An analysis of problem solving ability among high school students in solving linear equation system word problems

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Abstract. Problem solving is a high-level thinking ability that can be developed through mathematics learning. Therefore, problem solving ability is one of the factors to achieve the goals of mathematics learning. This study aims to analyze a problem solving ability of Senior High School students in solving linear equation system word problems. This study was descriptive qualitative involving 10 students of SMA Negeri 2 Pati, 10 students of SMA PGRI 1 Pati, and 10 students of SMA Nasional Pati as the subject of research. The research variable was indicators of problem solving abilities, namely: identifying data known and asked, choosing the right problem solving strategies, solving the mathematical model, and checking the solution that had been obtained. The data were collected using a test and an interview. The result showed that 3 students (10%) categorized as excellent, 8 students (26.67%) categorized as very good, 6 students (20%) categorized as good, 5 students (16.66%) categorized as fair and 8 students (26.67%) categorized as poor. Students categorized as excellent fulfilled all indicators, students categorized as very good fulfilled all indicators but incomplete, students categorized good fulfilled first, second and third indicators, students categorized fair fulfilled first, second and third indicators but incomplete, and students categorized poor only fulfilled first and second indicator.

1. Introduction

Mathematics is one of the sciences that has an important role in the education field. Mathematics is known as a queen of science because mathematics can generate other sciences such as physics, chemistry, geography and many other [1]. However, mathematics is often considered as difficult and frightening lesson for students. Most of the students are not interested in joining the lesson.

Mathematics is one of the most important subjects that is so instrumental in advancing the civilization of a nation, mathematics can be interpreted as a study of patterns and relations, a path or thinking pattern, an art, a language, and a tool, therefore mathematics is not a solitary knowledge, but its existence to assist human beings in understanding and mastering various other problems [2]. For that reason, mathematics in schools needs to function as a means to develop intelligence, ability, skills to shape students’ personalities.

One of the most important goals for teaching is teaching students to use basic facts and concepts in flexible way so that they can deal with new situations, predict various consequences and solve problems [3]. Problem solving is a high-level thinking ability that can be developed through mathematics learning. In other words, mathematics learning process emphasizes problem solving abilities. Therefore, problem solving ability is one of the factors to achieve the goals of mathematics learning. In classroom situations, problem solving can be viewed from two angles, which are: a way of thinking and a way of teaching [3]. Sometimes teachers emphasize more to memorize formulas in
order to solve problems such as math, although sometimes this method is considered to be more instantaneous but it actually inhibits the development of students’ reasoning and creativity [4].

Problem-solving is one of the very important ability in science learning [5, 6]. The goal of mathematics learning, especially problem solving, is to build new mathematical knowledge through problem solving, solving problems that arise in mathematics and in other contexts, able to apply and adapt various appropriate strategies to solve a problem and to monitor and reflect on the process of solving mathematical problems [7]. Problem-solving skills used in solving problems of science in mathematical form and solves the problem of phenomena happens in the environment [8].

Problem-solving is one of the skills that students must develop to meet the digital era in addition to critical thinking skills, creativity, innovation, communication and collaboration [9]. But in fact, students experiencing difficulties because of the strategies taught in learning only to solve problems that require mathematical calculations [10].

Studying mathematics means learning to solve problems, both problems related to everyday problems as well as solving mathematical problems themselves [11]. Problem solving activities consist of four steps, namely: (1) understanding of the problem (See), (2) planning the problem solving (Plan), (3) carrying out the plan (Do), and (4) checking the solution (Check) [12].

The problem which was used in this research is contextual type problem. The student chosen as the research’s subject were from class X of SMA Negeri 2 Pati, SMA PGRI 1 Pati, and SMA Nasional Pati. This study aims at analyzing problem solving ability of Senior High School students in solving linear equation system word problems. Analysis of mathematical problem solving ability in this study based on problem solving’s modification indicator. Problem solving ability stands for identifying data known and asked, choosing the right problem solving strategies, solving the mathematical model, and checking the solution that had been obtained. This research is used to investigate, categorize, and analyze students’ problem solving ability in solving linear equation system word problems which can be used as a basis to improve the learning process.

