Mathematical problem-solving skills of junior high school students

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Abstract. Student problem-solving skill is the focus of mathematics learning. Students are expected to have specified skills to solve mathematical problems. This study aimed to describe students’ mathematical problem-solving skills at a junior high school in Calang. The method used in this study was qualitative. Two year-9 students were selected by purposive sampling as the participants. Data collection was conducted using a test and interview. The test comprised mathematical problems, aiming to determine students’ ability to solve the problems. The interview was conducted to verify the students’ answer, as some indicators were not fulfilled without the interview. The results showed that the students’ mathematical problem-solving skills were poor. The students did not understand the problems well. They had a plan for solving the problems, but it was not in line with the concept. Their problem-solving implementation was not in order, and they did not recheck their solution. This finding implies that teachers need to pay attention to students’ skills in solving non-routine problems. Teachers should use contextual word problems that are directly related to students’ daily life so that students feel familiar with the questions.

1. Introduction

In both developed and developing countries, problem-solving is emphasized in the curriculum as one of the objectives of mathematics learning, including in Indonesia as stated in the curriculum 2016. Problem-solving can develop and encourage students’ creativity [1]; develop students’ cognitive [2]; motivate students in learning mathematics [3], and develop students’ written and verbal skills as part of mathematical application process [4]. Hence, problem-solving skills are undoubtedly becoming the main goal in mathematics teaching and learning. This is as recommended by the Ministry of Education and Culture [5] and the National Council of Teachers of Mathematics [6] that problem-solving is the ultimate objective and approach in learning.

Whether a mathematical problem provided to students will be a problem is relative, depending on the perspective of each student. A problem in mathematics is a problem that a student can solve without employing a routine method or algorithm [7]. Students’ ability to use non-routine methods or algorithms is a challenge for students to encourage them to be creative in solving problems.

The teacher strives to improve students’ problem-solving skills, yet students still find it challenging to solve problems, especially mathematics problems. This circumstance is indicated by the observations of the students’ learning outcomes that did not achieve the minimum criteria of mastery learning, the score of 75; and by the declining mathematics score of national examination score for junior high school in Aceh from 2011 to 2016. The score went down from 8.05 to 4.97 [8]. The failure to achieve the
minimum criteria of mastery learning and the declining mathematics scores of national examination indicates that students find it hard to solve mathematical problems. As stated by Cooney, Davis and Henderson [9] that poor achievement is one evidence of difficulties in student learning.

Previous researchers have conducted many research concerning problem-solving. Siswono [10] reported that one of the problems in mathematics teaching and learning is the lack of students’ ability to solve non-routine or open-ended problems. Another study by Nurdin [11] revealed that every student has a different flow of thinking when viewed from problem-solving skills based on gender and the stages of Polya’s problem-solving. Sudarman [12] also found that junior high school students have varied thinking process when employing the Polya’s stages based on Adversity Quotient (AQ). Referring to the studies, this article describes students’ problem-solving skills based on Polya’s stages, namely: understanding the problem, devising a plan, carrying out the plan, and looking back [13]. The rationale of this study was that students’ problem-solving skills were lacking. Thus, this study described the students’ weaknesses in solving the problems based on Polya’s problem-solving stages. The research question of this study was how was the students’ mathematical problem-solving skills at a junior high school in Calang.

2. Methods
This research employed a descriptive qualitative method. 2 out of 23 students of class IX at a junior high school in Calang, Aceh, Indonesia were selected for this study. They were chosen by purposive sampling technique, based on the following specific criteria: 1) the students had studied the topics of sets, social arithmetic, proportion, and the system of linear equations of two variables, 2) the students had participated in problem-solving tests, 3) the students achieved the highest score based on the problem-solving rubric, and 4) the students who had good communication skills.

