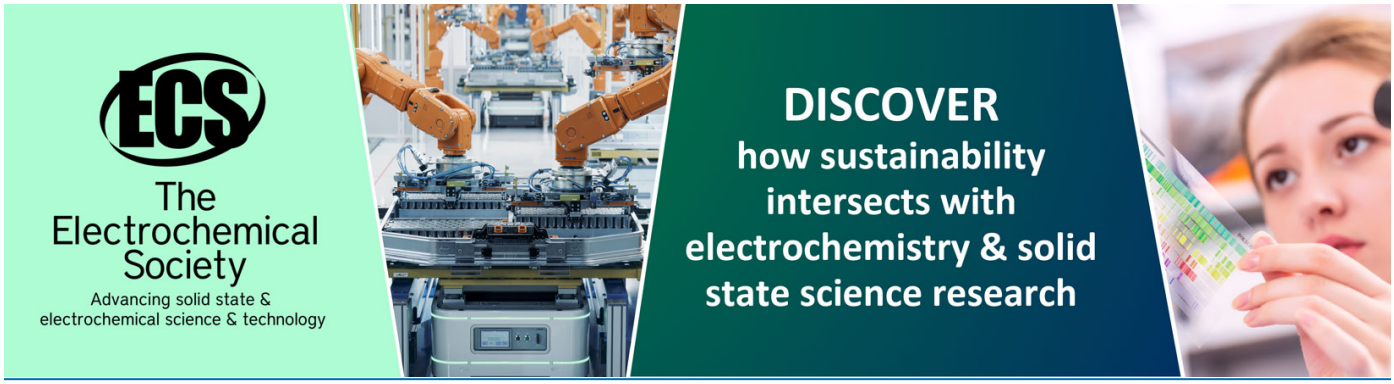
# Mathematics problem-solving skills of vocational high school students related to the 21st-century education





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# Mathematics problem-solving skills of vocational high school students related to the 21st-century education

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**Abstract.** 21st-century education demands critical thinking, problem-solving, communication, and collaboration skills, as well as creativity and innovation. National Council of Teachers of Mathematics has set five standards on student mathematical skills required by students; one of them is problem-solving. Programme for International Student Assessment showed the lack of Indonesian student problem-solving skills. There is a need for revamping the education system to improve the quality of human resources so that Indonesian students' problem-solving skills can be better. This qualitative descriptive research aimed to examine the mathematics problem-solving skills of vocational high school students. The research subjects were 22 vocational high school students and the data collection involved a problem-solving test and interview. The results showed that out of 22 subjects (11 groups) in the research, no subject achieved the 'very good' and 'good' category of problem-solving skills. Four groups had 'adequate' problem-solving skills and seven groups had 'poor' problem-solving skills. The results showed that students had difficulty in solving problems because they did not understand the problems, and thus they can not solve problems. They were also not accustomed to non-routine problems and had a lack of understanding of designing mathematical models and connecting mathematics to the real world.

## 1. Introduction

Competition in many aspects of the 21st-century, including education and science education, is very high. We face the demands of high quality and competent human resources. High-quality human resources, generated by high-quality education, can be the primary solution to the current problems. One of the methods is to improve the quality of education in 21st-century education. It demands to focus on critical thinking, problem-solving, creativity, innovation, communication, and collaboration [1]. Similarly, the National Council of Teachers of Mathematics (NCTM) determined five standards of student mathematical skills required by the students, namely problem-solving, communication, connection, reasoning, and representation skills [2]. One of the objectives of mathematics learning is for equipping the student with problem-solving skills, including the skills to understand the problem, design a mathematical model, complete the model, and interpret the solutions [3].

Problem-solving skills are included in the competency standards determined by the National Education Standards Agency of 2013 and NCTM. It means that these skills are important to be developed by the students. Problem-solving has become a priority in current education. The term "problem-solving" is related to problems that potentially present intellectual challenges to improve the development and understanding of mathematics. Next, contextual problems demanding the students to connect their mathematical knowledge to solve their daily life problems are also believed to influence student problem-solving skills [4].