2. Method
The study is descriptive with qualitative approach. This study focuses on the thinking process of the senior high school students in solving mathematics word problems about linear equation system. The subjects of the study are ten students of class X SMA Negeri 2 Pati, ten students of class X SMA PGRI 1 Pati, and ten students of class X SMA Nasional Pati. There are selected using a random sampling technique to be the research subjects. The research variable is indicators of problem solving abilities, namely: identifying data known and asked, choosing the right problem solving strategies, solving the mathematical model, and checking the solution that had been obtained. Furthermore, an interview with the students is conducted to know more about the strategies used when they answering the questions. A description of the modification of problem solving indicators used in this research is shown in Table 1.

| No | Indicators                                      | Description                                                                 |
|----|------------------------------------------------|-----------------------------------------------------------------------------|
| 1  | Identifying data known and asked                | a. Students write down the information of data known                        |
|    |                                                | b. Students write down the information of data asked                        |
| 2  | Choosing the right problem solving strategies   | a. Students write mathematical models                                      |
| 3  | Solving the mathematical models                 | a. Students do the process of finding solutions and doing calculations      |
| 4  | Checking the solution that had been obtained    | a. Students interpret the final answer by writing conclusions               |
|    |                                                | b. Students check the right solution to the initial problem                |
The triangulation is used to confirm the findings of data. The confirmed data process is done by comparing information or data of test result and interview. The data analysis’ stages in this study involve: (1) giving word problems test about linear equation system to the students; (2) analyzing the test’s results; (3) conducting interviews with some students from several levels; and (4) analyzing the result of interview. The final step is drawing conclusions. In this step, researcher draws conclusions from data analysis result which has been done before.

3. Results and Discussion

3.1. Results

The analysis result of students test’s answer using problem solving indicators among 30 different senior high school students. The results shows that students who fulfilled the first indicator identifying data known and asked is 83.33%, choosing the right problem solving strategies indicator is 50.83%, indicator of solving the mathematical models is 58.33%, and indicator of checking the solution that had been obtained is 26.25%. The summary of the results shows in Table 2.

| Table 2. Percentage of Problem Solving Ability in Senior High School |
|-------------------------|------------------|------------------|------------------|
| Indicator               | Problem 1 | Problem 2 | Percentage |
|-------------------------|-----------|-----------|------------|
| Identifying data known and asked | 92.78%    | 73.89%    | 83.33%     |
| Choosing the right problem solving strategies | 70%       | 31.67%    | 50.83%     |
| Solving the mathematical models | 76.67%    | 40%       | 58.33%     |
| Checking the solution that had been obtained | 39.17%    | 13.33%    | 26.25%     |

Based on table 2, there are two problems that will be analyzed. Each problem will be explained as follows. Problem 1 related to linear equation system material to the 10th grade of Senior High School.

The problem of number 1 as follows:
A stationary store sells a pencil for Rp2,500.00, and an eraser at a price of Rp1,500.00. If Nata pays Rp22,000.00 and wants 10 items from both, determine how many items that Nata can buy.

The results showed that the percentage of students who fulfilled the first indicator of question number 1 is 92.78 percent. The students were able to identify the information of data known and asked correctly. Figure 1 shows that this student (AM) wrote down the known things in the given problem, but did not write what is asked. Subject did not write what is asked of the problem number 1, because AM still writes the information given of data known.

The second indicator, choosing the right problem solving strategies on problem 1 can only be fulfilled by 70% of students. The following of figure 1 shows the results of student works related to the first indicator.

Figure 1. Test’s result of AM on problem 1.

Step 1: Write down the information of data known from the problem
Pencil: Rp2,500.00
Eraser: Rp1,500.00
Nata pay Rp22,000.00

Step 2: Write down the information of data asked from the problem
Nata wants 10 items from both

Step 3: Write down the mathematical models
\[ Pencil = a \ (1) \ 2,500a + 1,500b = 22,000 \]
\[ Eraser = b \ (2) \ a + b = 10 \]

Figure 2. Test’s result of PIK on problem 1.
Figure 2 shows that this student (PIK) wrote down all of mathematical models of the problem number 1.

