

## PROBLEM-SOLVING PROCESS OF PRE-SERVICE MATHEMATICS TEACHERS IN STATISTICS

Ratri Rahayu<sup>1\*</sup>, Himmatul Ulya<sup>2</sup>, Evanita<sup>3</sup>

<sup>1-3</sup>Universitas Muria Kudus, Indonesia

[ratri.rahayu@umk.ac.id](mailto:ratri.rahayu@umk.ac.id)<sup>1</sup>, [himmatul.ulya@umk.ac.id](mailto:himmatul.ulya@umk.ac.id)<sup>2</sup>, [evanita@umk.ac.id](mailto:evanita@umk.ac.id)<sup>3</sup>

\*Correspondence: [ratri.rahayu@umk.ac.id](mailto:ratri.rahayu@umk.ac.id)

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### Abstract

Problem-solving skills are essential for pre-service mathematics teachers as a foundation for guiding students in addressing mathematical challenges. However, students' problem-solving abilities in statistics courses remain relatively low. This study aims to analyze the problem-solving processes of pre-service mathematics teachers in a statistics course at Universitas Muria Kudus, Indonesia, based on their levels of problem-solving ability. Employing a qualitative–exploratory design, data were collected through statistical problem-solving tests and in-depth interviews, and then analyzed using Miles and Huberman's qualitative framework, which involves data reduction, data display, and conclusion drawing. Thirty-three students participated and were categorized into five ability levels. The results indicate that students with very high abilities demonstrated systematic reasoning, accurate hypothesis testing, and reflective evaluation. Students with high abilities completed calculations correctly, but often neglected modelling and identification of known elements. Those with moderate abilities could represent and solve problems, but they often skipped strategic planning. Meanwhile, students with low and very low abilities relied mainly on procedural computation without conceptual understanding. The study provides valuable insights for improving pedagogical strategies to strengthen statistical problem-solving competence among pre-service mathematics teachers.

**Keywords:** mathematical thinking, pre-service teachers, problem-solving, qualitative analysis, statistics education

### Introduction

Mathematics is the mother of all branches of science and the basis of all scientific research, as most scientific and engineering problems require mathematics to be solved (Genc & Erbas, 2019; Kenedi et al., 2019; Muhtadi et al., 2018). Mathematics can be described as a formal science that uses symbolic language to study concepts such as numbers, structure, variation, and space. Today, mathematics is used in various fields, from engineering to medicine, and is taught as a compulsory subject for primary schools in many countries (Lee, 2017; Rahman & Ahmar, 2016). One of the main focuses of learning mathematics is problem-solving ability (Ai Hui et al., 2020; Alfin et al., 2019; Foshay & Kirkley, 2003; Jonassen, 2010; Susantini et al., 2016). Problem-solving skills are important to be developed in the curricula of the 21st century (Aydogdu & Kesan, 2014; Shabrina & Kuswanto, 2018) due to one of the main focuses of learning mathematics being



problem-solving skills (Ai Hui et al., 2020; Foshay & Kirkley, 2003; Jonassen, 2010). Learning mathematics may never be meaningful without problem-solving (Maf'ulah & Juniati, 2020).

Problem-solving ability is the ability to solve routine and non-routine problems, both applied and non-applied, in the field of mathematics (Lestari & Yudhanegara, 2017). Finding solutions to problems, or problem-solving, occurs through higher-order thinking skills (Nitko & Brookhart, 2011). Problem-solving requires thinking skills, including observing, reporting, describing, analyzing, classifying, interpreting, criticizing, predicting, drawing conclusions, and generalizing (Moore, 2012). Problem-solving ability is the ability to solve routine and non-routine problems, both applied and non-applied in the field of mathematics (Lestari & Yudhanegara, 2017).

Many experts have suggested stages/strategies/problem-solving steps. Polya suggests four steps of problem-solving, which have been widely used, namely understanding the problem, designing a plan to solve the problem, implementing the plan, and reflecting on the problem (Lee, 2017). Sternberg (Nguyen, 2009) reveals that a person's cycle in solving problems includes activities: (1) identifying the problem, (2) defining the problem, (3) constructing a strategy to solve the problem, (4) organizing information about the problem, (5) allocating resources and sources, (6) monitor problems, and (7) evaluate problem-solving. Problem-solving is a process that requires higher-order thinking skills. To be able to solve problem-solving problems, students use the stages: reading and understanding, analyzing and planning, organizing a strategy or organization on particular cases, solving the problem, confirming the process, and accepting the answer (Pujiastuti et al., 2018). In this study, the problem-solving steps that will be used as a reference for process analysis are: (1) read and understand the problem; (2) make mathematical models; (3) representing the problem; (4) finding the goal; (5) constructing problem-solving strategies; (6) solve the problem, and; (7) confirming the answer.

