Mathematics Modeling Ability of Students in Class XI Linear Program Materials with Problem based Learning Model

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Mathematics Modeling Ability of Students in Class XI Linear Program Materials with Problem based Learning Model

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ABSTRACT

Mathematical modeling ability is a significant aspect of learning mathematics. Real problems can be solved through a mathematical process with modeling. The background of the problem in this study was the low mathematical modeling ability of students, especially in the Linear Programming materials. The application of the PBL model can be used as a problem solution for these matters. The purpose of this study is to obtain an overview of the modeling ability of students' mathematics on linear programming material after applying the PBL model. The research was held at SMA YPI Tunas Bangsa Palembang with 37 students as research subjects. The method used in this research is descriptive with data analysis techniques carried out quantitatively and qualitatively based on mathematical modeling indicators. The data was obtained from the test results in the form of essay questions and results of interviews with students. Based on the results of the data analysis, it can be concluded that the ability of mathematical modeling students on linear programming material after the PBL model was applied is in a medium category with a percentage of 46.24%. Therefore, the PBL model can be used as an alternative for teachers in improving students' mathematical modeling skills.

Keywords: *Mathematical Modeling Ability, Linear Programming, Problem Based Learning*

1. INTRODUCTION

Mathematical modeling ability is an essential aspect that students must possess. The importance of this modeling ability is in line with the objectives of learning mathematics as stated in the competency standards of graduates in mathematics subjects based on Permendikbud RI No. 22 of 2016, namely solving problems which include the ability to understand issues, mathematical design models, complete models and interpret solutions obtained [1]. In addition, the importance of mathematical modeling in mathematics learning can be seen from the use of mathematical modeling as a significant element in curriculum content by several developed countries [2, 3, 4, 5]. Germany and Singapore make mathematical modeling one of the mandatory competencies in the national education standard for learning mathematics [6, 7].

Mathematical modeling is a process of understanding, simplifying, and solving real-life problems using mathematics [8, 9]. One of the materials related to issues in the real world is linear programming material. Linear programming is a material that studies the value of limitations where the maximum and minimum values are as an objective function, and the availability of materials or goods is a constraint factor. The problems are in the form of story questions that require students to translate these problems into mathematical language. For this reason, good abilities are needed in understanding problems and designing mathematical models of the given situations.

This study started from several previous research results, which showed the low ability of students' mathematical modeling, especially in linear programming material. This is shown from the mistakes that students often make in the form of errors in making mathematical models and errors due to a lack of understanding of prerequisite material such as arithmetic operations on algebraic forms, straight-line equations, and systems of linear equations and inequalities [10]. Based on Fauziyah's research, students made mistakes in determining formulas or making mathematical models from linear program story problems and incorrectly related what was known and asked in the problem [11]. From Suratih's research, one of the students' errors in linear programming problems, namely reading errors, is marked by errors in interpreting sentences correctly, finding keywords or information in questions, and mathematical modeling language into mathematical symbols [12]. Khusnatun also stated that one of the students' difficulties was expressing algebraic ideas from the problems given that they were still lacking, causing errors in modeling [13].

To overcome these problems, an alternative that can be used is to apply the Problem Based Learning (PBL) learning model. The PBL learning model can be used as a solution to create learning that demands student activity. In this model, education emphasizes students to think by collecting various concepts they have learned from multiple sources to solve problems. The teacher's role in this learning is as a facilitator to support the teaching carried out by students. The advantages of applying the PBL learning model can be seen from Silmina's research showing that after being taught using the PBL learning model, students' mathematical modeling abilities are in the high category and have increased [14]. It is also supported by the results of Yusritawati's research, students who receive learning using the Problem Based Learning (PBL) model through Mathematical Modeling have better mathematical problem-solving abilities than through conventional learning [15].

In addition, so that learning in the classroom is exciting and meaningful, teachers need to develop lesson plans that allow students to interact actively in education [16]. Learning tools can be used as a guide for teachers in carrying out the learning process in the classroom so that the learning process can be more directed towards the competencies to be addressed [17]. In this study, the learning tool used is a mathematical modeling learning tool based on the KIkuduko guide developed by Indaryanti et al. The KIkuduko guide-based learning tool is a learning plan that is formulated from analyzing the SKL, KI, and KD that has been determined by the curriculum which then produces an indicator known as the Competency Achievement Indicator (IPK) [18].

