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Students' errors in solving climate change context mathematical modeling problems

Mursyidah J Parandrengi, Cecil Hiltrimartin *

Faculty of Teacher Training and Education, Sriwijaya University, South Sumatra, Indonesia

* Correspondence: cecilhiltrimartin@fkip.unsri.ac.id

Abstract

This research is a descriptive study that aims to describe the errors of students of the Faculty of Education and Teacher Training (FKIP), Sriwijaya University, in solving Climate Change context mathematical modeling problems, to minimize errors made in solving mathematical modeling problems, especially in the context of climate change in the future. No one has researched student errors in solving mathematical modeling problems in the Climate Change context using the Newman error procedure. Data collection techniques used in this study included tests and semi-structured interviews. The data analysis technique used for test data is by analyzing errors using the Newman procedure. The results of this study with 52 participants were types of errors by FKIP Sriwijaya University in solving Climate Change context mathematical modeling problems as follows for question 1 and question 2, and respectively there were 23.1% and 15.4% errors in understanding the problem, 46.2% and 96.2% transformation errors, 32.7% and 96.2% writing. The causes of errors are errors in reading, errors in determining the problem and existing information, errors in making assumptions, errors in identifying variables, and errors in making mathematical models.

Keywords: error; mathematical modeling; climate change; Newman's procedure errors

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Introduction

One useful way to present a complex problem in a mathematical sentence is mathematical modeling (Ndii, 2022). Mathematical modeling is also a field of mathematics that aims to present and explain real-world problems into mathematical statements so that the understanding gained from these real-world problems becomes clearer (Widowati & Sutimin, 2007). A mathematical model is a product or result of modeling the mathematical representation of abstract symbols, equations, graphs, tables, diagrams, and math pictures or something else which is a mathematical representation of problems outside of mathematics (Muzaki & Masjudin, 2019). In other words, mathematical modeling is a technique that aims to present complex and complicated real-world problems into mathematical statements or mathematical models, so that a clearer understanding of the problem is obtained. According to Bliss and Libertini (2016), mathematical modeling is a process consisting of several components, namely identifying problems, making assumptions and identifying variables, mathematizing, analyzing and assessing solutions, interpreting, and implementing models. On the other hand, mathematical modeling is one of the participants in the Mathematics Education Curriculum of FKIP Sriwijaya University.

Mathematical modeling is also a field of mathematics that aims to present and explain real-world problems into mathematical statements so that the understanding gained from these real-world problems becomes clearer (Widowati & Sutimin, 2007). Mathematical modeling is a process that uses mathematics to represent, analyze, make predictions, or provide insights about real-world phenomena (Bliss & Libertini, 2016). Mathematical modeling is one of how it aims to present a complex problem in a mathematical model (Ndii, 2022). It can be concluded; mathematical modeling is a system of equations that can represent a complex problem being observed. Thus, the formulated mathematical model is expected to be able to explain the complex situation being observed. According to Bliss and Libertini (2016), mathematical modeling is a process that consists of several components, which are identifying the problem, making assumptions and identifying variables, mathematics, analysis, and asses solutions, interpreting, and implementing the model.

Errors are non-compliance or deviations from predetermined rules or procedures that are systematic, consistent, and incidental (Pramita, 2020). Errors are deviations from the truth that are carried out by students as a form of difficulty they experience when learning (Suardi et al., 2022). Mistakes in what students do are important to know to eliminate student misconceptions (Setiawan, 2020). To find out the errors made, an analysis of these errors is needed. One of the procedures that can identify errors made by students is the Newman procedure. The Newman error analysis method was first introduced in 1977 by Anne Newman, a teacher in mathematics in Australia. In this method, he suggests five specific activities as very crucial to help find where errors occur in student work when solving a problem in the form of word problems (Kahar & Layn, 2017). According to Safitri (2017), there are five errors in the Newman procedure, namely reading errors, errors in understanding the problem, transformation errors, processing skill errors, and writing errors.

