

# Analysis of Students' Mathematical Representations in Solving Geometric Problems

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**Abstract**—The objective of this present research is to describe students' mathematical representations in solving geometric problems. A qualitative approach was adopted, and the subject was 6 Students Grade IX, MTs Muhammadiyah 1 Malang, Indonesia. The subject consisted of 3 female and 3 male students. The data were collected through tests, interviews, and document analysis. The research results showed that: 1) the representation forms mostly used by the students were varied, among others are description and pictures; 2) most students solved the problems using picture first to facilitate their work, but some of them used representations of written expressions, symbols, and conjectures, and 3) students' fluency and flexibility in constructing the representations may be called to be good enough, and then after interviews, students could represent their mathematical ideas completely either in pictures or written form to solve problems dealing with geometric materials.

**Keywords**—mathematical representation; problem solving; geometry

## I. INTRODUCTION

Geometry is science that is mostly touching almost all aspects of life [12]. In our surrounding environment in which we live, there are many objects similar to the forms of geometric shapes such as the roofs, tables, doors, drinking cans, and the like. *Geometry touches on every aspect of our lives, It is important to explore the shapes, lines, angles, and space that are woven into our students' daily lives as well as our own* [16;25;18]. Therefore, it is natural to say that geometry is one of mathematical materials which is easily understood by the students than other branches in mathematics.

Efforts to understand geometry are needed to understand its concepts, so that students are able to apply geometric skills they own such visualizing and recognizing various

types of two- and three-dimensional shapes, describing pictures, sketching two-dimensional figures, labeling certain points, and being able to recognize differences and similarities between geometric shapes. [19;31]. Moreover, in solving geometric problems, ability to think to apply concepts and skills in the problem solving is needed [20; 21].

Problem solving is one of mathematical skills needed in the daily life, and efforts to improve the problem-solving ability should be improved, especially in understanding problems, making mathematical models, solving problems and interpreting its solution [29; 4; 13]. The fact in the field shows that students still have difficulties in studying and solving geometric problems [17; 32; 9; 20; 19], and the students' ability in solving geometry is also still low [23; 28; 20; 15]. Students should have been able to solve a geometric problem by relating it to his/her daily life, but in fact he is still difficult to solve problems.

Their difficulties studying geometry is caused by their low ability in solving problems and understanding concepts. This is supported by some research results [9; 2; 14] stating that students did not understand concepts and principles in problem solving. Ozerem also showed that the majority of students had some misconceptions in solving geometric problems. Mistakes are caused by low mastery in concepts of geometry and low analysis ability in geometry elements related to problem solving. [23]

Moreover, the cause of the low ability in problem solving geometry in each level is the teacher professionalism factor in carrying out learning activities, which then may result in students' low understanding in concepts in

geometry and their low skills in solving geometry problems [20;11].

Based on the descriptions above, it is necessary to have learning activities leading to the understanding of concepts by developing the skills in visualizing, describing pictures, sketching two- and three- dimensional figures, labeling certain points, and solving problems especially in geometry. It should be noted that mathematical representation that is one of the five standards in basic mathematics learning and that should be mastered by students is an effort to improve their skills in problem solving. The five aspects are as follows: 1) problem solving; 2) reasoning and proof; 4) connection, and 5) representation. [22]

The fifth aspect the students master is interrelated. A student in solving a problem needs an ability in communicating mathematical ideas in a certain manner [10; 11]. It is also stated that a picture may represent and symbolize something.[1]

The process to gain relevant knowledge and its use is really related to the coding of the past time experiences. Internal representations certainly cannot be visibly observed and as a result it cannot be evaluated, and what happens in mind cannot be known. However, this realization of the mind may be seen in words or writing in the form of statements, symbols, expressions, mathematical notations, pictures, graphs, and other forms. The realization is called external representations [8; 5; 7].

Students' mathematical representations are measured through some indicators of mathematical representations as presented in Table I.