The third indicator, solving the mathematical models on problem 1 with various alternatives, achieved by 76.67% of students. The following of figures 3, 4, 5 and 6 are some alternatives which were used by the other students to solve the given problem.

Figure 3. Test’s result of KAMDH on problem 1.

Figure 4. Test’s result of RDT on problem 1.

Figure 5. Test’s result of MSA on problem 1.

Figure 6. Test’s result of R on problem 1.
The number of ways students used to solve the given problem in the test number 1 is 4. In Figure 3 student eliminates the value of \( x \) (pencil) by simplifying equation 1 first which is one known things in problem. In Figure 4, student eliminates the value of \( y \) (eraser), then substitutes the value of \( y \) into equation 2, so the value of \( x \) (pencil) can be found. In Figure 5, student eliminates equation 1 and 2 to find both value of \( a \) (pencil) and \( b \) (eraser). In Figure 6, student only write down the value of each variable, without computing.

Subject R did not write down the information of data known and asked from problem 1. The subject did not write mathematical models that can be formed from the problem. The subject assumes that the problem can be done using logic without doing calculations. The subject also do not interpret the final answer by writing conclusion or checking the correct solution to the initial problem. Subsequently, the interview was conducted on subject with poor categories (R) to confirm the subject’s responses. Furthermore, the result of first interview can be seen in table 3.

| Code | Interview Result |
|------|------------------|
| Q1   | “From problem 1, have you identified and written down the information given? Could all the information obtained be used to answer the question?” |
| A1   | “I did not write the information given. Because I think it is useless, so I use logical to answer it.” |
| Q2   | “So, what about write down the information of data asked from the problem. Have you written it?” |
| A2   | “No, I have not written it.” |
| Q3   | “Then, how can you solve the problem if only use your logical? Is it means without computing when you solve it?” |
| A3   | “I use trial and error in my logic, neither elimination nor substitution. And, I got the answer 7 for pencil, 3 for eraser.” |
| Q4   | “Is that just the values of variables you get? Have you written the conclusion of the final answer or checking the answer to the initial problem?” |
| A4   | “Yes, just it. No, I have not, neither written conclusion nor checking the answer.” |

The fourth indicator on problem 1 achieved by 39.17% of students as subject research. Most students do not interpret the final answer by writing conclusions. They only found the values of what is asked from the problem, either using elimination and substitution or logical. They also do not check the correctness of the solutions. Most of the students do the same analysis that only see the final results that have been done without interpret and checking the answer. Furthermore, summary of students’ results on problem 1 can be seen in Table 4.

| Indicator                                      | Amount of Students’ Score | Maximum Score | Percentage  |
|------------------------------------------------|---------------------------|---------------|-------------|
| Identifying data known and asked               | 167                       | 180           | 92.78%      |
| Choosing the right problem solving strategies  | 42                        | 60            | 70%         |
| Solving the mathematical models                | 69                        | 90            | 76.67%      |
| Hecking the solution that had been obtained    | 47                        | 120           | 39.17%      |

Problem number 2 related to linear equation system material. The problem of number 2 as follows: “Aneka Kue” store enforce honesty buying and selling systems in their store for every buyer who buys layer cakes and donuts. The price of one layer cake is Rp2.000.00 and the price of donut is
Rp2,500.00. One day Alya checked the money in the honesty box. She gets money in the honesty box of Rp75,000.00. Determine the possibility of layer cakes and donuts sold.

In question number 2, students only reached 73.89 percent on the first indicator. The example of student work results related to the first indicator can be seen in figure 7.

**Step 1:** Write down the information of data known from the problem
- price of one layer cake: 2,000,00
- price of one donut: 2,500,00
- money in the box of honesty: Rp75,000,00

**Step 2:** Write down the information of data asked from the problem
- Determine the possibility of layer cakes and donuts sold?