Climate change is an event where the average temperature of the earth's surface increases and changes other climatic factors such as rising sea temperatures, increased evaporation in the atmosphere, and changes in rainfall patterns and pressure which ultimately change the world's climate (Meiviana, 2004). Global climate change is an issue that is currently a concern for many people (Harmoni, 2005). Climate Change itself is one of the problems in the real world that we are currently experiencing. The events that occurred were very complex, so a clearer presentation was needed to gain an understanding. The causes of climate change, namely the greenhouse gas effect and emission sources of carbon dioxide. According to Obe (2018), there are four very significant pieces of evidence of climate change, namely global warming, melting ice and sea level rise, increasing number of extreme events, and increasing carbon dioxide.

Fitra (2021) states that when working on simple mathematical modeling problems, students still have difficulty determining the method of solving the problem itself. Based on the difficulties encountered by students in solving mathematical modeling problems, causes errors that students will make in solving mathematical modeling problems. Meanwhile, the factors that cause student errors in solving simple mathematical modeling problems are due to students' ignorance of basic mathematical concepts, lack of understanding of mathematical symbols and units, and students lack accuracy in calculations (Fitra, 2021). Some previous research on errors in mathematical modeling includes an analysis of student errors in solving simple mathematical modeling problems which were researched by Fitra (2021). Bahir and Mampouw (2020) also researched to identify errors made by students in mathematical modeling problems and the reason that led to students' mathematical modeling errors was that students did not know the variables in the problem, so they did not have description of the variables, students did not make any assumptions about the mathematical model that will be converted into a mathematical equation, and students are wrong in compiling and solving mathematical equations. This shows that many parties are interested in researching errors in mathematical modeling. In the research, Fitra (2021) and Bahir and Mampouw (2020) have not used an analysis indicator based on the Newman procedure error where they analyzed using the indicators they designed based on the data collected. Even so, no one has researched student errors in solving mathematical modeling problems in the climate change context using the Newman error procedure.

Based on the description above, the formulation of the problem in this study is what is the error of FKIP Sriwijaya University students in solving mathematical modeling questions in the context of climate change? So this research aims to describe the errors of students of FKIP Sriwijaya University in solving climate change context mathematical modeling problems, to minimize errors made in solving mathematical modeling problems, especially in the context of climate change in the future.

Methods

The research conducted was a descriptive study that aimed to describe the errors of FKIP Sriwijaya University students in solving mathematical modeling problems in the context of Climate Change. The focus of this research is to analyze the errors made by FKIP students in solving mathematical modeling problems in the context of Climate Change. 52 participants took the test and interviews were conducted with 7 participants, namely WA (Female), SH (Male), S (Male), AMM (Female), ID (Female), SM (Female), and RF (Man). The participants of this study were 5th-semester students of mathematics education at the Faculty of Teacher Training and Education, Sriwijaya University in the Mathematics Education Study Program at the Faculty of Mathematics and Natural Sciences, Sriwijaya University. This research phase consists of three stages including.

First of all, the preparation stage consists of making research instruments, validating instruments carried out by lecturers who are experienced in mathematical modeling and lecturers who teach mathematics modeling courses at Sriwijaya University, revising the instrument based on the results of the validator if necessary, and apply for and administer a research permit. In the second, implementation phase, at this stage, Sriwijaya University FKIP students will be given teaching materials for Climate Change modeling to study and then given test instruments in the form of mathematical modeling questions in the context of Climate Change. Lastly, the final stage is in the form of an analysis stage on the data obtained so that results will be obtained followed by concluding the research.

Data collection techniques used in this study included tests and semi-structured interviews, where the participants to be interviewed were selected based on their communication skills and availability. The researcher made the instrument first, before carrying out the research directly in the form of test questions and interview guides. The test questions were developed by Mitta Agustarina, S.Pd. graduate student in Mathematics Education FKIP Sriwijaya University who was validated by Mrs. Elika Kurniadi, M.Sc. Meanwhile, the interview guide was validated by a lecturer in mathematics education at Sriwijaya University, Elika Kurniadi, M.Sc. The research was divided into 2 times, namely conducting tests and conducting interviews, where the tests were carried out on 30 September 2022 and the interviews were carried out on 24 October 2022 and 25 October 2022.

The data analysis technique used for test data is by analyzing errors using the Newman procedure after which the errors are summed, then the percentage of each type is determined. Existing errors are classified according to the type of error and its indicators.