It is also important to develop problem-solving skills for students. Prospective mathematics teacher students need to understand and learn about the ability to design learning, implement learning, and evaluate learning outcomes, especially to explore problem-solving, so that later, after becoming a teacher, they can learn well and professionally (Nugroho et al., 2020). The reality on the ground shows that the problem-solving ability of prospective mathematics teacher students at Universitas Muria Kudus is still low. This is based on the results of the problem-solving ability test given to prospective teacher students. The test results showed that only 33% of students scored above the minimum criteria, and the remaining 67% of students scored below. Based on the results of interviews with prospective teacher students, it is known that the causes of their low problem-solving abilities include: (1) students have not been able to develop their ability to solve problems; (2) not familiar with non-routine questions; (3) difficulty in solving the given mathematical problem.

Seeing the importance of problem-solving skills, the researchers analyzed the statistical problem-solving process of students in terms of problem-solving abilities. The purpose of this study was to analyze the problem-solving process of research statistics courses from students of the mathematics education study program at Universitas Muria Kudus in terms of mathematical ability.

## Method

This research is qualitative-exploratory research. The researcher conducted an exploration of the students of the major in Mathematics Education at Universitas Muria Kudus. A total of 33 students were involved in this study. Students are given a problem-solving ability test in the statistics course, which is then grouped into 5 categories based on the test results. The next research step is to choose 1 subject from each problem-solving category who can provide information consistently. In-depth interviews were conducted on research subjects so that information was obtained about students' thinking processes in solving problems.

The instruments used in this research are problem-solving test result documents and interview sheets. The statistical problem-solving ability test consists of five questions in the form of a description. The interview sheet contains questions that contain students' thinking processes in solving problems based on problem-solving steps, namely: (1) read and understand the problem; (2) make mathematical models; (3) representing the problem; (4) finding the goal; (5) constructing problem-solving strategies; (6) solve the problem, and; (7) confirming the answer.

Data were obtained from the results of problem-solving ability tests and in-depth interviews with research subjects. The data from the problem-solving ability test are then grouped into the five categories referring to the rating scale in Table 1 (Arikunto, 2013).

Table 1. Criteria for Problem-solving Ability Test Score

Range	Category
$80 \leq score \leq 100$	Very High
$65 \leq score \leq 79.99$	High
$55 \leq score \leq 64.99$	Medium
$40 \leq score \leq 54.99$	Low
$0 \leq score \leq 39.99$	Very Low

The credibility of the data obtained by triangulation techniques, namely, interviews, was compared and explored to compare and explore information about students' problem-solving steps. The data analysis technique used refers to Miles et al. (2014), namely data reduction, data presentation, and conclusions.

## Findings and Discussion

The results of the statistical problem-solving ability test conducted on 33 students are presented in Table 2. The results of the test showed that there were 7 students with very high and high categories, 2 students who got the medium category, 5 students in the low category, and 12 students belonging to the very low category.

Table 2. Test Results of Problem-Solving Ability

Category	Number of Students
Very High	7
High	7

Medium	2
Low	5
Very Low	12

The test results indicate that the statistical problem-solving ability of students in the mathematics education study program is still low. The following are the results of the analysis of student problem-solving processes in each category.

### ***Problem-Solving Process of Students with Very High Problem-Solving Ability***

Based on the analysis of research data shows that students have very high mathematical problem-solving abilities (PS1 subject) in each stage of problem-solving (understanding the problem, developing a plan of completion, implementing a plan of completion, and re-examining). At the stage of reading and understanding the problem, the PS1 subject was able to analyze the problem by writing down what was known and asked in the question.

From the answers of PS1 subject, it was discovered that students with very high problem-solving abilities can understand problems. It was shown that students could find out the dependent variable and the independent variable in the problem. The ability to understand problems by PS1 subject was influenced by experiences in working on problem-based questions.