This study aims to obtain an overview of students' mathematical modeling abilities on linear programming material after applying the PBL model. Based on the background description, the researcher is interested in studying the students' mathematical modeling abilities in the linear programming material for class XI with the PBL model.

2. METHOD

This type of research is descriptive research with quantitative and qualitative methods. The research subjects were students of class XI IPA 4 SMA YPI Tunas Bangsa Palembang. The total number of research subjects was 37 students, further grouped based on three ability categories: high, medium, and low. The instruments in this study were in the form of mathematical modeling ability test questions and interview guidelines. Lecturers and teachers of mathematics subjects validate the instruments that have been compiled. Test instruments that have been suitable for use are then tested on students after applying the PBL model of learning.

Meanwhile, was used the interview guide instrument to support the test result data. The data analysis stage used is data reduction, data presentation, and concluding. With data analysis techniques are carried out quantitatively and qualitatively. In this study, the data analysis process begins by quantitatively calculating the test scores according to the scoring table to determine the categories of students' mathematical modeling abilities. The following table presents the scoring guidelines for each mathematical modeling indicator.

Table 1. Test scoring guidelines

Indicators	Descriptors	Score
Identify problems	Identify what information is needed to solve the problem	3
	Formulate the problem asked in the problem to find a solution	3
Making assumptions and defining variables	Making assumptions or assumptions that are not known from the problem	2
	Using symbols to express information of unknown value	3
Doing mathematic	Formulate a mathematical model based on the given information and the previously defined variables	3
	Solve the model	3

	mathematically to get the correct solution	
Analyze and assess solutions	Interpreting the solution of the obtained mathematical model	2
	Write down whether the solution obtained is reasonable	2
Looking back	Checking the results obtained through the mathematical model that has been made	2
	Proving the truth of the results obtained	2
Applying the model	Interpreting solutions into the real world	2
	State the conclusion based on the solution obtained as a solution to the problem	3

Then the scores obtained from each student's test results are based on the scoring rubric that has been made, then added up and converted using the following formula.

$$\text{Total score} = \frac{\text{Score obtained}}{\text{Maximal score}} \times 100$$

The converted test result data are then grouped into students' mathematical modeling abilities based on the following table.

Table 2. Category of student's mathematical modeling ability

Student Score Range	Modeling Ability Category
$75 \leq n \leq 100$	High
$45 \leq n < 75$	Medium
$0 \leq n < 45$	Low

After being grouped into three categories of mathematical modeling abilities, the percentage of each category is calculated using the following formula.

$$\frac{\text{Number of students in category} - \text{i}}{\text{Number of students take the test}} \times 100\%$$

Furthermore, the average score of students was calculated and concluded the category of students' overall mathematical modeling ability using the formula in equation (1) below.

$$\bar{x} = \frac{\sum x}{n} \qquad (1)$$

The results of student work are analyzed based on whether or not the expected indicators appear. Then the test results describe how students' mathematical modeling abilities are supported and supported by data from interviews with two selected subjects from each category. After describing the information obtained, a conclusion is drawn about the students' mathematical modeling abilities from each category.

3. RESULTS AND DISCUSSION

The research was in three meetings consisting of learning activities and tests at the third meeting. The research activity was carried out from October 9, 2021, and completed on October 19, 2021. In the implementation phase, the researcher learned with the PBL model at the first and second meetings. The instrument used is LKPD which has been compiled based on the stages of mathematical modeling on linear programming material. The material taught at the first meeting was a system of linear inequalities of two variables, a prerequisite material. In contrast, for the second meeting, the learning material was linear programming. This LKPD was tested on students during the learning process.

Learning activities are carried out online through the zoom application with a discussion learning method through the breakout room feature. At the third meeting, a test was conducted to measure the students' mathematical modeling ability after the PBL model was applied. The instrument used is in the form of a mathematical modeling test question which contains one essay question. The test was carried out online through a zoom meeting with 37 students taking the test, which is the total of the research subjects. The process of doing this test is done in 60 minutes. The following is a linear programming problem used in the implementation of the test. This problem is related to determining the minimum value of a linear function.