Table 1. Classification and indicators of error types (Fitriatien, 2019)

No.	Error Type	Error Code
1.	Reading errors Indicator: Students are unable to find the meaning of words from difficult sentences or terms in the problem.	K1
2.	Understanding problem errors Indicator: Students are unable to find out what is known and what is asked in the problem	K2

No.	Error Type	Error Code
3.	Transformation errors Indicator: Students know what is known and what is being asked about, but students do not know what operations are used to solve the problem.	K3
4.	Processing skill errors Indicator: Students do not know the procedures needed to complete the operation properly.	K4
5.	Writing errors Indicator: Students do not conclude settlements into mathematical sentences.	K5

To see what the percentage of types of student errors in each given item is using the formula (Rahmawati & Permata, 2018):

$$P = \frac{n}{N} \times 100\% \quad (1)$$

Information:

P : Percentage of students who make type i errors. (i=1,2,3,4,5)

n : The number of errors for each type of error

N : Number of FKIP Sriwijaya University students

Student interview data will be analyzed based on answers to questions that have been prepared using interview guidelines, as Table 2 below.

Table 2. Interview guidelines

No	Error Type	Indicator	Question
1.	Reading errors	Students are unable to find the meaning of words from difficult sentences or terms in the problem.	● Did you find words or numbers that you didn't know the meaning of in the questions? ● So what solution do you provide so that you can solve the problem when you do it?
2.	Understanding problem errors	Students are unable to find out what is known and what is asked in the problem.	● Explain the information you know from the problem? ● Explain the problems that exist in the question?
3.	Transformation errors	Students know what is known and what is being asked about, but students do not know what operations are used	● Based on the problem and the information provided from the question, what is your next step?

No	Error Type	Indicator	Question
		to solve the problem.	● Describe what assumptions you made? ● Explain why you identified the variable that way? ● Explain why you made the model the way it did?
4.	Processing skills errors	Students do not know the procedures needed to complete the operation properly.	● After doing the previous steps, why did you finish like that?
5.	Writing errors	Students are able to solve problems correctly, but students do not conclude the solution into mathematical sentences.	● After getting the results of the problems given from the questions, explain what you should do next?

Results

Following are the results of the answers of 52 participants based on the classification of the types of errors and their indicators. For the type of reading error (K1) cannot be seen through the test results alone, so specifically the type of reading error (K1) will be seen from the results of the interview. For this type of processing skill error (K4), in question 1 no participant made this type of error because in question 1 the participant only needed to work on it until it made the mathematical model.

Table 3. Total and percentage of answers to participant test questions

Error		K1	K2	K3	K4	K5
Question 1	Error Total	-	12	24	-	17
	Persentage (%)	-	23.1	46.2	-	32.7
Question 2	Error Total	-	7	50	50	19
	Persentage (%)	-	15.4	96.2	96.2	36.5

Based on Table 1, it is known that the total and percentage of participant errors in questions 1 and 2. Each type of error is discussed further as follows:

Reading errors

In this reading error, researchers cannot add up based solely on test data. So, the researcher interviewed the participant where specifically for this type of error the researcher chose the participant to be interviewed from the participants who made an error in understanding the problem (K2).

For question 1, participant WA, participant S, and participant AMM did not experience reading errors, and even so participant WA, participant S, and participant AMM could not solve the problems in question 1. Meanwhile, participant SH itself experienced reading errors where participant SH do not understand the meaning of the word "climate change".The solution that SH participant did so that the SH participant could continue working on the questions by re-reading so that the SH participant could gradually understand the meaning of the word.

For question 2, participant WA, participant AMM, and participant RF did not experience reading errors, and even so participant WA, participant AMM, and participant RF could not solve the problems in question 2. Meanwhile, participant S himself experienced reading errors where participant S had not to understand the meaning of the word "canal". The solution that participant S does so that participant S can continue working on the problem by guessing the meaning of the word.

Understanding the problem errors

The indicator for this type of error is that students are unable to find out what is known and what is asked in the problem.