TABLE 1: STUDENTS MATHEMATICAL REPRESENTATIONS

Representation	Operational Form
Visual in the forms of: - Picture - Table	<ul style="list-style-type: none"> <li>- Presenting again the data or information from the representations into tables, diagrams, graphs, and so on</li> <li>- Using visual representation.</li> <li>- Making pictures of geometric patterns</li> <li>- Clarifying geometric dimensions</li> </ul>

TABLE 1: STUDENTS MATHEMATICAL REPRESENTATIONS

Mathematic Expression or Equations	<ul style="list-style-type: none"> <li>- Making arithmetic equations or mathematical models from one representation to the other</li> <li>- Making conjectures from the discovered patterns</li> <li>- Solving problems through mathematic equations.</li> </ul>
Description or statement	<ul style="list-style-type: none"> <li>- Making a problem situation from the given problem</li> <li>- Writing an interpretation from representation.</li> <li>- Writing the problem solution through written sentences</li> <li>- Using stages of solving mathematics using words.</li> </ul>

Abilities in expressing ad stating mathematical ideas in verbal forms, pictures, tables, graphs, symbols or mathematical expressions and also as the way to understand certain concepts to solve problems are the understanding of mathematical representations [24; 30; 271; 6]. The ability in the mathematical representation varies ad always appears when one is learning mathematics at all educational levels [5; 7]. Based on then descriptions, this study would reveal students' mathematical representations in solving geometric problems.

## II. RESEARCH METHOD

### A. Research Subject

In this research, the researchers determined the subject to describe the speciality existing in the formulation of a unique context. Moreover, it is also intended to dig out information that would be used as the basis for the emerging design and theories. The subject was 6 students in grade IX, MTs Muhammadiyah 1Malang, consisting of 3 females and 3 male students who would be studied in the ability of their mathematical representations in solving geometric problems. The subjects were chosen since the 6 students had a better ability in representations than others.

### B. Data Collection

The data were collected through documentary and interviews instruments. The instrument used is a test on the ability of geometric representations consisting of three instruments in this this present research that had fulfilled the reliability ad validity. The validity instrument in this research is the test validity, namely how each problem supports the whole scores, so that to know the test validity, the test score and the whole scores should be correlated. On the basis of the results of the tryout from the three test items, the coefficient is 0.64;0.56 ad 0.67, respectively, meaning that the three test items had fulfilled the validity requirement, while dealing with the test reliability, the coefficient obtained is 0.79, meaning that it is under the high category

### C. Data Analysis

After the data were collected, the next step is to reduce the data, present them ad make conclusions. Data reduction is activities of selecting, focusing ad simplifying all data obtained. It is intended to obtain clear information so that the researcher are able to make accountable conclusion. Data presentation is activities of presenting the results of data reduction narratively that enable to make conclusions and decision taking actions. The data presented were then interpreted ad evaluated for the next action. Conclusion drawing and verification are making conclusion from the results of the interpretation and evaluation. This activity also covered the search for meaning of data and giving explanation. Verification is intended to test the correctness, rigidity, and compatibility of meanings found.

## III. RESULTS

This research was made through the results of the geometric tests of 31 students in the first semester in the academic year of 2016/2017. Their learning results were grouped into two categories namely male and female students. From each group, two results of representations were analyzed and the concerned respondents were interviewed as the step to analyze the aspects of the students' mathematical representations in their problem solving.

### A. Mathematical Representations of the Students from SP-1 and SL-1 in the First Question

The answer to a question is like to find out a value of a right triangle in the form of

story intended to understand how far is the mathematical representation of the students in solving a problem. This can be seen from various ways students make in solving the problem, as shown in the Fig. 1.

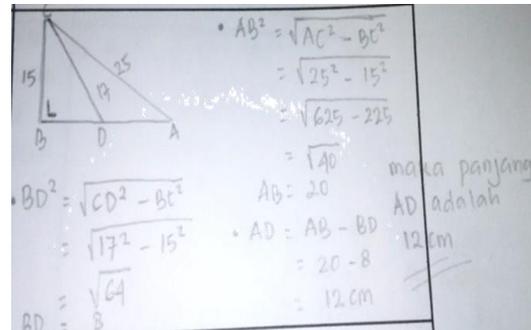


Fig. 1. Problem Solving made by SP-1

The answer to find the length of the side of the triangle that has been unknown is stated in the problem solving in Picture 1, and it showed that the respondent SP-1 know what to do in making a good plan. It can be seen from the answer to the problem solving that fulfills the indicators of the representation. At the first step, SP-1 firstly made a picture with the intention to facilitate the solution. The second step showed that SP-1 employed the postulate of Pythagoras to find the lengths of BD and AB. The third step showed that SP-1 used the postulate of Pythagoras to find the length of AB. The fourth step is that SP-1 found the solution to the question of the length of AD of a right triangle using the reduction of AS by BD of which the result has been solved in the second step. On the basis of the steps in the solutions made by SP-1 that the representation of SP-1 is said to be very good since SP-1 solved a mathematical problem in geometry which is in line with the indicators of the representation namely: 1) visualizing it in the form of picture; 2) using mathematical expression, and 3) describing a solution.