"The State Civil Service Agency (BKN) officially opened the registration for CPNS 2021 on June 30. In the selection carried out there are conditions that must be met by selection participants regarding the value provisions of the results of the national insight test (TWK) and the general intelligence test (TIU). After graduating from high school, Ira was interested in participating in the CPNS selection. In order to pass the selection, Ira must obtain a minimum TWK test score of 65, a TIU test with a score of not less than 80, and the total number of TWK scores and TIU scores is at least 150. For example, x is Ira's scores of twice the TWK value and three times the TIU value. Define:

a. *What is the minimum value of x that Ira must get in order to pass the CPNS selection?*

b. *Can Ira pass the 2021 CPNS selection if the x-score obtained is 365? Give your reasons!*"

After the data from the test results were obtained, the researcher then corrected the results of the students' work based on the scoring guidelines. From each category seen based on the test results, two people were then selected to be interviewed. The following is the result of the scoring of one of the research subjects with the initials AS.

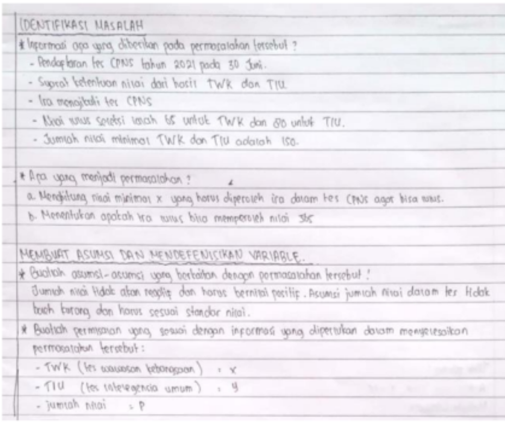

Figure 1 Student AS's answers on indicators 1 and 2

The work results on the subject AS show that the student can identify the given problem as seen from the score obtained for this indicator is six scores. At this stage, subject AS can determine what information is provided and understand the problem's problem. Subject AS can also make assumptions and define variables in the situation; this can be seen from their score, which is five scores. The ability to identify this problem can also be seen from the AS subject's response when interviewed. Subject AS explained that the information provided from the question regarding CPNS registration is the limit of values that must achieve. Subject AS can also understand the problem and must obtain, namely, how much value to pass the CPNS selection. In the indicator of making assumptions, at first, when asked the subject, AS explained that he did not understand the assumptions section when working on the LKPD, but when interviewed, subject AS was enough to understand the assumptions of the problem.

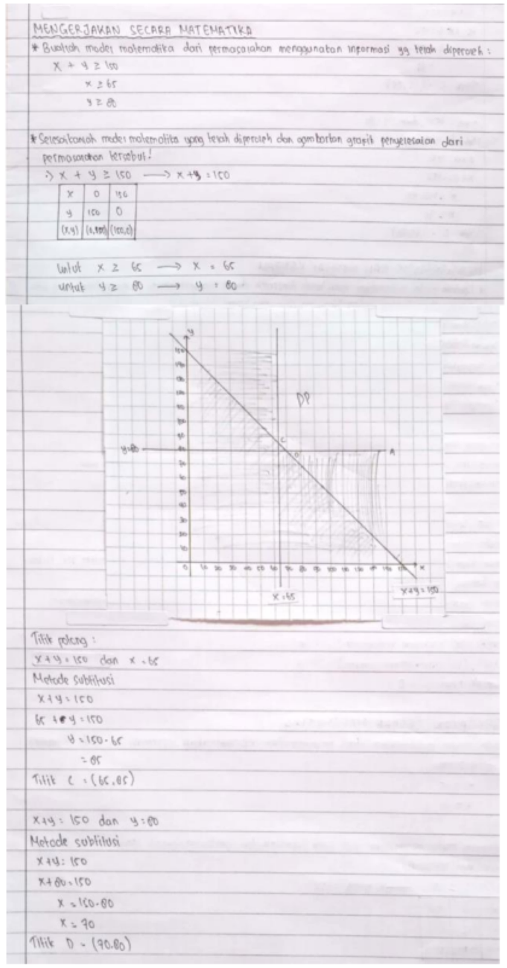

Figure 2 Student AS's answers on indicators 3

At the stage of working on mathematics, subject AS can formulate a mathematical model of the problem and perform mathematical calculations. From the test results, subject AS were also able to draw graphs from the models obtained and determine the settlement area from the graph images obtained. Based on interviews, she understands what the variables mean and is appropriate in symbolizing the variables x and y. subject AS can explain well when asked the strategies used and the steps in solving these problems. However, a process is skipped, namely, the re-checking section, which concludes at the end, is wrong. Subject AS can explain again how the steps are in drawing graphs and understand the purpose of the stages. It can be seen from AS's response when asked that the purpose of finding the intersection point of the graph is so that later it will get the minimum value sought.