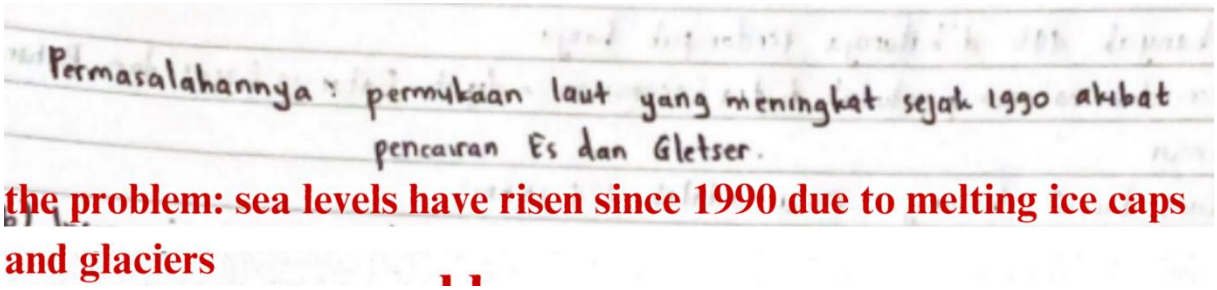

Figure 1. Example of type of errors in understanding problems in question 1

In Figure 1, it can be seen that the participant made an error in the type of error in understanding the problem where the participant incorrectly determined the problem or the thing asked in question 1 which was the correct error in the question, namely "making a mathematical model to determine the sea level in year t".

From the results of the interviews, it was found that the cause of the participant making this error was that the participant was not careful in reading the problem or the information contained in the problem. This is supported by the results of interviews with participant SH, namely:

Q: Does that mean you weren't careful in reading the instructions?

SH: Yes, you're right sis, I wasn't careful in reading.

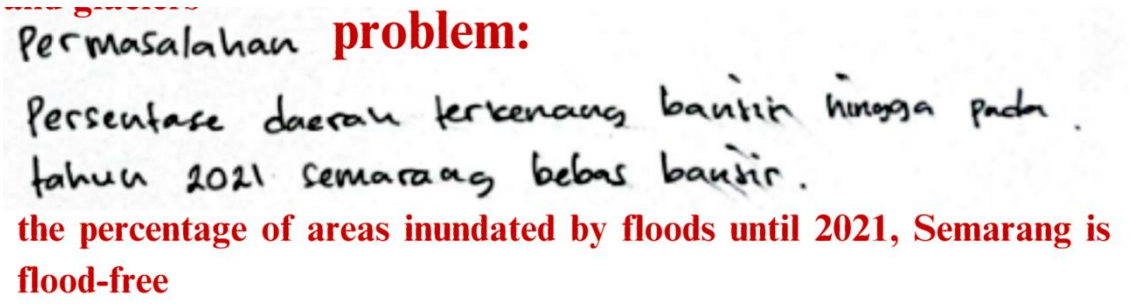

Figure 2. Example of type of errors in understanding problems in question 2

In Figure 2, the participant only wrote 1 problem. Meanwhile, there are 2 problems in question 2, which are making a mathematical model to determine the percentage of flooded areas in Semarang city in 2013 and determining the percentage of flooded areas in Semarang city in 2013.

From the interview results, it was found that the cause of the participant making this type of error was that the participant was not careful in reading the questions as a whole. This is supported by the results of interviews with participant AMM, namely:

Q: Based on the questions, there are 2 problems to look for.
AMM: It means I made a mistake sis.
Q: What do you think caused you to make that mistake?
AMM: Because I didn't read all of Sis's questions completely.

Transformation errors

The indicator for this type of error is that students know what is known and what is being asked about the problem, but students do not know what operations are used to solve the problem. The operation used for this error is to create a mathematical model, where assumptions and identification of variables are needed before creating a mathematical model.

