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The development of teaching materials based on mathematical modeling in the context of climate change for prospective teachers

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Abstract
Mathematical modeling ability is one of the important skills prospective teachers and students possess in solving contextual problems. One that often happens around us is climate change. This study aims to develop teaching materials based on mathematical modeling in the context of climate change that is valid and practical. The method used is research and development with the ADDIE development model. This research was conducted at one of the state universities in Indonesia with a total of 53 subjects. Data collection techniques using observation, interviews, and tests. Data analysis techniques use qualitative research methods by looking at indicators and mathematical modeling abilities. This research produces teaching material based on mathematical modeling in the context of climate change that is valid and practical for prospective teachers. The evaluation results showed that most of the research subjects could not solve the problems correctly. Teaching materials based on mathematical modeling that have been developed can be input for prospective teachers regarding teaching materials that will be given, especially in the context of climate change, so that later they will help develop students' problem-solving abilities.

INTRODUCTION

Modeling is an integral part of learning, one of which is learning mathematics. Mathematical modeling is the basic thing that needs to be mastered to give students opportunities to develop an understanding of mathematics following the mathematics education curriculum, which will play a role in connecting a problem in the real world and translating it into the form of mathematical language using mathematical symbols (Carberry & McKenna, 2014; Hiltrimartin et al., 2022; Mohammad et al., 2022). Developing mathematical modeling skills will help students more easily understand mathematical concepts (Erbas et al., 2014; Hartono & Karnasih, 2017). This is a special concern that is important for teachers and students to have, which will make it easy to solve a contextual problem and represent it in mathematical form (Fitzmaurice et al., 2021; Karabörk & Durmus, 2020; Kurniadi et al., 2019; Riyanto et al., 2022). Contextual problems contain real-world conditions that will later be associated with mathematical material. Indi rectly, when someone is accustomed to solving contextual

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problems and applying them in mathematical modeling, they can form a good habit so that they will remember learning for a long time.

According to Blum and Kaise, mathematical modeling ability consists of several stages: structuring, mathematization, solving, interpreting, and validating. During the structuring stage, real problems are identified. The mathematization stage involves 3changing the real problem that has been identified into a mathematical form. The solving stage, namely solving mathematical problems mathematically, the interpreting stage involves converting the mathematical solutions obtained into real-world solutions, followed by the validating stage, which involves re-checking the answers found in the previous stage (Khusna & Ulfah, 2021). Fulfilling the stages of mathematical modeling will help students improve their problem-solving abilities (Munawarah et al., 2020; Obukhov et al., 2020) so that it encourages students to do more analysis of a contextual problem.

Mathematical modeling ability in Indonesia is still relatively low. This can be seen from the results of Indonesia's PISA, which show that the mathematics score in 2018 was 379. Indonesia's PISA score is still below the international average of 489 (Ahmad & Latif, 2021; Ramadhani & Saptono, 2022). In addition, some research results show that students' ability to understand and solve math problems in word problems is low (Khusna et al., 2021). This is in line with Fitra's research (2021), which states that student mistakes in solving simple modeling problems are because students do not understand the solving methods for word problems. In addition, errors also occur in concepts (73.3%), principles (3%), facts (1.6%), and operations (5.4%). Based on the data from the research that has been done, it appears that some errors in mathematical modeling are caused by a lack of understanding of the concept of problem-solving and the information obtained.

Mathematical concepts students do not understand they are usually found in math story problems. Word problems in mathematics contain contextual problems, which are made to train students' analysis in solving problems, especially in real life. Students are not used to solving problems with the characteristics of real contexts and only work on exemplary questions without knowing the benefits in everyday life (Li et al., 2022). Therefore, a good learning process must be supported by appropriate teaching materials. Teaching materials based on mathematical modeling will support the implementation of learning that can analyze information and determine good and appropriate problem-solving methods. Therefore, the development of teaching materials based on mathematical modeling will assist in improving students' abilities, especially in contextual problems.

Climate change is one of the real-world conditions that we frequently encounter. Climate change is a phenomenon that is being discussed not only in Indonesia but also around the world (Dawson et al., 2022). Climate change is a change in long-term weather patterns that occurs on a global scale and has multi-sectoral effects that affect the quality of living things and the environment in general (Kulkarni et al., 2022; Pörtner et al., 2022). Climate change is a problem that creatures on earth cannot avoid. From the various impacts of climate change in Indonesia, much can be learned to understand changes in weather patterns. In the end, it can result in the loss of many lives and infrastructure losses as well as regional or national economies (Rahman et al., 2021; Sekaranom et al., 2021). Climate change that has occurred can be converted into mathematical modeling as a form of representation in real life (Fitrinitia et al., 2022; Mukhlis & Perdana, 2022; Sheriffdeen et al., 2022).

Similar studies have been carried out, including research conducted by Wibisana & Kamandang (2022) by making a mathematical model that can optimally determine climate change by measuring sea surface temperature. Research by Yerizon (2014) states that mathematical modeling with statistical analysis is used to measure the effect of flooding in the capital city of Jakarta. Research by Sun et al. (2022) produces the impact of climate change on vegetation patterns by using mathematical modeling and data analysis properly. Furthermore, research on model-based teaching materials has also been carried out by Turmudi et al. (2014), who found that students can teach mathematics with process modeling based on a realistic approach.

Several previous studies that have been conducted have not found research related to the development of teaching materials based on mathematical modeling in the context of climate change. The findings obtained can be input for prospective teachers regarding the teaching materials that will be provided, especially in the context of climate change, so that later they will help develop real-life-oriented student problem-solving abilities. Therefore, this study aims to conduct research on the development of teaching materials based on mathematical modeling in the context of climate change for prospective teachers.