**Figure 7.** Test’s result of TA on problem 2.

Student (TA) in figure 2 wrote down all of data known from the problem given and what is asked from the question number 2. In problem 2, students only achieved 31.67% on second indicator. The results of student works related to the second indicator can be seen in figure 8.

**Step 3:** Write down the mathematical models
- Suppose = layer cake = \( x \)
- Donuts = \( y \)

**Figure 8.** Test’s result of NF on problem 2.

Student (NF), in Figure 8, only wrote down what is known of mathematical models of question number 2.

The third indicator, solving the mathematical models on problem 2 with various alternatives, only achieved 40% by the students. The following figures are some alternatives which were used by the other students to solve the problem.

**Step 4:** Write down all the solutions to the mathematical model you have made
- Layer cake \( x \) = 2000 \( \text{suppose}=10 \)
- Donuts \( y \) = 2500

\[
20000x + 2500y = 75000
\]
\[
2000.25 + 2500y = 75000
\]
\[
5000 + 2500y = 75000
\]
\[
2500y = 75000 - 50000
\]
\[
2500y = 75000 - 20000
\]
\[
2500y = 75000 - 20000
\]
\[
2500y = 55000
\]
\[
2500 + 2500
\]
\[
y = \frac{2500}{2500}
\]
\[
y = 10 \text{ cakes}
\]
\[
y = 22 \text{ layer cakes}
\]

**Figure 9.** Test’s result of CCS on problem 2.

**Step 4:** Write down all the solutions to the mathematical model you have made
- Layer cake = 2000 \( \times 20 = 40,000 \)
- Donuts = 2500 \( \times 14 = 35,000 \) + 

\[
75,000
\]

**Figure 10.** Test’s result of LRA on problem 2.
The number of ways students used to solve question number 2 is 2 ways. More students use trial and error to solve it. Then, they substitute one of variable value that had been obtained into other mathematical model. For example, from Figure 9, student assumes the value of \( x \) variable is 10, then substitutes it into mathematical model and get the value of \( y \) variable is 22. This is also done on the second possible answer of the student. In figure 10, student does calculations by trial and error. Subject write the value of each variable, then multiply it, and get result from the sum of the two variables.

Subject CCS wrote down the information of data known and asked from problem 2. The subject write mathematical models that can be formed from the problem. The subject assumes the problem can be done using trial and error. The subject also does not interpret the final answer by writing conclusion or checking the correct solution to the initial problem. Subsequently, the interview was conducted on subject with very good categories (CCS) to confirm the subject’s responses. The result of the interview can be seen in Table 5.

### Table 5. The Result of Second Interview’s Activity.

| Code | Interview Result |
|------|------------------|
| Q5   | “From problem 2, have you identified and written down the information given? Could all the information obtained be used to answer the question?” |
| A5   | “Yes, I have write the information given. Indirectly, the information gives me instruction to answer the question.” |
| Q5   | “So, what about write down the information of data asked from the problem. Have you written it?” |
| A5   | “Yes, I have written it.” |
| Q6   | “Have you written the conclusion of the final answer or checking the answer to the initial problem?” |
| A6   | “No, neither written conclusion nor checking the answer, I just do trial and error to solve the problem.” |

The fourth indicator only fulfilled by 13.33% of students. They do not interpret the final answer by writing conclusions. They only find the values of what is asked from the problem. They also do not check the correctness of the solutions. They do the same analysis that only see the final results that have been done without interpret and checking the answer. Furthermore, summary of students’ results on problem 2 can be seen in Table 6.

