Students’ mathematics problem-solving skills through the application of Problem-Based Learning model

I Suryani, E Maidiyah, Salasi and MZ Mardhiah
Department of Mathematics Education, Universitas Syiah Kuala, Banda Aceh, 23111 Indonesia
E-mail: ernimaidiyah@unsyiah.ac.id

Abstract. Education aims to foster a variety of potential which exists in human, including the potential to solve any problems, involving solving mathematical problems. This study aimed to describe students’ problem-solving skills during mathematics learning about social arithmetic through Problem-Based Learning (PBL) model. The subjects of this research were 32 Year 7 students in Banda Aceh. This study used a qualitative descriptive approach. Data collection was conducted by problem-solving skills test and interview. The interview data were analysed descriptively, while the data of the test results were analysed based on the assessment guideline of students’ problem-solving skills. It was found that students' mathematical problem-solving skills through PBL model were already classified as good. High-achieving students of problem-solving skills solved the problem by understanding the problem, planning the solution, doing the solution and rechecking it. Middle-achieving students of problem-solving skills solved the problem by understanding the problem, planning the solution and doing the solution without rechecking it so they get incorrect results. Low-achieving students of problem-solving skills solved the problem by understanding the problem and planning the solution, yet they presented the incorrect solution and did not recheck it. PBL model can be used to improve students’ problem-solving abilities.

1. Introduction
Mathematics aims to train student’s logical, critical, analysis and systematic thinking. However, most students think that it is difficult for them to learn and understand mathematics. One of the reasons is the teaching and learning techniques applied by the teacher. If the teacher used instructional models incoherent with students’ situations, the learning process would be less effective and efficient [1]. Therefore, further information about the students’ environment is necessary for the students’ problem-solving skills.

A problem requires a problem solver to identify a problem situation and to make a decision about the solution, directing an individual to achieve the desired goals [2]. Problem-solving skills are structured learning process, so these skills must be taught to students [3]. Students will have the skills if they understand and comprehend what is gained from learning. Therefore, teachers should discover and determine innovations in learning activities that can boost students’ problem-solving skills. Thus, the learning process will proceed as expected.

Mathematical thinking and problem-solving can be identified by way of understanding mathematical problems [4]. Problem-solving skills work together with thinking. Many mental activities and problem-solving include in the thinking that involves the working of the brain.
Previous studies show that problem-solving skills in mathematics learning are still lacking. Sumartini [5] assumed that students’ mathematical problem-solving skills are still lacking because of the mistakes they committed when they solved the mathematics problems provided by the teacher. It can be seen by the errors in forming mathematical models from word problems and their carelessness in doing basic calculations. Whereas, the problem given is very useful to help students to improve their problem-solving skills. Furthermore, Shodikin [6] found that only high-achieving and middle-achieving students in mathematics showed an improvement in problem-solving skills.

The detail condition about the two previous statements can be investigated by conducting research. Therefore, researchers observed Year 7 students in one classroom in one of the junior high schools in Banda Aceh. The conclusion made after the researchers conducted a direct review of the school was that students’ problem-solving skills were indeed classified as lacking. The lack of problem-solving skills was due to the tedious learning process in the classroom, and only the teacher conveyed information in the learning activities without the reciprocal information presented by students. In addition, the learning model applied did not support the teaching and learning process. The selection of the best learning model can boost student learning activities in the classroom. The lack of students’ problem-solving skills was also because of the students’ attitude who were less creative in completing the initial process of a problem. Although, generally, they could solve problems after the teacher explained the purposes of the problems. Further investigation of these skills is needed.

The efforts to improve students’ problem-solving skills are by selecting and applying innovations in learning; one of them is the Problem based Learning (PBL) model. The innovations to develop students’ problem-solving skills are not only in the form of learning models but also in media and technology that support the learning process. Teachers also need to understand that not all learning models, media, and learning technologies are suitable to be applied in the teaching and learning process in the classroom. They must also consider the classroom environment, the condition of students, and the material to learn. In this study, researchers chose the PBL model because it provides an opportunity for students to develop and express their thinking on the problems given by the teacher, both by working in a group and individually.

PBL model has five learning steps [7], namely (1) Orienting the problem (the teacher provides problems); (2) Organizing the learning (guiding students to solve the given problem); (3) assisting individual and group investigations (guiding students to collect the information to solve the problems); (4) Developing and presenting results (guiding students to find the best result of the problems); and (5) Analysing and evaluating (guiding students to check and evaluate the steps of the problem-solving written).