The importance of problem-solving skills in mathematics was also stated by Bell, who believed that the problem-solving strategy learned on specific aspects could be transferred and applied to other problem-solving situations. Mathematical problem-solving could help the students in improving their analytical ability and help them apply that ability in various situations [5].

However, a survey by the Programme for International Student Assessment (PISA) reported that Indonesian student problem-solving skill remains poor [6]. PISA is a survey that aims to examine how far can the student apply their knowledge. Based on the PISA study in 2012, Indonesia was ranked the 64$^{th}$ from 65 countries, with an average score of 375, far below the international average of 494 [6]. PISA study in 2015 revealed that Indonesia was ranked 61$^{st}$ from 70 nations, with an average score of 386 and the international average score was 490 [6]. Kertayasa [7] argued that the cause of Indonesian students' low score on PISA was the poor problem-solving skills on non-routine problems or advanced problems. The problems tested by PISA are contextual; it consists of 6 levels (level 1 is the lowest dan level 6 is the highest). Meanwhile, Indonesian students were only accustomed to routine problems on level 1 and level 2. Thus, it can be concluded that Indonesian student problem-solving skills remain poor [7].

Problem-solving is basic human activities. In daily life, humans will have to face problems. One of them is a problem in learning. Problems in the learning process can originate from a lack of students' ability to understand problems to determine solutions for problem-solving. The problems the students need to face are the problems presented by the questions in all the study subjects [8]. When the student is solving a mathematical problem, the student faces several challenges; for example, the students face a problem that they have never encountered [9].

The problem-solving activity requires complex and abstract cognitive procedures, including all the previous learning experiences. The students are required to think about what they have learned, from collecting past information to arrange the information into steps to solve the problem [10]. Problem-based learning also demands teamwork between students in small groups. It aims to help the students in developing their thinking process [11].

There are several skills in mathematics problem-solving; namely, problem-solving skill for routine, non-routine, applied routine, non-applied routine, applied non-routine, and non-applied non-routine problems [12]. Polya [13] explained several steps in problem-solving. First, understanding the problem, the student cannot solve the problem if they do not understand the problem. Second, planning, this second step depends on the student experience in solving the problem. Generally, a student with more experience will be more creative in planning the problem-solving strategy. Third, solving the problem according to the plan. Finally, evaluating, the student rechecks the solution.

There are four steps in problem-solving, namely: (1) Identifying the problem, (2) Planning the solution, (3) Solving the problem and (4) rechecking the problem [14]. The Indonesian education system needs improvement to enhance human resources quality so that students problem-solving skills can also be improved. Therefore, first, we need to examine and identify the overall students' skills in problem-solving. It is hoped that the diversity of student skill levels could be explored directly so that reliable data could be obtained. However, limited studies have investigated the ability of students to solve problems based on 21st-century learning. Some researchers studied the profile of problem-solving skills in vocational high schools in terms of cognitive style. However, not many studies have elaborated students' problem-solving skills based on the 21st century learning at

vocational high school; considering that vocational high school is one of the platforms for creating the human resources to face technological and industrial developments [5].

This research aimed to assess students' problem-solving skills based on a test that focuses on problem-solving in 21st-century education. The result of this research is expected to give information about students' problem-solving skills of a vocational high school in Banda Aceh. It is hoped that the information can help develop the student problem-solving skills, which in turn ultimately will improve the mathematics performance of Indonesian students.

## 2. Method

The method of this study was qualitative descriptive, employing 22 vocational high school students as the subject. The test was administered by grouping the students into small study groups consisted of two students. However, two groups with 'adequate' skill category and one group with 'poor' skill category were selected as the sample to be observed and analyzed. The data needed in this research were students' answer sheet and self-reflection note after the problem-solving was done. The research methodology is illustrated in Figure 1.