On the basis of the result, the researcher interviewed SP-1 to support the document finding of the test result. The result of the interview with the respondent SP-1 is shown in the transcript below.

- I : Do you understand what you should do in solving the problem of the right triangle?
- SP-1 : I understood what I should do in solving the right triangle problem. To understand a story problem of the right triangle. To understand a story problem on the right triangle, first I made a picture to make me

understand the question of the right triangle. Then I made the picture of the question and I could understand. So I found the value of the figures of BD and AB using the postulate of Pythagoras, then I reduced the results of AB and BD to find the length of AD figure.

The condition of the explanation above shows that SP-1 is at the good representation in solving problem of right triangle since SP-1 understood in solving the problem.

Fig. 2. shows that SL-1 had a good enough representation in solving the problem of right triangle. On the basis of the steps made by SL-1, it is seen that in solving the problem, he understood the solution. It is seen from the steps taken by SL-1 in solving the problem. But SL-1 did not make a picture in his solution. However, at the next step no mistake was found in his solution. He used the postulate of Phytagoras to find the value of BD and AB. The fourth step, SL-1 found out the solution to the question of the length of AD in a triangle using the subtraction between AB and BD from which the result of the AB and BD was solved in the second and third steps. The fifth step shows that SL-1 made a solution using words.

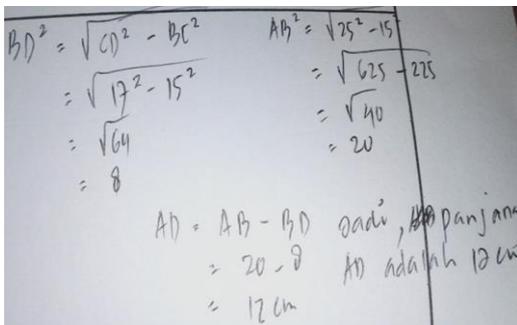


Fig. 2. Problem Solving made by SL-1

The description in Picture 2 is relatively the same with that in Picture 1 where SL-1 in his problem solving fulfilled the indicators of the representation. However, SL-1 did not used a picture to solve the problem, but the end result made by SP-1 and SL-1 are correct. To confirm the result, an interview with SL-1 is shown in Picture 2. The result of the interview is present below.

- I : Do you understand of what you should do in solving the problem of the right triangle?
- SP-1 : Yes, I understood of what I should do in solving the problem of the right triangle, because in the

problem, what is asked is the length of AD, so I found the values of BD and AB by using the postulate of Pythagoras, after that subtracting the result from the subtraction to find the length of AD.

- I : How can you solve the problem without making the illustration of the triangle?
- SP-1 : I made a picture before solving the problem, but in the answer sheet, I did not make it because the picture should not be made in it since it is not too important in the solution.

The explanation above shows that SL-1 is at a good representation in solving the right triangle problem, however he merely passed the first indicator of the representation.

#### Mathematical Representations of SP-2 and SL-2 Students in the Second Question

The answer to the problem like finding the whole cost for building the street in the form of story problem is intended to know the student's mathematical representations in solving a problem. It can be seen from various ways taken by students in solving the problem, as shown in the student's answer sheet below.

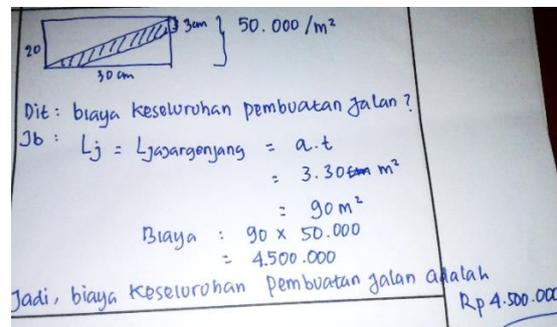


Fig. 3. Problem Solving Made by SP-2

The answer to the problem in determining the whole cost in building the street as stated in the problem solving presented in Picture 3 shows that the respondent SP-2 understood of what to do in making a very good plan. It is seen from the answer to the problem fulfilling three indicators of the representation. In the first step, SP-2 made a picture, where he presupposed that the shading line is the street that would be built. In the second step, SP-2 used a rhomboid formula to find the width of the street that would be built. After the width of the street was found, SP-2 multiplied it with the the cost needed to build a street per meter with the purpose of obtaining the whole cost of building the street.