### Table 6. Percentage of Students’ Problem Solving Ability in Senior High School on Problem 2

| Indicator                                      | Amount of Students’ Score | Maximum Score | Percentage |
|-----------------------------------------------|----------------------------|---------------|------------|
| Identifying data known and asked              | 133                        | 180           | 73.89%     |
| Choosing the right problem solving strategies | 19                         | 60            | 31.67%     |
| Solving the mathematical models               | 36                         | 90            | 40%        |
| Checking the solution that had been obtained  | 16                         | 120           | 13.33%     |

From the result determining the percentage of students’ problem solving ability with 30 subject students hence get excellent category as many as 3 students, the number of students who categorized very good are 8 students, the number of students who categorized as good is 6 students, the number of students who categorized as fair level are 5 students and the number of students who categorized as poor level are 8 students. The following of table 7 will describe the summary of Senior High students’ achievement based on problem solving indicators and the results of determining problem solving level.
Table 7. Problem Solving Level Determination of Senior High Students’ Result

| No | Name     | Indicator Analysis | Level   |
|----|----------|--------------------|---------|
| 1  | A M      | ✓ ✓ ✓ ✓ ✓ ✓        | Good    |
| 2  | C A N    | ✓ ✓ ✓ ✓ ✓ ✓        | Good    |
| 3  | K A M D H| ✓ ✓ ✓ ✓ ✓ ✓        | Excellent|
| 4  | M A N    | ✓ ✓ ✓ ✓ ✓ ✓        | Very good|
| 5  | R F A F  | ✓ ✓ ✓ ✓ ✓ ✓        | Good    |
| 6  | S M H S  | ✓ ✓ ✓ ✓ ✓ ✓        | Good    |
| 7  | A D P    | ✓ ✓ ✓ ✓ ✓ ✓        | Good    |
| 8  | D T      | ✓ ✓ ✓ ✓ ✓ ✓        | Poor    |
| 9  | M F R P  | ✓ ✓ ✓ ✓ ✓ ✓        | Poor    |
| 10 | R Z      | ✓ ✓ ✓ ✓ ✓ ✓        | Poor    |
| 11 | A K N    | ✓ ✓ ✓ ✓ ✓ ✓        | Excellent|
| 12 | C C S    | ✓ ✓ ✓ ✓ ✓ ✓        | Very good|
| 13 | N F      | ✓ ✓ ✓ ✓ ✓ ✓        | Very good|
| 14 | S S      | ✓ ✓ ✓ ✓ ✓ ✓        | Excellent|
| 15 | R D T    | ✓ ✓ ✓ ✓ ✓ ✓        | Very good|
| 16 | T A      | ✓ ✓ ✓ ✓ ✓ ✓        | Very good|
| 17 | V A P    | ✓ ✓ ✓ ✓ ✓ ✓        | Very good|
| 18 | D Y G    | ✓ ✓ ✓ ✓ ✓ ✓        | Poor    |
| 19 | M A S    | ✓ ✓ ✓ ✓ ✓ ✓        | Very good|
| 20 | P I K    | ✓ ✓ ✓ ✓ ✓ ✓        | Very good|
| 21 | A S      | ✓ ✓ ✓ ✓ ✓ ✓        | Poor    |
| 22 | A P L    | ✓ ✓ ✓ ✓ ✓ ✓        | Poor    |
| 23 | F R      | ✓ ✓ ✓ ✓ ✓ ✓        | Fair    |
| 24 | L R A F  | ✓ ✓ ✓ ✓ ✓ ✓        | Poor    |
| 25 | R        | ✓ ✓ ✓ ✓ ✓ ✓        | Poor    |
| 26 | S Y L    | ✓ ✓ ✓ ✓ ✓ ✓        | Fair    |
| 27 | L A P    | ✓ ✓ ✓ ✓ ✓ ✓        | Fair    |
| 28 | M N P    | ✓ ✓ ✓ ✓ ✓ ✓        | Fair    |
| 29 | R N P    | ✓ ✓ ✓ ✓ ✓ ✓        | Poor    |
| 30 | T S R    | ✓ ✓ ✓ ✓ ✓ ✓        | Good    |

From the table can be summarized as the percentage of students who categorized as excellent were 10%, 26.67% as very good, 20% as good, 16.66% as fair and 26.67% as poor.

3.2. Discussion

The results shows that students in general can solve the problem based on problem solving indicators. They try to identify the information on problem, solve the problem by answering questions through mathematical models that have been written or checking the solutions, although in practice, the problem solving is not all done well.