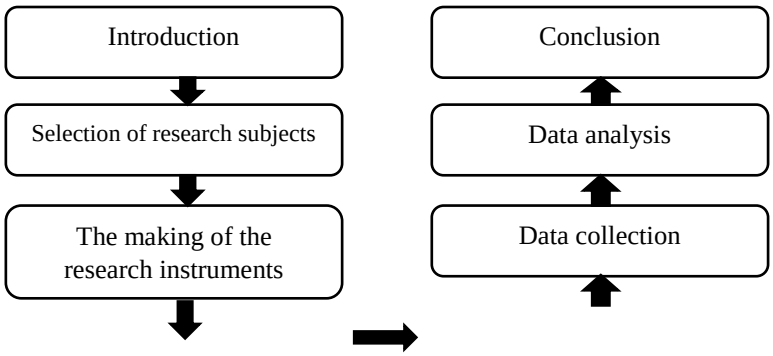



**Figure 1.** Research methodology plot.

Figure 1 shows that the first step of the research is the introduction. The researcher determined the location of the research, which was one vocational high school in Banda Aceh. Next, the researcher determined the research subjects, 22 vocational high school students that were grouped into 11 groups of two students.

The instruments used in this research was an assessment rubric created based on the guidance of professionals, problem-solving test, and an interview guideline. The problem-solving test given was a test related to a 21st-century education. It includes 4C, namely: critical thinking and problem-solving, creativity and innovation, communication, as well as collaboration. Data collection was carried out by administering the problem-solving test, followed by an interview for more in-depth data.

As for the indicators used in this research, it was adopted from Polya [13], namely: (1) understanding the problem, (2) planning, (3) solving the problem according to the plan, and (3) evaluating or rechecking the solution. The students' score was based on the rubric presented in Table 1.

The score criteria were based on the Regulations of Ministry of Education and Culture, No. 81, the Year 2013 [15] as follows.

Very good : $3.33 < \text{score} \leq 4.00$
Good : $2.33 < \text{score} \leq 3.33$
Adequate : $1.33 < \text{score} \leq 2.33$
Poor : $\text{score} \leq 1.33$

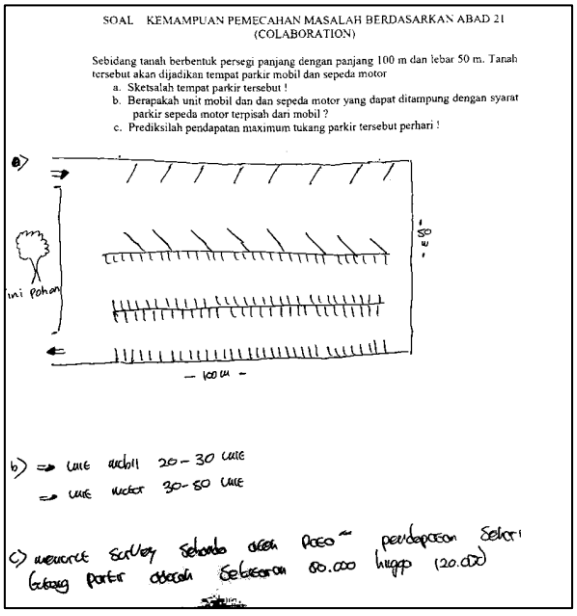
**Table 1.** Assessment rubric about problem-solving

| Components | SCORE | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| 1. The solution for size problem | No correct answer | Few correct answers (at least two components) | Most answers are correct (at least four components) | Perfect answer includes all six components:<br>1) Parking lot width<br>2) Parking lot length<br>3) Car parking distance<br>4) Motorcycle parking distance<br>5) Vehicle entrance way measurement<br>6) Vehicle exit path measurement |
| 2. The solution for Vehicle number problem | No correct answer | Few correct answers | Most answers are corrects | Perfect answer |
| 3. The solution for Parking man income problem | No correct answer | Few correct answers | Most answers are corrects | Perfect answer |
| 4. Creativity | Not creative | A bit creative | Creative | Very creative |
| 5. Tidiness | Not tidy | A bit tidy | Tidy | Very tidy |

## 3. Results and discussions

The results showed that out of 22 subjects or 11 groups of the research, no subject achieved 'very good' and 'good' category of the problem-solving skills. However, four groups had 'adequate' problem-solving skills and seven groups had 'poor' problem-solving skills.