An individual's ability to identify a given problem is influenced by the individual's own experience and knowledge (Allport, 1960). Experience and knowledge stored in memory will affect each individual in response to the stimulus that comes (Gagne, 1985). Experience will give the shape and structure of objects described by the senses, while knowledge will give meaning to objects, individuals, and people involved in the answers to the available answers in the form of individual attitudes and behavior towards existing objects (Allport, 1960). Gagne (1985) also explains that a person's understanding depends on how much the individual has studied the stimulus or previous learning.

In the stage make mathematical model, the student tried to find keywords and then wrote them down in a mathematical model. The indicator at this stage was that students were able to write examples of sentence questions into mathematical models. This is in accordance with Figure 1. PS1 subject assumed  $Y$  as the dependent variable,  $X_1$  and  $X_2$  as the independent variables.

The next stage was representing the problem. PS1 subject could choose the right representation according to the problem presented. The representation used by PS1 subject was a mathematical expression symbolized by  $x$  and  $y$ , and they used a table to write down the elements needed to solve the problem. In this stage, finding the goal, the student began to formulate the goals of problem-solving. PS1 subject was able to write down what was asked in the question and the research hypothesis proposed by the question.

At the stage of constructing problem-solving strategies, the subject could write down the sequence of strategies used in a coherent and precise manner, starting from the selection of statistical tests, processing the known elements of the questions, and setting test criteria. Problem-solving construction is a mental activity in finding information and linking the information possessed with previous information to help solve the problems encountered (Setyawan & Rahman, 2013).

Constructing problem-solving in learning mathematics always links old knowledge with new knowledge to help solve problems (Subanji & Supratman, 2015).

In the sixth stage of solving the problem, PS1 subject worked on problem-solving problems by performing mathematical calculations correctly, according to formulas, strategies, and the selected representation. At this stage, the subjects performed calculations assisted by SPSS, and the results obtained were correct. This shows that the PS1 subject was able to perform mathematical calculations accurately and correctly.

The seventh stage was confirming the answer, which is the last process in solving mathematical problems. The indicator in this stage is that students find the final answer in accordance with the purpose of the question and are able to express the answer in the interpretation of the question, no longer in the form of symbols or mathematical models. Students with very good categories conclude the answers at the end, and the conclusion is correct. Figure 1 is the PS1 subject's answers in the process of solving statistical problems.

Diketahui : Kemampuan pemecahan masalah ( $y$ ), kemandirian belajar ( $x_1$ ),  
Keterampilan pemecahan masalah ( $x_2$ )

Ditanya : Apakah terdapat pengaruh yang signifikan antara kemandirian belajar dan keterampilan pemecahan masalah terhadap kemampuan pemecahan masalah ?

↳ Langkah - langkah pengujianya .

1. Uji normalitas dan homogenitas → data diasumsikan normal dan homogen.
2. Menentukan hipotesis yang akan diuji  
 $H_0$  : Tidak terdapat pengaruh yang signifikan antara kemandirian belajar dan keterampilan pemecahan masalah terhadap kemampuan pemecahan masalah  
 $H_1$  : Terdapat pengaruh yang signifikan antara kemandirian belajar dan keterampilan pemecahan masalah terhadap kemampuan pemecahan masalah
3. Melakukan Uji Regresi Linier Ganda → dapat dilihat pada tabel ANOVA

ANOVA					
Model	Sum of Squares	df	Mean Square	F	Sig.
1 Regression	2877.357	2	1438.679	3.751	.042
Residual	7287.722	19	383.564		
Total	10165.079	21			

4. Kriteria pengujian  
 Jika sig. >  $\alpha$  maka  $H_0$  diterima  
 Jika sig. <  $\alpha$  maka  $H_0$  ditolak

5. Kesimpulan  
 Karena sig = 0,042 <  $\alpha$  = 0,05 maka  $H_0$  ditolak dan  $H_1$  di terima .  
 Sehingga " Terdapat pengaruh yang signifikan antara kemandirian belajar dan keterampilan pemecahan masalah terhadap kemampuan pemecahan masalah. "

**Known:**  
Problem-solving ability (Y), learning independence (X<sub>1</sub>), problem-solving skills (X<sub>2</sub>)

**Question:**  
Is there a significant influence between learning independence and problem-solving skills on problem-solving ability?