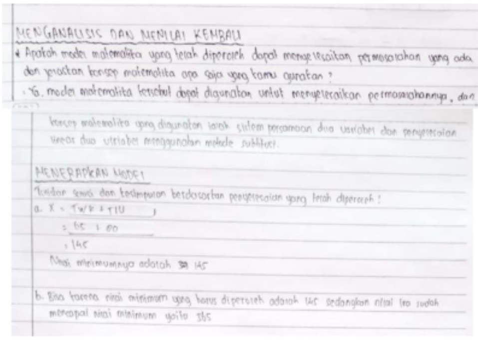

Figure 3 Student AS's answers on indicators 4 and 6

Figure 3 shows the results of the work of AS students at the stage of analyzing and assessing solutions and the steps of applying the model. Subject AS can explain whether the mathematical model obtained can solve the problem with a total score obtained is four scores. It can be seen from the understanding of subject AS in applying the concept of a system of equations with the substitution method and linear inequalities of two variables in solving problems. However, for the fifth indicator, the subject skipped the stage of re-checking the solution obtained. Subject AS don't check the corner points obtained into the objective function to determine the minimum value sought when applying the model from the indicator interpreting the solution into a real problem, namely for the problem (a) students miscalculated resulted in the situation (b). So, concluding the solutions obtained is still not right.

Subject AS explained that he had doubts about the calculations from the model he obtained from the interview results. After listening to the students' explanations, it turned out that the provision of values fooled the students at the beginning that differed significantly from the results of their calculations. So that when doing the math at the end, the objective function used is wrong so that in determining the minimum value of the AS subject, it is still wrong. However, in concluding, the response from the AS shows that it understands how to conclude solutions to answer the primary problem. After being corrected based on the scoring guidelines, the total score from each student's work is then calculated and categorized into mathematical modeling abilities based on the scores obtained. The results of grouping based on this category can be seen in the following table.

Table 3. The results of the category of students' mathematical modeling abilities

Student Score Range	Modeling Ability Category	Frequency
$75 \leq n \leq 100$	High	2
$45 \leq n < 75$	Medium	14
$0 \leq n < 45$	Low	21

The table shows that the highest frequency of the modeling ability category is low category, which is as many as 21 students, as for medium category as many as 14 students and high category only two students. The percentage of each category is 5.4% for the high category, 37.8% for the medium category, and 56.8% for the low category. Based on the results of the categorization, the average of the overall student scores was 46.24%. These results show that the mathematical modeling ability of the students of class XI IPA 4 SMA YPI Tunas Bangsa is the medium category. After analyzing the test result data quantitatively from the number of values obtained, analyzed the data based on indicators from each stage of mathematical modeling. The average percentage of each indicator is calculated, and the results are presented in the following table.

Table 4. The percentage results of mathematical modeling indicators

Mathematical Modeling Indicators	Percentage
Identify problems	48.65%
Making assumptions and defining variables	57.44%
Doing mathematic	68.92%
Analyze and assess solutions	4.05%
Looking back	31.08%
Applying the model	43.92%

The first modeling indicator is to identify the problem; the percentage of occurrence is 48.65%. In this indicator, there are two descriptors, namely identifying the information needed and formulating the problem. Most students can identify the problem in this stage, but some students skip this stage and are still incomplete in writing down what information is needed to solve the problem. Students go directly to operating variables to find solutions without paying attention to identifying related issues [19, 20]. Understanding the information and the problem to be sought is an essential aspect of determining the steps to solve the problem. In solving problems, there are three types of information that are important to note: information about the problem presented, information about the operations used in solving the variables of the problem, and information about solving the problem sought [21].

The results of interviews with six students from three modeling abilities categories show that students whose modeling abilities are categorized as very good can identify information and understand the problems presented. It is supported by the responses of student NA who explained that the instructions and question sentences were easy to understand. Meanwhile, the subject AS, who was also in the high category, said that he was constrained at the stage of re-checking to pass that stage. Students in the medium category can understand the information and problems presented; this is supported by the results of interviews with students with the initials AY. Although the subject of AY did not clearly state what the problem was when asked, he understood what to look for and how to solve it. The following is an excerpt of an interview with the subject AY.