Figure 2 and 3 show the answers of two students representing the 'adequate' category of problem-solving skills.



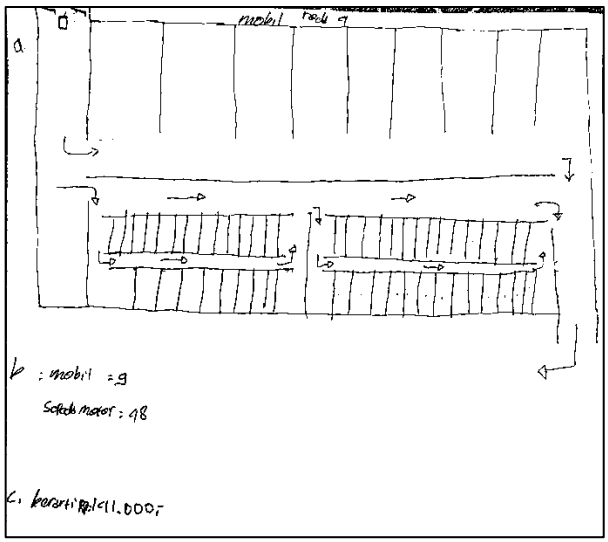

*Translation:*

There is a rectangular land, 100 m long and 50 m wide. The land will be used as a parking area for cars and motorcycles.
a. Sketch out the parking area!
b. How many units of cars and motorcycles can be accommodated in the land, with the condition that motorcycle parking is separate from the car?
c. Predict the maximum income of the parking man per day!

The answer
a. Sketch
b. 20-30 car units and 30-50 motorcycle units
c. According to a survey across Banda Aceh, the average daily parking income of the parking lot is around IDR. 80,000- Rp. 120,000

**Figure 2.** Answer from the student with 'adequate' skill

Figure 2 presents the work of RA and IQ, one study group with 'adequate' skills. For problem (a), in terms of drawing, they are in the 'creative' category group because they positioned the car and the motorcycle parking lot well. However, they did not specify the distance between the car and motorcycle, nor they determined the car and motorcycle entrance-exit path. They cannot specify the parking distance due to the lack of understanding of a vehicle parking area; they only drew both car and motorcycle parking lot. For problem (b), due to the lack of understanding of the parking distance, they cannot calculate how many cars and motorcycles that the parking lot could accommodate. For problem (c), based on their survey, the calculation was wrong due to their mistake in measuring the area of the parking lot and the number of vehicles.



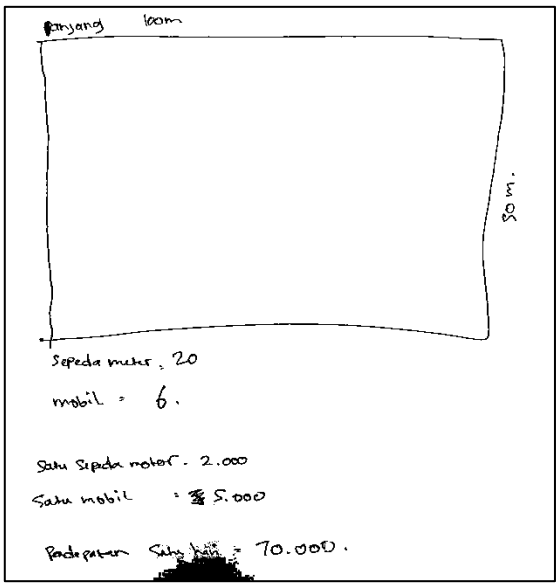
*Translation:*

The answer
a. Sketch
b. Nine cars and 48 motorcycles
c. Total income of the parking man is IDR. 141,000

**Figure 3**. Answer from the student with 'adequate' skill

Figure 3 displays the work of KA and MU, the second group with 'adequate' skill. In terms of drawing, they had drawn the parking lot better than the previous group. However, this group also did not specify the vehicle parking distance. In term of the vehicle calculation, based on the interview, they calculated the total vehicle by analyzing the parking position that they had drawn. For calculating the daily income, based on the interview, they calculated the income by multiplying the number of vehicles by the parking fee, and both results of car and motorcycle fee were added. The 'poor' problem-solving skills answer can be seen in Figure 4.