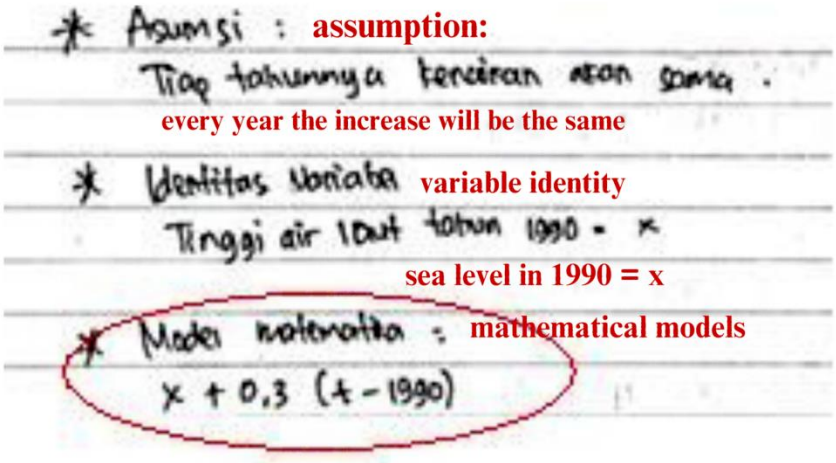

Figure 3. Example of type of transformation errors in question 1

In Figure 3, the errors made by the participant are in determining the mathematical model, where the correct mathematical model is.

From the interview results it was found that the cause of the participant making this error was the participant not being focused and careful in reading, still making errors in making assumptions, and the participant still making errors in identifying variables. This is supported by interviews with participant SH, participant ID, and participant AMM, namely:

Q: The problem is the sea level at a certain time, it's just that in the math mode you made it only determines the sea level rise in year t. it's just that you forgot the initial sea level in 1990. Because you had an error in making the model, of course you also had an error in identifying the variables, is that correct?

SH: That means less, sis?

Q: Yes, that means what caused you to make that mistake?

SH: Yesterday I wasn't focused on reading because I just thought that the rise in 1990 didn't have a water level.

Q: Assumptions are made to simplify calculations. Where a more appropriate assumption is used, namely the rise in sea level in every decade is 3 cm, which is constant. What factors make you make mistakes when making assumptions?

ID: Maybe because I didn't think to make such an assumption.

Q: It means that in this problem, you still have difficulties in identifying variables so it is also difficult to model them

AMM: Right, sis. So confused, how to identify the variable.

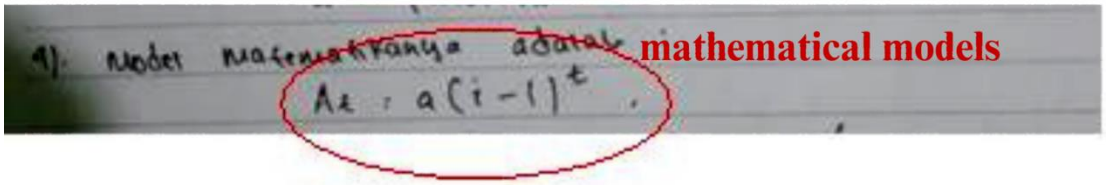

Figure 4. Example of type of transformation errors in question 2

In Figure 4, the participant made an error in making the right mathematical model, where the right mathematical model is.

From the results of the interviews, it was found that the cause of the participant making this error was the lack of ability to model the participant's mathematics because the participant was difficult to imagine or determine the correct mathematical model, besides that the participant still made errors in making assumptions and identifying variables that hindered the participant in making the mathematical model. This is supported by the results of interviews with participant S and participant SM, namely:

Q: What is the cause?

S: Because of the decline in year t, namely t itself, from 2013 to 2017, 24% was obtained, which is impossible for a decrease. The reason is how to imagine that the decline in 2013 to 2017 is constant or there is a decrease and in 2021 it is free from flooding. And also I still haven't really mastered the decay material that I use the formula for.

Q: Does that mean you still haven't mastered the mathematical model you made?

S: Yes, that's right, sis.

Q: It means that to be able to determine a model, you have to focus, and your assumptions have to be true. Is it true?

SM: Yes, that's right, because to make a model, you need the previous steps, namely making assumptions and variables. If the assumptions and variables are wrong, then the mathematical model will be wrong.

Processing skills errors

An indicator of this type of error is that students do not know the procedures needed to complete the operation correctly.