**Steps of the Analysis:**

1. Test for normality and homogeneity → the data are assumed to be normal and homogeneous.
2. Determine the hypotheses to be tested:  
H<sub>0</sub>: There is no significant influence between learning independence and problem-solving skills on problem-solving ability.  
H<sub>1</sub>: There is a significant influence between learning independence and problem-solving skills on problem-solving ability.
3. Perform multiple linear regression test → results can be seen in the ANOVA table below.

ANOVA						
Model	Sum of Squares	df	Mean Square	F	Sig.	
Regression	2877.357	2	1438.679	3.751	0.042	
Residual	7287.722	19	383.564			
Total	10165.079	21				

**Testing Criteria:**  
If Sig. > α then H<sub>0</sub> is accepted.  
If Sig. < α then H<sub>0</sub> is rejected.

**Conclusion:**  
Since the Sig. value = 0.042 < α = 0.05, H<sub>0</sub> is rejected and H<sub>1</sub> is accepted.  
Therefore, there is a significant influence between learning independence and problem-solving skills on problem-solving ability.

Figure 1. Answers of PS1 Subjects (Translated)

Based on the analysis results of PS1 subject's problem-solving process, it is known that the statistical problem-solving process is carried out very well. All problem-solving processes can be carried out well. PS1 subject was able to solve problems by formulating hypotheses, determining statistical tests, H<sub>0</sub> acceptance criteria, performing calculations, and interpreting results. This situation shows that students can solve problems by involving excellent abilities in realizing and regulating their thinking processes (Pramono, 2017). Students with excellent mathematical problem-solving skills have a positive effect on the development of their creativity in non-routine problem-solving (Cho & Kim, 2020).

***Problem-solving Process of Students with High Problem-solving Ability***

The results of research data analysis show that students with high problem-solving skills are successful in each stage of problem-solving. PS2 subject is a student with high category problem-solving abilities. The first stage of the problem-solving process is to read and understand the problem. PS2 subject was able to analyze the problem by writing down what was known and asked in the question. PS2 subject understood the problem by reading the problem several times, even though he did not write down what was known in the problem. PS2 subject was able to identify the problem in question by expressing what was understood about the problem.

In the stage of making the mathematical model, PS2 subject did not explain in detail the modelling of variables Y, X<sub>1</sub>, and X<sub>2</sub>. PS2 subjects were able to choose the right representation according to the questions presented. The representation

used by the PS2 subject was a mathematical expression symbolized by  $x$  and  $y$ . The mathematical expression consists of algebraic and numeric symbol language (Nerit & Amit, 2004). In the finding the goal step, the PS2 subject was able to determine the goals to be achieved in the problem by writing down the goals correctly and correctly.

PS2 subject was able to construct problem-solving strategies to solve problems. PS2 subject wrote down the steps of the strategy used in detail, and even wrote down the steps of using SPSS in detail. PS2 subject solved problems using calculations assisted by SPSS software. The results of the calculations carried out by PS2 subject were correct, and they completely wrote down the results of the SPSS calculation table in the answer. Thus, at the stage of solving the problem, PS2 subject with the high problem-solving category was able to do the calculations correctly. At the confirmation stage, PS2 subject was able to conclude the answer in the form of a description, not just the results of the hypothesis acceptance criteria. Based on this, it was concluded that PS2 subject was able to confirm the correct answer.

Based on the results of the analysis of the PS2 subject's problem-solving process, complete metacognition activities, namely planning, monitoring, and reflection, starting from understanding the problem to the last stage, namely the evaluation of the solution, have been carried out properly. The entire problem-solving process could be passed. However, some problem-solving processes were less than optimal in writing the answer. This situation shows that the subject can solve problems by involving good abilities in realizing and regulating their thinking processes.

***Problem-solving Process of Students with Medium Problem-solving Ability***

PS3 subject is a student with a moderate ability in mathematical problem-solving. Figure 2 shows the steps for solving statistical problems carried out by PS3 subject.

5.) Ujilah apakah terdapat pengaruh yang signifikan antara kemandirian belajar dan keterampilan pemecahan masalah siswa?

Jawab =

Model Summary							
Model	R	R Square	Adjusted R Square	Sig. of F	F	df1	df2
1	.283	.080	.034	.277	1.741	1	20

  

ANOVA						
Model		Sig. of Square	df	Mean Square	F	Sig.
1	Regression	13.355	1	13.355	1.741	.0202
	Residual	153.417	20	7.671		
	Total	166.773	21			

Dari hasil output yg pertama didapatkan  $k = 0.283$  dg koefisien determinasi di  $(k \text{ square}) = 0.080 = 8\%$ .  
 Dari hasil output yg kedua nilai sig didapatkan  $0.202 < 0.05$  maka korelasi signifikan, maka terdapat pengaruh dg pengaruh 8%.

