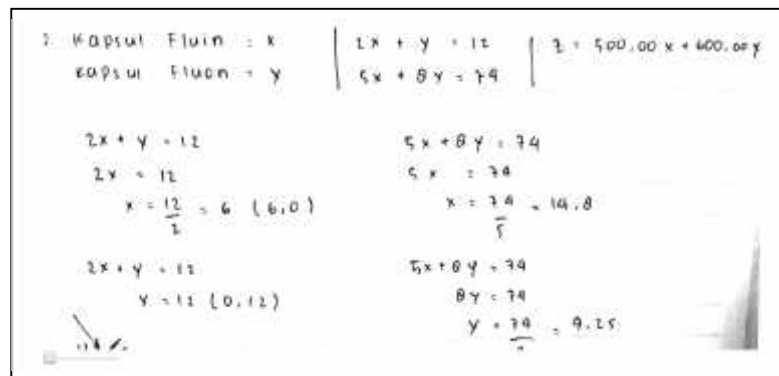


Fig. 1. Pictorial Representation of S1

In symbolic representation, S1 makes the symbol for the housing type and capsule type with the symbols  $x$  and  $y$  (see Fig. 2). Next, S1 makes two equations using the assigned symbol. Finally, S1 operates these equations. Based on the results of the

interview, S1 made an example to make it easier to make equations. Furthermore, the operation of the equation is carried out to get the connection points which will be drawn into a graph.



$Z = 500,00x + 400,00y$   
 $2x + y = 12$   
 $5x + 8y = 74$

$2x + y = 12$   
 $2y = 12$   
 $y = \frac{12}{2} = 6 \quad (6, 0)$

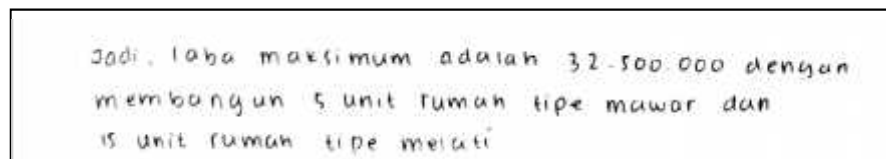
$2x + y = 12$   
 $y = 12 \quad (0, 12)$

$5x + 8y = 74$   
 $5x = 74$   
 $x = \frac{74}{5} = 14,8$

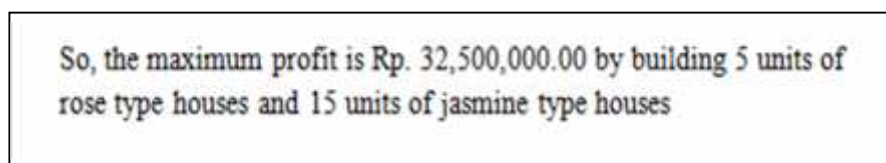
$5x + 8y = 74$   
 $8y = 74$   
 $y = \frac{74}{8} = 9,25$

Fig. 2. Symbolic Representation of S1

In the next form of representation, namely verbal representation, S1 translates the final result of the calculation in the form of the x and y symbols into the conclusion in the form of words as shown in Fig. 3.



Jadi, laba maksimum adalah 32.500.000 dengan membangun 5 unit rumah tipe mawar dan 15 unit rumah tipe melati



So, the maximum profit is Rp. 32,500,000.00 by building 5 units of rose type houses and 15 units of jasmine type houses

Fig. 3. Verbal Representation of S1

### Student with Moderate Ability (S2)

Based on the answer sheet, it can be seen that S2 represents the problem in three forms of representation, namely pictorial representation, symbolic representation and verbal representation. In pictorial representation, S2 draws a graph to find the coordinates of the corner points which will produce the maximum and minimum values (see Fig. 4). However, in problem 2 S2 is not able to draw the graph correctly. Based on the results of the interview, this happened because in the previous step the students were not able to operate the equations that were obtained properly.