A test was used to assess the students’ mathematical problem-solving skills. The test consisted of four word problems. The students’ work was assessed based on Polya’s problem-solving stages which consisted of understanding the problem, devising a plan, carrying out the plan, and looking back [13]. A 4-point Likert scale was used to assess the students’ work on each Polya’s problem-solving stage.

Interviews were conducted with the students and their teacher. The students’ interview aimed to obtain information about the students’ responses and difficulties in solving the problems. The teacher’s interview was carried out to strengthen the data and to triangulate the data. Data were analyzed based on the concept of Miles and Huberman, namely: data reduction, data presentation, and concluding [14].

3. Results and discussion
Results showed that the students’ problem-solving skills required significant attention. None of the students answered the problems satisfactorily. During the interview the students confessed that they were not able to solve the problems. This finding is in line with Siswono’s remark that one of the reasons for students’ difficulty in solving mathematical problems is their low ability [10]. Another factor is the form of the problems. This is as stated by Nissa [15] that non-routine problems are unfamiliar problems for most students. The students’ difficulties in understanding the problems hindered them from conducting necessary steps to solve the problems which involve the planning and communicating of problem-solving plans [16]. In this section, we described the students’ problem-solving skill based on Polya’s stages.

3.1. Understanding the problem
A student is said to be able to understand a problem if they are able to identify the information available in the problem [11]. During interview, the students could not clearly express their understanding of the problems. For example, when asked about the linear equation problem, the students could no restate what the question was.

Furthermore, the students had difficulty in understanding the meaning of some words and images in the problems. Steinbrink [17] argued that students’ reading ability is an essential part of problem-solving. The reading ability of students was lacking; they were unable to link the meaning of one
sentence with another. When referring to Kintsch’s opinion about the level of mental ability to read, the students’ ability was at the surface component level [18]. For example, the students could identify what was known and asked, but they did not have any idea about the prerequisite materials required. Hence, it influenced the next Polya stage, namely: devising a plan, carrying out the plan, and rechecking.

During interview, the teacher said that the forgetful character of the students was the main obstacle. Even though the teacher always tried to connect the previous to the current materials at the beginning of the lesson, the students still found it difficult to relate a lesson to previous materials. The teacher repeated the materials but not entirely due to time constraint.

3.2. Devising a plan
In order to plan a problem well, a student should be able to mention their strategies to be used to solve the problem [11]. During interview, both students had settled a plan, but it was not in accordance with the concepts in the problem. When the strategies did not work, the students resorted to guessing the answer. For example, when solving problems about linear equations, the students seemed to have a plan to determine the variables and coefficients of the problem and they were able to present a mathematical equation of the word problem, but when entering the next step they did not know what to do. So they guessed the answer accordingly with daily habits and the results obtained are true for logical reasons.

If related to the strategy used by the students to solve the problem, they use guessing and checking strategy. The strategy is based on aspects that are relevant to existing problems, and in accordance with prior knowledge [18].

3.3. Carrying out the plan
At the stage of carrying out the plan, the two students carry out the completion plan, but it is not in accordance with the concept that should be. Their calculation is less thorough, and their solution steps are irregular. This is because the students do not know the concepts well. A student’s ability to solve a mathematical problem has five standards, namely conceptual understanding, calculation, application, reasoning, and productive disposition [19].

3.3.1 Student 1. Of the four problems, Student 1 only managed to solve one problem that was the fourth problem concerning linear equation with two variables. Whereas for the other three questions, he implemented a problem-solving plan that was not in accordance with the concepts in the problem. This is as seen in Figure 1.

Figure 1. The work of student 1 for the first problem

Figure 1 showed that Student 1 did not use set symbols and operations and he drew a Venn diagram incorrectly. Based on the interview, it turns out that he forgot about the concept of set. Besides, there was missing information from the solution he wrote, which was the dot inside the circle. Subject 1 said
that the dots represent the number of students who took extracurricular activities, while the purpose of a dot is actually to mark a number so that the number is clearly located. Based on the results of the analysis of the questions and interviews, it appears that Student 1 has the desired goal, but his problem-solving steps are unclear. This is in accordance with Aisyah’s remark that a problem is something that arises due to the existence of a broken chain between desires and how to achieve them, desires or goals to be achieved are clear, but the way to achieve the goals is not clear [20].