There are four steps for solving problems, namely: understanding the problem, planning the solution, devising the plan, and reviewing the process and results [8,9]. Polya [9] believed that if students do all of the steps, they will have high problem-solving skills.

Social arithmetic is the topic chosen by the researchers to apply the learning model. This material is selected because it is very close to the students’ real life. However, students usually have difficulty to solve arithmetic problems, because they often involve word problems that are difficult to interpret into mathematical models. Therefore, this topic is suitable for the implementation of the PBL model. The PBL model is contextual and allows students to express their ideas in resolving the problems given freely.

Students’ problem-solving abilities increased through the application of Problem based Learning (PBL) model [10]. But, they did not see the way students solve the problem. They just tried to find whether the abilities increases or decreases. It is stated that the average test result of students in the experimental class is better than in conventional class [10]. Therefore, they suggest using Problem based Learning (PBL) model.

Based on the description above, it is believed that there is a connection between the application of the PBL model and students’ problem-solving skills. Therefore, the research problem of this study is “How do Year 7 students’ mathematical problem-solving skills through the application of problem-s
based learning model?” This study aimed to determine Year 7 students’ mathematical problem-solving skills through the application of the Problem based Learning model.

2. Method
This research was qualitative descriptive research. The subjects of this research were 32 Year 7 students from one of the junior high school in Banda Aceh. The instruments involved problem-solving skills tests and interviews. The test contained four problems that were developed by the researchers and validated with logical validation by validators who are experts. The test results were evaluated based on a problem-solving skills test adapted from NCTM [11]. The test was conducted at the end of the lesson after learning with the PBL model had been completed. The test results were then converted into the 0-100 level. Based on the final score, students were classified into high-achieving (80-100), middle-achieving (66-79), and low-achieving (56-65). This classification refers to the category proposed by Arikunto [12].

Based on the result of the tests, six students were randomly chosen to be interviewed, two students each for the high-achieving, medium achieving, and low achieving problem-solving skills. The interview instrument also was developed by the researchers and validated by experts. The interview was conducted to validate various information related to the problem-solving steps done.

3. Result and discussion
A mathematics test of problem-solving skills was administered to all Year 7 students. The test aimed to review the extent of their problem-solving skills. The test results reported that three students were high-achieving problem-solving skills, 11 students were medium-achieving, four students were low-achieving and 14 students were very-low achieving. Based on the test, six subjects were chosen, two high-achieving students (YP and ARP), two medium-achieving students (MRZ and NFR), and two low-achieving students (DR and RR). When working on the test, the teacher guided students to look for various alternatives (scientific methods and theories), so that they can solve the problems optimally. It turned out that in the problem-solving process, the ability of high and medium-achieving students did not show much difference.

| No. | Students | Understand the Problem | Plan the Solution | Do the plan | Review |
|-----|----------|------------------------|-------------------|-------------|--------|
| 1.  | YP       | ✓                      | ✓                 | ✓           | ✓      |
| 2.  | ARP      | ✓                      | ✓                 | ✓           | ✓      |
| 3.  | MRZ      | ✓                      | ✓                 | ✓           | x      |
| 4.  | NFR      | ✓                      | ✓                 | ✓           | x      |
| 5.  | DR       | ✓                      | ✓                 | x           | x      |
| 6.  | RR       | ✓                      | ✓                 | x           | x      |

The table above is problem-solving skills indicators that were fulfilled by the subjects. The table shows that students YP and ARP did all of the indicators and classified as high-achieving problem-solving skills. Students MRZ and NFR did three indicators that classified as medium-achieving. Students DR and RR only did two indicators that classified as very-low achieving.

Problem 1: Grandma Wati sold cassava chips to finance grandchildren’s school. She bought 30 packs of cassava chips from an agent for IDR 5,000.00 per pack. Because she was feeling not well, she only sells 18 packs in the afternoon. Then, the other chips were sold in the evening at the price of IDR 4,500.00 per pack. After counting, it turned out
that the grandma had suffered a loss of IDR 24,000.00. Determine the selling price of each pack of the chips that grandma sold in the afternoon!