Based on the steps of the solution it is shown that SP-2 fulfilled three indicators of the representations namely: 1) visualizing in the form of picture; 2) using mathematical expressions; and 3) describing a solution.

The researchers interviewed SP-2 to support the finding the document finding from the test results. The results of the interview with SP-2 is presented in the transcript below.

*I : Did you understand what you should do in solving the story problem dealing with the whole cost that would be spent to make the street?*

*SP-2 : I knew what I should do to solve the problem. To understand the story problem, the first step I made is to make a picture that shows the street that would be made with Rp. 50.000/m. After that, I solved the problem by using the rhomboid formula to obtain the whole cost for building the street.*

The explanation above shows that SP-2 is at the position of a very good representation in solving the story problem since he understood the problem solving.

Picture 4 shows that SL-2 SL-2 had a good enough representation in the problem solving. The steps made by SL-2 are the same with those by SP-2, but at the steps of the counting operations, SL-2 separated the cost for building the street and the whole cost. This causes that the end result made by SL-2 is different with that by SP-2. SL-2 made a less proper result. He should multiply the result of the width of the street with the cost per meter intended to obtain the whole cost for building the street marked by the red ink. On the basis of the solution, SL-2 fulfilled three indicators of representation namely (1) visualizing in the form of a picture, (2) using mathematical expressions, and (3) describing a solution.

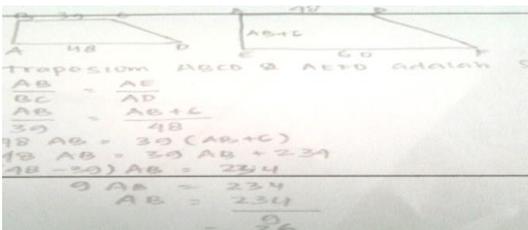


Fig. 4. Problem Solving Made by SL-2

The description presented in Picture 4 is relatively the same with that in Picture 3 where

SL-2 in solving the problem fulfilled the indicators of the representation. However, the end result made by SL-2 is less accurate. To confirm the result, the researchers interviewed SL-2 as shown below.

*I : Did you understand what you should do in solving the story problem dealing with the whole cost to spend for building the street?*

*SL-2 : I understood what I should do in solving the problem. To understand the story problem, the initial step I need is to make a picture showing a street that will be built costing Rp. 50.000/m. After that I solved the problem by using a rhomboid formula to obtain the whole cost in building the street.*

*I : Did you understand the question in the problem?*

*SL-2 : I didn't understand the question fully, so in solving it, I separated the result of the cost calculation from the whole cost. But after I reread the problem, I just understood what to be asked in the problem.*

The explanation above shows that SL-2 is at the position of a very good representation in solving the story problem itself.

#### B. Mathematical Representations of the Students from SP-3 and SL-3 in the Third Question

An answer to a problem such as finding a value of a trapezium form made in a trapezium is intended to understand students' mathematical representation the problem in the the trapezium. It can be seen from various ways students taken in solving it, as shown by a student's answer below.

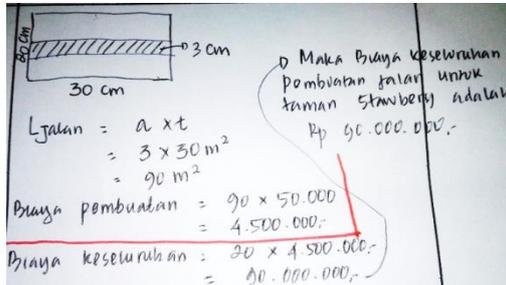


Fig. 5. Problem Solving Made by SP-3

The answer to the problem to determine the AP trapezium stated in the problem solving in Picture 5 shows that the respondent SP-3 understood what he should do in making a good plan. It is seen from the answer to the problem solving fulfilling two indicators of the representation. In the first step, SP-3 made a picture by separating the picture first where ABCD is the first trapezium and ADEF is the second trapezoid intended to facilitate the solution. In the second step, SP-3 employed a comparison to obtain the results of trapezium AB where the values of the trapezium AB is 26 cm as shown in Picture 5. But, SP-3 did not fulfill three indicators of representation. He merely met two indicators namely visualization in the form of picture and the use of mathematical expressions.