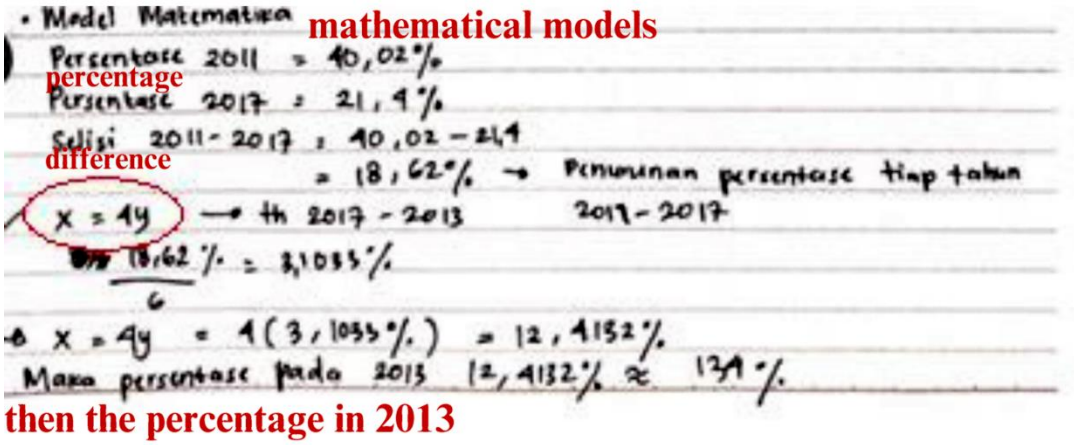

Figure 5. Example of processing skill error type in question 2

In Figure 5, the participant made an error in solving it, it can be seen that the mathematical model that was made was still wrong causing the solution that was made to be wrong. From the results of the interviews, it was found that because the predetermined mathematical model was wrong, it caused the existing solutions to be wrong. This is supported by the results of interviews with participant SM, namely:

Q: After determining the mathematical model, the next step is solving the model. Why did you finish like that?

SM: For the next step, which is to solve the problem where I make a percentage for the year to be calculated. There I made the model like that because of the previous assumptions and variables. Because the assumptions and variables that I specified were wrong, the mathematical model and solution were wrong.

Writing errors

The indicator for this type of error is that students do not conclude the solution in mathematical sentences.

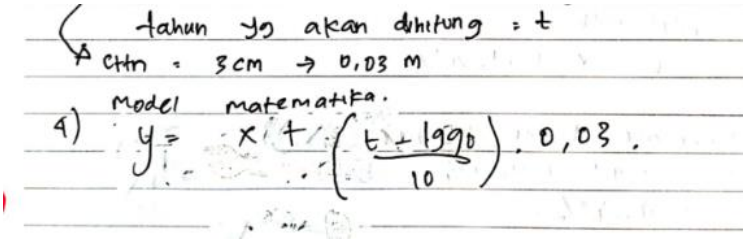

Figure 6. Example of type of writing errors in question 1

In Figure 6, it is clear that the participant did not write down the conclusions from the results of the mathematical model he obtained. From the interview results, it was found that the cause of the participant making this type of error was a lack of focus and the participant was in a hurry in working on the questions. This is supported by the results of interviews with participant ID, namely:

Q: After determining the assumptions, identifying the variables, determining the mathematical model, after that there is the stage of solving the problem and finally there is a conclusion. Why don't you write down your conclusions in mathematical form?

ID: It's not too late and I think the last step is just to solve the problem.

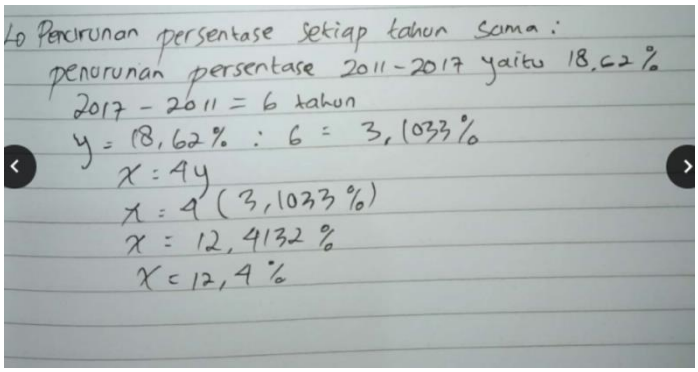

Figure 7. Example of type of writing errors in question 2

In Figure 7 it is clear that the participant did not write down the conclusions from the results of the mathematical model he obtained. From the interview results, it was found that the cause of the participant making this type of error was a lack of focus and the participant was in a hurry to work on the questions and was too focused only on the previous questions. This is supported by the results of interviews with participant ID, namely:

Q: Why don't you write a conclusion from the results you have obtained?