**Figure 1.** YP answer to question number 1

Figure 1 presents one of the high-achieving students’ works in solving the first problem. The validity of the test result presented in Figure 1 was done by interviewing YP. YP said, "*In this problem, Grandma bought 30 packs of cassava chips for IDR 5,000.00 each. However, she was unfit, so she could only sell 18 packs.*" Then YP said, "*From this problem, we have investigated the selling price of each packet of cassava chips sold by Grandma.*" Furthermore, the problem-solving steps done by YP were assessed based on the indicators of mathematical problem-solving skills adopted from Polya [9], namely: understanding the problem, developing a problem plan, resolving problems according to plan, and rechecking. YP did all of the steps well. Both YP and ARP used the same method to solve this problem.

**Problem 3:** Nita went to a shopping centre to buy a dress and bag to wear at a wedding party. The store gave a 50% discount for the bag and a 70%+25% discount for the dress. Then, Nita chose a bag with a price of IDR 400,000.00 and a dress with a price of IDR 250,000.00. How much money did Nita have to pay for the purchase of the bag and dress?

Figure 2 is the answer provided by one of the middle-achieving students. The researcher interviewed MR to examine the validity of test results. In the interview, MR mentioned that from the problem, he knew that there were six baskets of broiler chicken bought by Mr. Lukman for IDR 5,250,000, one basket contains 25 chickens, and Mr. Lukman sells one chicken for IDR 45,000. MR’s problem-solving steps were assessed based on indicators of mathematical problem-solving skills adapted from Polya. The results showed that MR did three out of four indicators, namely: understanding the problem, planning the solution for the problem, and devising the plan without
rechecking. Thus, based on the results of the interview, it was concluded that MR fulfilled three indicators only.

Figure 2. MR answer for question number 3

Figure 3 displays the answer provided by one of the low-achieving students in solving the problem given by the teacher. The interview was also conducted for the students. RR explained what he knows from the problem, that there were 30 packs of chips worth five thousand each and the grandmother sells 18 packs by noon. RR also mentioned that he also knew the grandmother sold the chips for IDR 4,500 in the afternoon and she had a loss of IDR 24,000. Then the researcher asked what the question require? And RR replied that he need to determine the selling price of the cassava chips. Furthermore, the researchers asked how RR solved the problem and he replied that he did not know.

Problem 2: Mr. Lukman is a boilers seller in Peunayong City. The boilers were Medan City Boilers that were carried by pick up car. Mr. Lukman bought 6 baskets of boilers with a total price of IDR 5,250,000, and each basket contained 25 boilers. Mr. Lukman set the price of a boiler is IDR 45,000.00.
   a. Determine whether Mr. Lukman gets a profit or loss!
   b. Determine the percentages!

Based on the excerpt from the interview above, it is noted that the subject understood the problem, formulated a problem-solving plan, but, he could not implement the problem-solving plan and review the solution. Based on the solution provided in the answer sheet and the results of the interview, it is evident that students with low problem-solving skills cannot go through all stages of Polya’s problem-solving.
Based on the results previously discussed, the mathematics problem-solving skills of high, medium and low-achieving students were similar. On average, the high and medium and low-achieving students could conduct all problem-solving stages, while the low-achieving students could not. Generally, the low achieving students were successful up to the first stage. This shows that students’ initial mathematical skills influence students’ problem-solving skills through the application of the PBL model. However, this model can be applied to increase students’ enthusiasm for learning.

The results also showed that students were confused about evaluating the problem-solving steps done. This is because they rarely recheck their solutions before and assume that they are correct, even though there are still many mistakes. In addition, another challenge faced by the students in learning using the PBL model was that they could not change their learning habits in term of students’ involvement. This is in line with Johar who argued that the students get used to receive information from the teacher only, and they find it hard to involve in active learning requiring both students and teachers to interact in conveying information [13]. Therefore, students are expected to be more engaged in learning in finding information from various sources for the problems provided by teachers.

The result was also relevant with Mulyono, Rahmawati and Amidi [10], who stated that students’ problem-solving abilities increased through the application of Problem Based Learning (PBL) model. Applying PBL impacts on the improvement of students’ problem-solving abilities. The other relevant study found that PBL is effective to use for improving students' problem-solving abilities [14]. Furthermore, the research of Suhartini [5] also relevant to this study. She also found that students’ problem-solving abilities improve by applying the PBL model.