R : *What are your ideas and steps in solving this problem?*

S : *First, look for the information and assumptions, then I turn it into a mathematical model. After that, make the Cartesian coordinates and the line. Next, calculate the point to the objective function and then to answer the problem.*

However, in contrast to students whose modeling abilities are categorized as low, students with the initials RT, when taking the test, he does not write down the stages of problem identification. When interviewed, subject RT explained that he understood the instructions for the questions but didn't understand the problems given. While subject TP who are also categorized as low can explain again what the problem is and the known information. It's just that when he did the work, subject TP didn't write it down because he didn't felt have enough time to solve the problem, so he just went straight to the next stage. When interviewed, subject RT explained that he understood the instructions for the questions but did not understand the problems given.

The second indicator of mathematical modeling ability is making assumptions and defining variables, which is 57.44%. This indicator has two descriptors; making assumptions or assumptions not known from the problem and using symbols to express information whose value is unknown. Many students skip this stage in making assumptions, which can also be seen when working on LKPD during discussion activities. Based on the results of interviews with students whose modeling abilities are categorized as a medium, subject AY can explain what assumptions mean. Subject AY explained that he did not write down the stages because he forgot and wasn't used to working on linear programming problems with such steps.

However, many students are still not right in making assumptions, judging from the work on the worksheets and test questions, because they are still confused about understanding assumptions. Like the subject SS, she wrote down the assumptions of the given problem, but the answer was still not entirely correct. But, the statement that subject SS gave can be explained logically. She assumed that each score had to be 150 and could not be less than 150. Meanwhile, from the questions, it was known that each score's provisions could still be below 150. Subject SS misunderstood the meaning of the word "*amount*" in the question.

R : *Why make such an assumption? TWK value (150) and TIU value (150).*

S : *Because the function must meet its value, if both values are not 150 then it cannot pass.*

Students' difficulties in making assumptions accordance with Shodikin et al.'s statement that the most common thinking error in mathematical modeling is making incorrect assumptions [22].

But, for descriptors using symbols, almost all students are correct and understand the use of symbols in expressing information. Students' ability in this descriptor can be seen from students' understanding of the problem's variables. From the results of interviews with subject AY with medium categories, he can explain why the underlying reason for supposing TWK and TIU values with the symbols x and y. And when asked about whether were changed the symbol to a and b, he said he could. And he could explain the reason for his answer. Likewise, with one of the students from the low category, the subject of RT, in this descriptor, the student already understands well the use of variables from this problem.

The next indicator is the indicator that gets the highest percentage, namely the indicator of doing math with a portion of 68.92%. In this stage, the indicators' descriptors formulate a mathematical model and solve the model mathematically to obtain a solution. From the descriptor formulate the model, some students are still not right; this can be seen from the students' mistakes in interpreting the sentences in the questions. It can be seen from the results of interviews with students from the low category, namely the subject TP, who misinterprets the word "minimal" so that the model made is wrong. Meanwhile, subject RT didn't write down the modeling stages when interviewed; the reason was that he didn't know how to answer the problem. During the interview process, the researcher tried to deepen the understanding of the subject RT on modeling. It turned out that after being given a more in-depth explanation and guided by various questions that direct students to think, finally, this RT subject understood the question sentence, and he was even able to model the sentence into a mathematical sentence correctly. Meanwhile, students in the medium and high categories are quite good at interpreting the important sentences in the questions. Students understand the word "*minimum, not less than, not more than*", which is a necessary term that determines students' understanding in making mathematical models in the form of linear inequalities.

However, for the mathematical work stage, most of the students could solve the given model by applying concepts related to solving a system of linear inequalities of two variables. Although, it can still be seen from some of the students' test results that the results obtained are still not correct. Students' mistakes in making models at the beginning of completion resulted in miscalculations but the steps and concepts used were correct. For example, subject AS was wrong in determining the objective function model, but the overall process was good. Likewise, subject AY categorized as a medium have inappropriate modeling because their thinking about assumptions is still wrong. When interviewed, subject AY said that caused the error because the question sentence differed from the usual question sentence. There was a varied use of words, which made he confused in determining the sign of the inequality. However, the work process and our students' responses showed their understanding of the concepts and strategies that he used in solving these problems. Subject AY, when given an illustration of a real problem related to this material, he was able to explain the critical terms and reasons for his answer. He is also capable of drawing graphs and determining settlement areas.