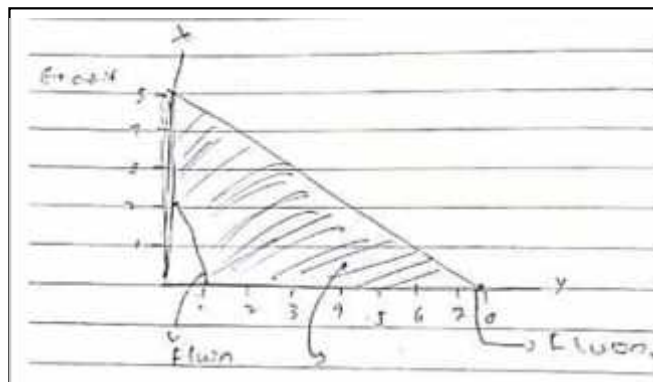


Fig. 4. Pictorial Representation of S2

In symbolic representation, S2 makes symbols for the type of housing and the type of capsule (see Fig. 5). Next, S2 creates two equations using the predefined symbols. Finally, S2 operates these equations to be converted into graphs. Based on the results of the interview, S2 gave symbols to the type of house and type of capsule to shorten the writing so that the next work was simpler to do. Furthermore, based on the S2 interview, the operation of the equation is carried out to find the points that will be connected to become a graph.

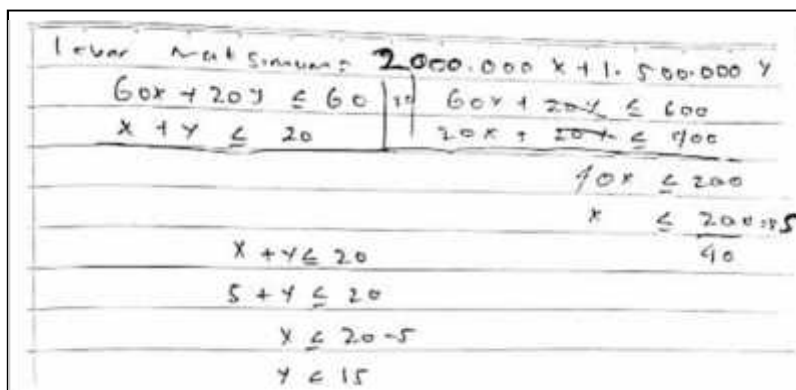
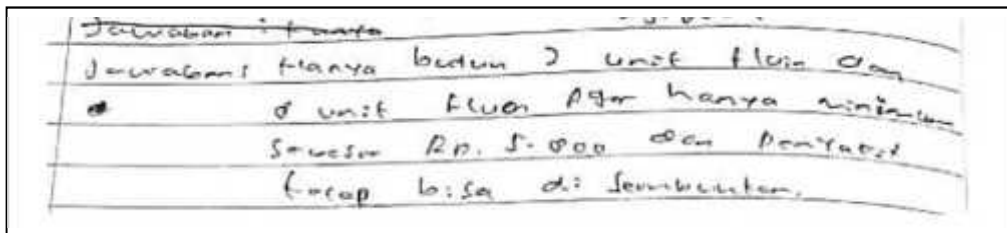


Fig. 5. Symbolic Representation of S2

In the next form of representation, namely verbal representation, S2 translates the final result of the calculation in the form of the x and y symbols into the conclusion in the form of words as shown in Fig. 6.



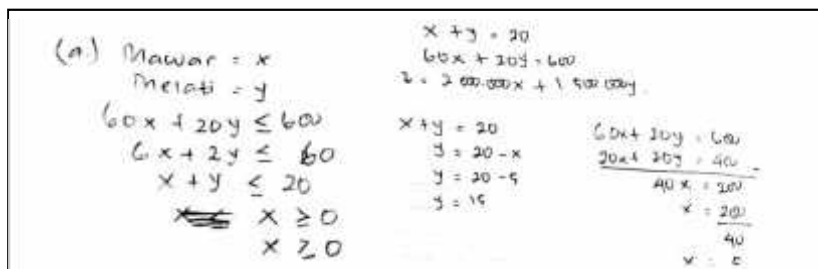
Jawaban: hanya  
 Jawaban: hanya butuh 2 unit fluin dan  
 8 unit fluon agar hanya minimum  
 sebesar Rp. 5.800 dan penyakit  
 tetap bisa di sembuhkan.