ID: because I'm not in a rush, sis

Q: besides that?

ID: I did this problem in the last 10 minutes.

Q: Does that mean you lacked time to complete it?

ID: Yes, sis. I was too focused on the previous question.

Discussion

Based on the test results, the indicator of transformation error is the highest percentage of occurrences. This is because students lack focus and thoroughness in reading the questions given, make errors in making assumptions, lack of ability to model mathematics and students still make errors in identifying variables. This is in line with the results of research by Mubarokah et al. (2020), namely, students still experience difficulties in determining variables in everyday problems, besides that this is also in line with the results of research by Kartikasari et al. (2021), namely at the transformation stage, the error that was made was not writing a mathematical model.

In addition, the indicator for processing skill errors is also the highest percentage of occurrence in line with the results of research by Pereira et al. (2022), that is, students experience many errors in processing skills, in other words, processing skill errors are the highest errors made. This is because students make errors in determining the model so the solutions that have been made by students are also wrong.

On the reading error indicator, students who make errors make different solutions so that these students can continue working on the problem. Starting from re-reading the questions carefully to guessing the meaning of words they find difficult, even so, students who make errors cannot solve mathematical modeling problems, especially in the context of climate change correctly. This is in line with the results of research by Fitra (2021), namely one of the factors that cause student errors in solving mathematical modeling problems is the lack of student knowledge in understanding symbols (symbols) and units in mathematics, in other words, students' lack of knowledge in understanding the meaning of symbols or symbols. difficult word.

The indicator of error in understanding the problem is the lowest percentage of occurrence, this error is caused because students do not write down problems or information they get from questions thoroughly, and students are not careful in reading problems or information in the questions as a whole. This is in line with the results of research by Halim and Rasidah (2019), namely, students are not used to writing down problems and information in questions.

In the writing error indicator, the error was caused by the lack of focus and the students in a hurry to work on the questions. This is in line with research by Mubarokah et al. (2020), namely, students still have difficulty in concluding the answers requested.

Based on the series of research activities that have been carried out, the researchers found various causes of errors made by FKIP Sriwijaya University students in solving mathematical modeling problems in the context of climate change. First, errors in reading, students are less focused and less thorough in reading the test questions as a whole. Second, errors in determining problems and existing information, students are not careful in writing down the problems and information contained in the problem as a whole, and students are not careful in reading and finding problems and information contained in the questions. Third, errors in making assumptions, students make errors in determining useful assumptions to make it easier for students to make mathematical models. Fourth, errors in identifying variables, students make errors in identifying variables so that students cannot make mathematical models correctly. Fifth, errors in making mathematical models, students make errors in making correct mathematical models which cause students to be unable to solve mathematical modeling problems correctly and completely.

Conclusion

For each question, the number of errors made will always be different, as well as the causes. The causes of errors made by FKIP Sriwijaya University students in solving mathematical modeling problems in the context of climate change are reading errors, errors in determining problems and existing information, errors in making assumptions, errors in identifying variables, and errors in making mathematical models. In question 1, the errors that appeared based on the test data were errors in understanding the problem by 23.1%, transformation errors by 46.2% and writing errors by 32.7%. Meanwhile, the errors based on the results of the test data for question 2 included errors in understanding the problem by 15.4%, transformation errors by 96.2%, processing skills errors by 96.2%, and writing errors by 36.5%.

From the results of this research, the authors hope this article can be useful and help many parties. Lecturers, to teach mathematical modeling with more emphasis on making mathematical models, to minimize mistakes made by students in solving mathematical modeling problems, especially in the context of climate change. For students to pay more attention in reading questions, determine existing problems and information, make assumptions, identify variables, and make mathematical models carefully, to minimize mistakes made in solving mathematical modeling problems, especially in the context of climate change. For researchers, to develop this research, use different procedures and more subjects so that more types and causes of errors are obtained in detail and more depth.

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Conflicts of Interest

The authors declare no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies, have been completed by the authors.

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Author Contributions

Mursyidah J Parandrengi: Conceptualization and design, writing - original draft, analysis and interpretation of data, editing, and visualization; **Cecil Hiltrimartin:** Review, editing, and supervision.

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