**Question:**  
Test whether there is a significant influence between learning independence and students' problem-solving skills.

Model Summary							
Model	R	R Square	Adjusted R Square	Std. Error	F Change	df1	df2
1	0.283	0.080	0.034	2.770	1.741	1	20

  

ANOVA						
Model	Sum of Squares	df	Mean Square	F	Sig.	
Regression	13.355	1	13.355	1.741	0.202	
Residual	153.417	20	7.671			
Total	166.773	21				

From the first output, it is obtained that  $r = 0.283$  and the coefficient of determination ( $R^2$ ) =  $0.080 = 8\%$ .  
From the second output, the Sig value obtained is  $0.202 > 0.05$ , meaning that the correlation is not significant.  
Therefore, the correlation is not significant, and the influence is 8%.

Figure 2. PS3 Subjects' Answers (Translated)

At the stage of reading and understanding the problem, PS3 subject did not write down what was known in the problem, but wrote down what was asked in the question. PS3 subject felt that he did not have time to write down the known elements of the questions because they would spend their time doing calculations. PS3 subject also did not make an example of a question sentence into a mathematical model. PS3 subject only represented problems with the same words as the given question sentences. In finding the goal, PS3 subject was able to know the goals to be achieved in the question, but did not write them down in the answer sheet. PS3 subject also did not write a problem-solving strategy, but he felt sure that the strategy was enough in his imagination. In the stage of solving the problem, PS3 subject did the calculations with the help of Ms. Excel, but the final answer was still incorrect. The accuracy of PS3 subject lacked data input, and the formulation in Ms. Excel caused the wrong answer. PS3 subject could confirm the answer; however, because the problem-solving process was wrong, the results obtained at the confirmation stage were still incorrect.

Based on the results of the analysis of the students' problem-solving process in the medium category, the PS3 subject missed several stages of problem-solving, namely reading and understanding the problem, making mathematical models, finding the goal, and constructing problem-solving strategies. PS3 subject tend to immediately solve problems without making a settlement strategy. PS3 subject's planning in solving immature problems caused the PS3 subject to be less able to control the calculations carried out. Hypothesis testing will be less than optimal if the stages are not carried out systematically and coherently.

***Problem-solving Process of Students with Low Problem-solving Ability***

PS4 subject is a student who has a low problem-solving ability. In the statistical problem-solving process, many troubleshooting steps were not performed by the PS4 subject. The student only performed calculations that were presented in tabular form and drew conclusions based on the interpretation of the results. A PS4 subject admitted that he was nervous when he received a question, so he immediately thought about how to solve it. PS4 subject was not confident in

statistics courses and did not know that the hypothesis testing steps needed to be completed.

At the read and understand the problem stage, the PS4 subject did not analyze the problem properly. PS4 subjects do not write down what is known and asked in the question. Based on the results of interviews with other PS4 subjects, information was obtained that PS4 subjects were confused about the questions because three data points were presented and had to analyze which ones were the dependent and independent variables before taking the test.

At the make a mathematical model stage, the PS4 subject did not write down an example of a question sentence into a mathematical model. The representation used by the PS4 subject is the SPSS output calculation table. However, the PS4 does not use any form of representation to present the problem. Tiffany et al., (2017) stated that mathematical ideas can be expressed in writing in the form of pictures, diagrams, or tables.

At the stage of finding the goal, the PS4 subject did not write down what was asked in the question. The results of the interview showed that the PS4 subject felt that they knew what the questions were asking, but did not write it down in the answer sheet. After confirmation, the PS4 subject was unable to distinguish the dependent and independent variables intended by the question. PS4 subjects only know that the statistical test to be used is the regression test.

In the stage of constructing problem-solving strategies, the PS4 subject has not yet written a comprehensive solution strategy. This is because there was an error in the previous stage, so that in the stage of constructing problem-solving strategies, it was also wrong. If students in the early stages of the modelling process have not been able to solve the problems, they cannot proceed to the next stage (Wijaya et al., 2014).