Answer: it only takes two units of fluine and 8 units of fluon so that the minimum cost is Rp. 5,800.00 and the disease can still be cured

Fig. 6. Verbal Representation of S2

Student with Low Ability (S3)

Based on the answer sheet, it can be seen that S3 represents the problem in two form of representation, namely symbolic representation and verbal representation. In symbolic representation, S3 makes symbols for the type of housing and the type of capsule (See Fig.7). Next, S3 creates two equations using the predefined symbols. Finally, S3 operates the equation obtained to find the slope of each equation and compares each gradient of the equation to determine the maximum and minimum values. Based on the results of the interview, S3 conducted an example to shorten the writing in the next process. Then S3 operates the equation to get the x and y values.



(a) Mawar = x  
 Melati = y  
 $60x + 20y \leq 600$   
 $6x + 2y \leq 60$   
 $x + y \leq 20$   
 ~~$x \geq 0$~~   
 $x \geq 0$

$x + y = 20$   
 $60x + 20y = 600$   
 $2 = 30000x + 15000y$

$x + y = 20$   
 $y = 20 - x$   
 $3 = 15$

$60x + 20y = 600$   
 $20x + 20y = 400$   
 $40x = 200$   
 $x = 200$   
 $40$   
 $y = 5$

Fig. 7. Symbolic Representation of S3

In the next form of representation, namely verbal representation, S3 translates the final result of the calculation in the form of symbols x and y into words as shown in Fig. 8.

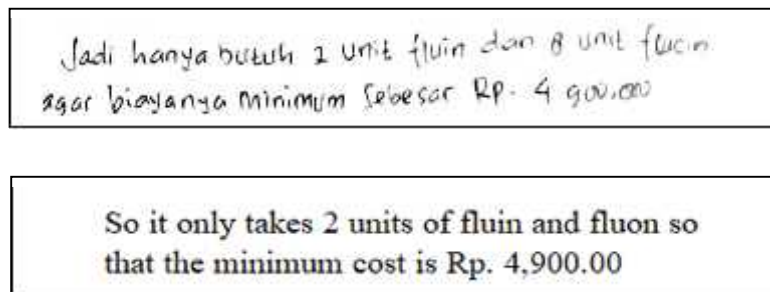


Fig. 8. Verbal Representation of S3

### 3.2 Discussion

Based on the answer sheets and the results of interviews with the three research subjects, it appears that the ability to use various forms of representation in students varies. In subjects with a high level of ability, S1 is the only research subject who is able to solve both problems correctly. This is because S1 is able to select and implement various forms of representation appropriately in solving linear program problems. This is in line with (Dündar 2015) which states that various forms of representation can help to understand problems better. In addition, S1 is also able to understand every form of representation and is able to change the form of a representation to another form of representation.

In subjects with a moderate level of ability, S2 is able to select and implement various forms of representation in solving linear program problems. However, S2 is still unable to change one form of representation to another. This can be seen from solving problem number 2, where S2 is not able to operate the equation correctly which results in students being unable to represent graphical forms correctly. This is because symbolic representations are closely related to pictorial representations in problem solving (Dündar 2015). This error in representing the pictorial representation results in an error in the final conclusion. In line with the research results of (Boonen et al. 2014) who found that inaccurate pictorial representations contributed to an incorrect end result.

In subjects with a low level of ability, S3 is less able to use various forms of representation to solve linear programming problems. This is indicated by the absence of pictorial representation in solving the two problems given and the absence of verbal representation in solving the first problem. Based on the interview, S3 statement of the difficulty of the problem is in the form of a graph, but students can still solve the problem by using a symbolic representation.



#### 4. Conclusion

Based on the results and discussion, there are 4 conclusions that can be scarred. First, students with high and moderate ability are using all forms of representation in solving linear programs problems. Whereas students with low ability only use a symbolic representation and verbal representations. Second, students with high ability implement the Pictorial Representation accurately. While students with moderate ability are not always accurate in implementing the Pictorial Representation. Third, students with high and low abilities implementing Symbolic Representation accurately. While students with moderate ability are not implementing Symbolic Representation accurately. Fourth, each student implementing verbal representation accurately.

This research only describes representation of students with a small number of participants. Therefore, it is necessary to have further studies regarding representation and its effects on the learning process.

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