Figure 4 illustrates the work of SA and RM, one of the groups with 'poor' problem-solving skills. In the drawing stage, they cannot draw the parking lot; they only drew a rectangle and added the information provided from the problem. They also did not draw the specific location for car or motorcycle parking area. They seemed not to understand the problem and were less creative in solving the problem. As for the number of vehicles, the parking lot could accommodate, they obtained the result by guessing. For the daily income calculation, they calculated the income by multiplying the parking fee by the number of both types of vehicles before adding them.




*Translation*

The answer
a. Sketch
b. Six cars and 20 motorcycle
c. one motorcycle IDR.2,000
   one car is IDR.5,000
   one day income of IDR. 70,000

**Figure 4**. Answer from the student with 'poor' skill

Based on the student answers described, the student score on the problem-solving skills test can be seen in Table 2.

**Table 2**. The result of the problem-solving skills test

| No | Name | Observed aspects | | | | | Average |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | |
| 1 | RA & IQ group | 2 | 1 | 1 | 3 | 2 | 1.8 |
| 2 | KA & MU group | 1 | 1 | 1 | 3 | 2 | 1.6 |
| 3 | SA & RM group | 2 | 1 | 1 | 1 | 1 | 1.2 |

Table 2 shows that RA and IQ group had an average score of 1.8, and they were classified as the 'adequate' category. This group obtained the highest point on the creativity aspect because they had drawn the parking lot creatively. Same goes for KA & MU group; they also obtained the highest score on the creativity aspect.

Based on the results of data analysis, it was found that students had difficulty in solving the problem because of their inability to understand problems and solve the word problem. Sulistiyorini and Setyaningsih [16] found that in the process of learning mathematics, many students have difficulties in solving mathematics problems. The difficulties may be due to the student not paying attention to the steps in solving the problem [16]. In the case of mathematics problems, it is important to understand the steps of problem-solving.

The difficulty in solving the problem is also because students are not accustomed to learning with non-routine problems. This is an effect of the model applied by the teacher. Buschman [17] explained the causes of student difficulties in solving mathematical problems is the inappropriate learning model applied the teacher.

Students also have difficulty in determining measurements of the sketch due to their lack of understanding in designing mathematical models. The students' challenges in solving problems are due to the lack of the problem understanding, difficulties in designing mathematical model, and difficulties in identifying the given information from the problem [18].

The students' difficulties in estimating the number of vehicles to accommodate in the parking area are also due to their inability to bring abstract mathematics into the concrete. According to Dhlamini [19], the cause of difficulties is the inability of students to bring mathematics to the concrete domain. In financial mathematical problems, students must not only identify relevant information but also simultaneously match certain answers with appropriate symbols and also build relationships between them.

## 4. Conclusion

The results showed that out of 22 subjects or 11 groups of the research, no subject achieved 'very good' and 'good' category of the problem-solving skills. However, four groups had 'adequate' problem-solving skills and seven groups had 'poor' problem-solving skills.

The student with 'adequate' problem-solving skills could determine the main idea, analyzing the problem, and use the given information to provide the solution to the problem. The student with 'poor' problem-solving skill could not determine the main idea nor analyze the problem. They also were not able to determine the use of given information to provide a solution to the problem. Hence, their problem analysis was poor.

This research did not find any student group with 'good' or 'very good' problem-solving skills due to the lack of student experiences in solving non-routine problems with a 21$^{st}$-century education.

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