On the basis of the result, the researcher interviewed with SP-3 to support the document finding of the test result. The results of the interviews is presented in the transcription below.

- I : Did you understand what you should do in solving the right triangle problem?
- SP-1 : I understood what I should do in solving the right triangle problem. To understand a story problem on the right triangle, I made a picture first so that I understood the right triangle problem, after that I made a picture of the question and I could understand it. I found the value of the BD and AD using the postulate of Phytagoras, then I subtracted the value of BD from AB to find the length of AD.

The explanation shows that SP-3 is at the position of a good representation in solving the trapezium, but he passed the third indicator of representation.

Fig. 6. shows that the answer to the trapezium problem stated in the problem solving in Fig. 6. suggests that respondent SL-3 understood what he should do in making a plan to solve the problem well. It is seen from the steps he took in solving it, but he seemed not write a word – his solution and end result is not correct.

SL-3 solved the problem of a trapezium with the following steps. In the first step, SL-3 made a picture first by dividing one trapezium picture into two as shown in Picture 6. He made the picture to facilitate his problem solving. the second step shows that He made use of a comparison to obtain the results of the AB trapezium. But, at the last step he was not correct in counting marked by the red ink. On the basis of the second step, SL-3 showed that the end result of his solution is not proper due to mistakes in the calculation.

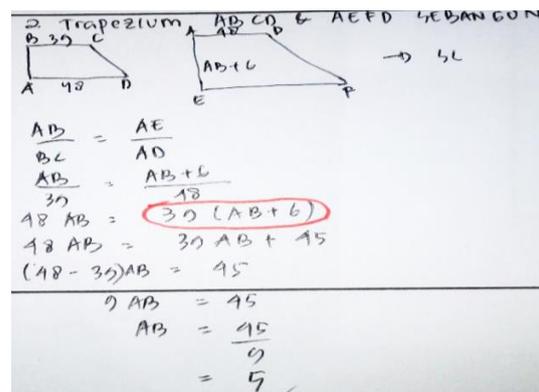


Fig. 6. Problem Solving by SL-3

The description in the problem solving presented in Picture 6 fulfills one indicator of the representations namely visualization in the form of a picture. To confirm the results, the researchers interviewed SL-3 to know his answer stated in Picture 6, where the transcript is presented below.

- I : Did you understand what you should do in solving the trapezium problem?
- SP-3 : I understood what I should do in solving the problem of trapezium. To understand the picture of a trapezium, I divided the picture into two where the ABCD trapezium is the first trapezium and he second, the ADEF trapezium is the second.

*I After that I made a picture of the question, then I found the value asked from the AB using comparison.*

*At the step of finding the AB value, have you corrected in making the counting operation?*

*SP-3 : Setelah melihat ulang hasil dari operasi perhitungan saya, saya melakukan kecerobohan dalam melakukan operasi hitung pada  $39+6$  yang seharusnya  $39x6$ . After reviewing the result of the counting operation, I was careful when made the counting operation I should write  $39x6$  instead of  $35+6$ .*

The explanation shows that SL-3 is at the position of a good enough representation in solving the problem of the trapezium, but he passed the third indicator of the representation.

#### IV. DISCUSSION

Indicators of mathematical representations in this present research are as follows: 1) Visualizing the form of a picture; 2) using mathematical expressions, and 3) describing a solution. All dealing with all indicators, test instruments in the form of three valid test items dealing with geometry were provided. The students' representations were good enough as proved the results of the analyses and the interviews with six respondents. The findings of the present research may become the reference on the importance and the roles of contextual problems in learning mathematics.

Through contextual problems, students would possess ideas and unique argumentations in line with their previously-understood knowledge [5; 6]. Moreover, a teacher should give chances to his students to be brave and willing to respond problems given by their teacher. Besides a representation in line with his capability is formed, he will also be enriched with forms of representations discovered by their classmates. The more the representations emerge, the easier the students choose the quickest and the most accurate way in solving a problem. Problem solving needs more than solid mathematical reasoning. [20]

#### V. CONCLUSION

The following is presented some conclusions of the research results: 1) the

forms of representations are more used by students in various ways such as descriptions and pictures; 2) most students solve problems using pictures first to facilitate them, but some students used representations of written statements, symbols and conjectures, and 3) the students' fluency and flexibility in constructing representations may be said to be good enough. It can be seen from some algebraic forms, and the number of the ways adopted by most students in finding representations is very low.

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