At the stage of solving the problem, the PS4 subject has not gotten the results correctly and precisely, even though they have used SPSS as a statistical tool. The seventh stage of problem-solving confirmed the answer. PS4 subject did not confirm the answer correctly. This is because the results obtained by the PS4 subject in the problem-solving process were wrong and resulted in the confirmation process of answers. Confirmation of answers was only done by rewriting the results, not interpreting the results in accordance with the intended purpose of the question.

Based on the results of the analysis, it can be said that the problem-solving process of students with low categories has not been completely implemented. Students stated that they did not understand the material being tested, so they had difficulty understanding questions that were different from practice questions. PS4 subjects do not identify problems and determine goals first, and even tend to do calculations without planning. The absence of the construction of a settlement strategy in the form of writing or in thought causes errors in the completion.

The difficulties experienced by students in the problem-solving category are less due to the low ability of students to solve problems. Suharta (2016) said that students tend to solve problems by paying attention to the numbers, regardless of the intent of the question. The difficulty in determining a problem-solving plan is also supported by the opinion of Lidinillah (2008) that educators usually provide the same strategy for solving problems.

### ***Problem-Solving Process of Students with Very Low Problem-Solving Ability***

PS5 subjects are students who have very low problem-solving skills. Based on the analysis of research data, it shows that students' ability to solve mathematical problems is very lacking in each stage of problem-solving. The following is the process of students with problem-solving abilities that are very lacking in problem-solving:

At the read and understand the problem stage, a PS5 subject read repeatedly but did not understand the problem. PS5 subjects were not able to analyze the problem, so they could not write down what was known and asked in the question. PS5 subjects also don't create mathematical models. PS5 subjects had difficulty representing problems because they thought the problems presented were difficult to understand. PS5 stated that in fact he did not understand the material being tested because he felt that statistics was a difficult subject. PS5 subjects could not distinguish the type of statistical test to be used in each different type of case. This was because students have not been able to bring mathematical knowledge to real situations.

In the finding the goal stage, the PS5 subject did not write down what was asked in the question. The same thing was also done by NS subjects at the stage of constructing problem-solving strategies. PS5 subjects have not written down the strategies used in problem-solving but have directly analyzed them using SPSS software. This was because NS subjects still had difficulty with writing strategies. After all, they were not familiar with non-routine questions. habits in practicing skills, in understanding and solving problems, need to be given to students (Abdillah & Budiarto, 2017). With practice and habituation to understand and solve problems, students will get used to and understand problem-solving strategies (Nurkaeti, 2018).

From the analyzed PS5 subject's answer sheet, he solved the problem directly at the problem-solving stage. The PS5 subject was able to write SPSS output, but the calculation result was wrong. This was because of the incorrect input data and the difficulty in determining the dependent and independent variables. The PS5 subject did not find a statistical problem-solving strategy; therefore, the risk of error in the questions increased. At the stage of confirming the answer, the PS5 subject made an error in interpreting the written SPSS output. He tended to be careless in making concluding answers and not in accordance with the purpose of the question. The PS5 subject felt that the written answer was not optimal, and he believed that the answer would be wrong.

Based on the analysis of the problem-solving process of students with very poor categories, it can be said that the problem-solving process carried out by the subject of the very low category in the research statistics course is still lacking in the problem-solving process. Students with very low categories have not been able to solve problems, causing errors in solving them. Students in the very low category were not familiar with non-routine questions, so they had difficulty solving problem-solving problems. So, it is necessary to get used to doing non-routine questions. When students are approached with a non-routine math problem, their reactions are more gentle, including body movements, and if the problem-solving time is long, the emotional response can be very intense (Díaz et al., 2018).

## Conclusion

Based on the results and discussion, it can be concluded that students with very high statistical problem-solving skills can solve problems at all stages of problem-solving. Students also complete the task according to the stages of statistical hypothesis testing. Students in the category of high mathematical ability were able to complete calculations and interpret results, but did not write down the known elements, and did not do modelling. Students with a moderate problem-solving ability category can make mathematical representations, solve the problem, and confirm the answer. However, this subject missed several stages of problem-solving, namely reading and understanding the problem, making mathematical models, finding the goal, and constructing problem-solving strategies. They tend to do the calculations directly without making a plan. Subjects with low and very low categories also immediately completed calculations without understanding the problem and developing a settlement strategy first. Because the subject does not understand the problem, the calculations made are still wrong and tend to be arbitrary in interpreting the results.

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