**Figure 3.** RR answer to question number 2

Based on the results previously discussed, the mathematics problem-solving skills of high, medium and low-achieving students were similar. On average, the high and medium and low-achieving students could conduct all problem-solving stages, while the low-achieving students could not. Generally, the low achieving students were successful up to the first stage. This shows that students’ initial mathematical skills influence students’ problem-solving skills through the application of the PBL model. However, this model can be applied to increase students’ enthusiasm for learning.

The results also showed that students were confused about evaluating the problem-solving steps done. This is because they rarely recheck their solutions before and assume that they are correct, even though there are still many mistakes. In addition, another challenge faced by the students in learning using the PBL model was that they could not change their learning habits in term of students’ involvement. This is in line with Johar who argued that the students get used to receive information from the teacher only, and they find it hard to involve in active learning requiring both students and teachers to interact in conveying information [13]. Therefore, students are expected to be more engaged in learning in finding information from various sources for the problems provided by teachers.

The result was also relevant with Mulyono, Rahmawati and Amidi [10], who stated that students’ problem-solving abilities increased through the application of Problem Based Learning (PBL) model. Applying PBL impacts on the improvement of students’ problem-solving abilities. The other relevant study found that PBL is effective to use for improving students' problem-solving abilities [14]. Furthermore, the research of Suhartini [5] also relevant to this study. She also found that students’ problem-solving abilities improve by applying the PBL model.
4. Conclusions
The results of this study found that the application of PBL model influenced students’ problem-solving skills. This study classified students into three categories of problem-solving skills, namely high, medium, and low achieving, based on Polya indicators of problem-solving. Based on the four indicators of mathematical problem-solving skill adopted from Polya, the activities of problem-solving conducted by high and medium-achieving students were similar. High and medium-achieving students generally fulfilled all indicators except for rechecking, while low-achieving students did not meet all indicators. Therefore, this model can be applied to enhance the enthusiasm of students in learning, which in turn will increase the learning outcomes. Future research should examine more deeply the problem-solving skills using the PBL model for more samples to obtain an overall trend of mathematical problem-solving skills.

References
[1] Maulidiana M 2010 Hubungan Motivasi Kerja dengan Produktivitas Kerja Karyawan Tetap Bagian Produksi pada Peseroan Terbatas (PT) Skripsi (Jember: Universitas Jember)
[2] Schoenfeld A 2011 How We Think: A Theory of Goal-Oriented Decision Making and Its Educational Applications (New York: Routledge)
[3] NCTM 2000 Principles and Standards for School Mathematics (Amerika: NCTM. Inc)
[4] Mustafa S, Sari V and Baharullah 2019 The implementation of mathematical problem-based learning model as an effort to understand the high school students’ mathematical thinking ability International Education Studies 12 117
[5] Sumartini T S 2016 Peningkatan kemampuan pemecahan masalah matematis siswa melalui pembelajaran berbasis masalah Mosharafa: Jurnal Pendidikan Matematika 5 148
[6] Shodikin A 2015 Peningkatan kemampuan pemecahan masalah siswa melalui strategi abduktif-deduktif pada pada pembelajaran matematika Kreano Jurnal Matematika Kreatif-Inovatif 6 101
[7] Arends R I 2012 Learning to Teach Ninth Edition (New York: McGraw-Hill)
[8] Ayuningrum D 2017 Strategi pemecahan masalah matematika siswa SMP ditinjau dari tingkat berpikir geometri van Hiele Kreano Jurnal Matematika Kreatif-Inovatif 8 27
[9] Polya G 1975 How to Solve It: A New Aspect of Mathematical Method Updated by Conway, J H 2004 (Princeton: Princeton University Press)
[10] Mulyono, Wati M I R, and Amidi 2019 The ability of mathematical problem solving reviewed from goal orientation to learning model of problem based learning assisted by problem card Unnes Journal of Mathematics Education 8 8
[11] NCTM 2000 Principles and Standards for School Mathematics (Amerika: NCTM. Inc)
[12] Arikunto S 2009 Dasar-dasar Evaluasi Pendidikan (Jakarta: Bumi Aksara)
[13] Johar R 2016 Strategi Belajar Mengajar (Yogyakarta: Deepublish)
[14] Amalia E, Surya E and Syahputra E 2017 The effectiveness of using problem based learning (PBL) in mathematics problem solving ability for junior high school students International Journal of Advance Research and Innovation Ideas in Education 3 3402