Students who categorized as excellent often solve the problems given correctly, although the results obtained are not quite optimal. Students with excellent category had been able to identify the information from the problem correctly. Besides that, excellent category students also written what is
asked on the problems, make mathematical models and doing computation, and checking the solutions that have been done.

Students with very good categories can solve the problems given, although the results obtained are not optimal. Students with very good category have been able to identify the information from the problem correctly. They also written what is asked on the problems correctly, make mathematical models and doing computation although not quite correct, and checking the solutions that have been done although not quite complete.

Students with good level solve the problems given by write the information of data known and asked correctly but incomplete. They can make mathematical models from the problem, but not complete. They also doing computations, but not expected as yet. They check the correctness solution, but they do not interpret the final answer by writing conclusions.

Students with fair categories have tried to solve the problems given, although less precise. Students with fair categories try to identify and write the information of data known and asked correctly, although incomplete. They have written the mathematical models and doing computations, but do not write the conclusion of the final answer that have been obtained.

Meanwhile, the students with poor category said that they had never made any illustration to solve problems. The problem solving indicators they used from the highest to the lowest frequency are: identify the information of data known and asked, solving the mathematical models, choosing the right strategies, and checking the truth. We can see that the indicator of choose the right strategies and solve the mathematical problems still become the rarest indicator they use to solve problem.

Based on the results of the analysis, different student answers are caused by a variety of influencing factors. One of the factors that influence was the way of students think less systematically. This is in line with [20], one of the factors in the problem-solving process is students’ way of thinking. It can be seen that the results of the research is most of students not able to solve mathematical models and check the truth correctly. The low of problem solving ability caused by students only memorize formulas instead of understanding concepts [13]. Students have difficulty understanding the intent of the problem, formulating what is known from the problem, student completion plan is not directed and the calculation process or resolution strategy of the student’s answer is incorrect [14].

To overcome this problems, some efforts should be made by teachers to improve students’ problem solving abilities by linking learning activities with contextual problems. This is in line with [15,16], learning strategy using contextual context is one of learning strategy that can be used to improve students’ concept understanding in problem solving process. If the learning activities are not related to contextual problems, students feel unfamiliar with the problem given. So, students cannot visualize the problem well and have an impact on low problem solving ability.

Problems in mathematics are questions in mathematics to be solved [17, 18]. Studying mathematics means learning to solve problems, both problems related to everyday problems as well as solving mathematical problems themselves [11]. Therefore, choosing the right strategies’ process aims to develop a meaningful learning process which will make students have flexibility decisions in solving mathematical problems. Students with flexibility in problem solving will either solve the problem with various strategies [19]. In addition, teachers, especially mathematics teachers should be attention of learning process, not only focuses on result, so students can develop their knowledge and improve their problem solving ability.

4. Conclusions
Based on the result of the analysis and discussion, the determination of students’ problem solving level in solving linear equation system word problems can be concluded. The number of students of SMA Negeri 2 Pati, SMA PGRI 1 Pati, and SMA Nasional Pati in X grade who categorized in excellent level as many as 3 students or 10% of the total students as research subject, the number of students who categorized in very good level is 8 students or 26.67% of the total students as research subject, the number of students who categorized in good level is 7 students or 23.33% of the total students, the number of students who categorized in fair level is 5 students or 16.67%, and the number of students who categorized in poor level is 7 students or 23.33% of the total students as research subject.
Students categorized as excellent fulfilled all indicators, students categorized as very good fulfilled all indicator but incomplete, students categorized good fulfilled first, second and third indicators, students categorized fair fulfilled first, second and third indicators but incomplete, and students categorized poor only fulfilled first and second indicator.

Most of the students not able to solve the mathematical models and check the result yet which influence the interpretation result. Thus, efforts can be made to improve students’ problem solving abilities by linking learning activities with contextual problems. Besides that, choosing the right strategies’ process aims to develop a meaningful learning process which will make students have flexibility decisions in solving mathematical problems.

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