Figure 2 illustrates the second problem related to discounts.

![Figure 2. The work of student 1 for the second problem](image)

In Figure 2, it can be seen that Student 1 implemented the plan to solve the problem, but it is not in line with the discount concept. Student 1 incorrectly determined the price after the discount with the discount, he thought the discount was the price to be paid. He also did not understand the meaning of a direct discount (50%) and further discount (20% + 30%). Student 1 did not present the steps in sequence. He went straight to concluding and making a choice. He completed the calculation, but it was not systematic; hence, the conclusion was incorrect. He should have first determined the discount for each item before determining the price to be paid and then select the items to purchase based on the money.

Based on the results of the analysis of several questions and the results of interview, Student 1’s ability to carry out the plan was affected by his initial knowledge. Because with good initial knowledge, a student will try to associate the relationship of several suitable concepts and it will affect their completion steps.

3.3.2 Student 2. Student 2 implemented the plan to solve the problem, but the steps were unorganized and not in line with the concept suitable for the problem. He also seemed doubtful when solving the problems. Figure 3 presents the work of Student 2 in solving the problem related to proportion. Figure 3 indicates that Student 2 was rather careless when solving the problem. He divided the number of cake pans with the number of flour, resulting in the amount of flour in each cake pan. He actually obtained the number of baking pans required for 6 kg of flour. In addition, he did not use the expected mathematical concept related to direct proportion.
9: 6: 1.5. So for every 1 baking pan, you need 1.5 kg of flour. So the result = 9 baking pans need 6 kg of flour. 1 baking pan needs 1.5 kg of flour. Mom add 3 pans, so 3 baking pans require 4.5 kg of flour. Then = 9 + 3 = 12, 6 + 4.5 = 10.5 so mom makes 12 baking pans and needs 10.5 kg of flour

![Figure 3](image-url) The work of student 2 for the third problem

The next problem about linear equations of two variables is presented in Figure 4.

![Figure 4](image-url) The work of student 2 for the fourth problem

Figure 4 shows that Student 2 did not use the concept of linear and quadratic equation system. Instead, he used the concept of the sum of integers by guessing the usual prices of pencils and books. Then he directly determined the number of books and pencils that can be purchased with the remaining money. Although the answer was correct, it was not in line with the concept. If he applied the right concept, he could start by transforming the problem into a linear equation with two variables and then solve the equation by elimination and substitution to obtain the price of one book and pencil. Next, he could determine the number of books and pencils that can be purchased.

3.4. Rechecking
At the stage of rechecking the two subjects re-examine the settlement, but still limited to checking the accuracy of the final results. Rechecking the solution of a problem should consist of four components, namely checking the results, interpreting the answers obtained, trying other ways, and checking for other possible solutions to the problem [11]. Based on the teacher interview, the teacher said that she has provided her students with an opportunity to re-check solutions by any method. However, it depended on the student as not all students were capable.

4. Conclusion
Based on the data analysis results of students' problem-solving skills based on Polya’s stages, it can be concluded that the students’ skills in understanding the problem were inadequate. The students could only mention what was known and asked, but they could not mention the other prerequisites materials to solve the problems. The students’ skills in devising a plan lacked because of their lack of knowledge of the prerequisite materials to solve the problems. The students’ skills in carrying out plans were lacking.
because they solved the problems without following the rules of the appropriate concept. Thus, the written solution was not in order. The students’ skills in rechecking also lacked because they did not check the accuracy and the order of the solutions. They paid more attention to the final results instead of the process. In summary, the students’ problem-solving skills were lacking. The students did not use Polya’s stages of problem-solving properly. They solved the questions, but it was incorrect.

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