Meanwhile, for students who have low categories, based on the results of interviews, students do not understand how to describe the inequality graph and do not understand the settlement area. Based on the results of Masfiyah & Shodikin's research, stated that the cause of students making mistakes in making models was due to several factors, including not knowing about mathematical modeling, rarely working on story-shaped questions, questions given too complicated sentences, being accustomed to answering using their reasoning or just experimenting. And there are still few student learning resources that train students' mathematical modeling skills [19, 20]. Errors in solving story problems are caused by a lack of understanding of information in the form of story questions based on students being lazy to read and lack of practice questions [23].

Furthermore, for indicators of analyzing and assessing solutions, the lowest percentage is only 4.05%. The descriptor of this indicator is to interpret the completion of the mathematical model obtained and explain whether the solution obtained is reasonable. In the two descriptors, almost all students skipped the stages in writing the concepts they used to get answers as solutions to the problems given and didn't interpret the solutions of the models obtained. Besides, for the second descriptor, many students skip this stage. Still, when viewed from the ability of students to work mathematically with coherent completion steps, it shows that students are able and understand the solutions they get can answer the problems given. However, because students work directly on calculations, this stage is often missed in the processing stage.

For students in the high category, the answers of students AS and NA, when interviewed, have shown their understanding in assessing whether the solution or model obtained is reasonable and can answer the existing problems. Students in this category understand that problems like this get a solution in the form of a mathematical model because it relates to the known value limits associated with a system of inequalities. Likewise, students from the medium category, subjects AY and SS were also able to explain the reasons for using solutions in the form of mathematical modeling. Though, some students don't understand how to solve the problems given. It can be seen from the work that it is only limited to the stages of identifying the problem. It is based on the fact that the difficulties faced by students aren't only in understanding the problem but also in choosing the knowledge or mathematical concepts needed to be able to solve modeling problems [24]. From transcript, subjects RT and TP in the low category indicate that they are still having difficulty determining solutions to the problems given. The factor that causes this is the students' lack of understanding of prerequisite materials such as linear inequalities, straight-line equations, drawing graphs of an equation, and determining the solution area.

In the indicator, re-check the percentage of occurrences obtained, which is 31.08%. From this indicator, there are two descriptors, namely checking the results obtained through the mathematical model made and proving the truth of the results obtained. Most of the students also skipped the stages of re-checking indicators; students were accustomed to directly writing conclusions from the results obtained without first proving the truth of the results obtained. It can also be seen from some students who are still wrong in the calculations so that the results obtained are still not correct. Based on the results of research by Ramadhan et al., it shows that students are not used to re-checking the completion, and there are still errors in the work process with the categories obtained are at a deficient level [19, 20]. Most students complete the plan of problem identification without re-evaluating it to minimize the occurrence of errors. Students usually write down the solution immediately, so they don't do the re-checking stage. Though this stage is essential to determine the correctness of the solution obtained. This is following the opinion that re-examining the mathematical model that has been made aims not to forget other important variables that influence or are useful to the conclusions obtained [25].

And the last indicator is applying the model; the result is 43.92%. There are two descriptors for indicators at this stage, namely interpreting solutions to the real world and stating conclusions based on the solutions obtained as problem-solving. In applying the model as a whole, students write down the conclusions of the solutions obtained. However, most students are still wrong in interpreting solutions to the real world as seen from students' mistakes in determining the corner point that is the solution to the problem or students' errors in determining the objective function so that there are still students who are not right in the stage of concluding answers to problems in the real-world context. From the formulation of the mathematical model, a solution will be obtained which can later represent the problem. Interpretation of the problem into the real world will impact decision-making from solving the problem sought. If the process of mathematical modeling and determining the solution does not match the problem encountered, the conclusions or decisions taken aren't appropriate [26].

4. CONCLUSION

Based on the data obtained through tests and supported by interview data, it can conclude that the mathematical modeling ability of students in class XI IPA 4 SMA YPI Tunas Bangsa Palembang shows a medium category with a percentage of 46.24%. It can be seen from the students' achievements in each indicator of mathematical modeling. Students can work mathematically from the problems given, as seen from the percentage on this indicator reaching 68.92%. In this stage, students can make mathematical models and perform mathematical calculations. However, for indicators of analyzing and assessing solutions, the percentage obtained is deficient at only 4.05%. Because in this indicator, many students skip the stages of analyzing and evaluating solutions in the given test.

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