METHOD

The authors used Research and Development (R&D) research to develop the ADDIE model in this study. Research methods used to produce new products or improvements to existing products can be accounted for in the future. The subjects in this study were 53 students who were at one of the State Universities in Indonesia. This study focuses on design and students' responses to the development of teaching materials based on mathematical modeling. The ADDIE development model consists of several stages: analysis, design, development, implementation, and evaluation. The following is a modified flowchart for developing teaching materials based on mathematical modeling in the context of climate change.

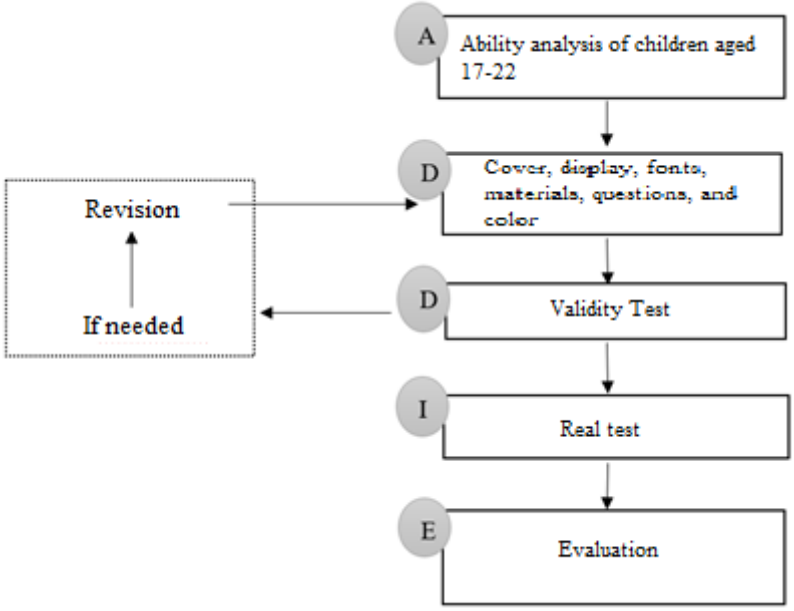


Figure 1. ADDIE Model Development Flowchart

At the analysis stage, the researcher analyzes the need for developing teaching materials in light of the problems that will arise in the teaching materials. Furthermore, an analysis of the

characteristics of students according to their knowledge, skills, and development in the age category 16 -22 years. This analysis aims to determine the diversity of possible answers that will appear when solving a given problem.

The second stage designs at this stage, the researcher designs teaching materials that are adapted to the characteristics of students aged 16-22 years. The design of this teaching material starts from selecting the cover, designing the material, including activities adapted to the climate change context, practicing questions, writing, and adjusting the colors to attract students' interest.

The third stage is development. After the teaching materials have been designed, the researcher validates them with two people who are experts in their fields, namely the first is a mathematics education lecturer to see the suitability of the teaching materials with the stages of mathematical modeling, and is a biology education lecturer to see the suitability of the teaching materials with the context of climate change.

The fourth stage is implementation. At this stage, the researcher implements the teaching materials that have been developed into actual situations in the classroom. Teaching material delivered in class follows ongoing learning. The purpose of implementing this teaching material is to guide students in the ongoing learning process so that learning outcomes can be fulfilled. In addition, implementing these teaching materials is also expected to improve students' abilities after learning is carried out using teaching materials based on modeling the context of climate change.

The last stage is evaluation. The researcher evaluates the results of the development of teaching materials at this stage by administering a two-question test. The problems contained in these questions refer to climate change.

The data analysis technique in this study was carried out qualitatively by looking at the appearance of the indicators set by the researcher. The indicators to be used are presented in Table 1.

Table 1. Competence and Measured Indicators

Competence	Indicator
Understand Problems	Identify the problem and find the information already contained in the problem.
	Make assumptions from the problems given.
	Identify the variables to be used.
Create a Mathematical Model	Make mathematical models precisely
Solve Problems Mathematically	Solve problems properly
Interpret results	Provide conclusions from the results that have been obtained

RESULTS AND DISCUSSION

This study reports the results of developing teaching materials based on mathematical modeling. The feasibility level of these teaching materials is known through validation by media experts, material validation, and subject lecturer validation.

Analysis

At the analysis stage, the researcher analyzed the importance of mathematical modeling-based teaching materials for a prospective mathematics teacher. Mathematical modeling has been taught from the

elementary school (SD) to the tertiary level (Khusna & Ulfah, 2021). So prospective mathematics teachers and prospective students must be able to model mathematics to teach students. The second analysis is of the characteristics of children aged 16 - 22.

This analysis is used to adjust each appearance and problem contained in teaching materials that are developed with knowledge, skills, and development. Based on the interviews that the researchers conducted with six students in the 16 - 22 year age category, the six said that the selection of colors used in teaching materials should not be too many and use un conspicuous colors.

Furthermore, the last analysis that researchers did was on their knowledge. In analyzing cognitive development, researchers refer to the theory of cognitive development according to Jean Piaget. According to Jean Piaget's theory, it is said that at the formal operational stage (11-15) years, children can already think about concrete experiences, think more abstractly, can think about possibilities, and also children can develop a hypothesis to solve a problem and draw conclusions systematically (Kilag et al., 2022). Based on this theory, the researchers concluded that for the 16-22-year-old category, their cognitive abilities were more than those of 11-15-year-old children.

Design

At the design stage, the researcher refers to the analysis that the researcher has done, starting from selecting colors, covers, and language and writing the material in the teaching materials. The problems contained in the teaching materials are also designed based on cognitive abilities according to the age category. The following is a design of the developed teaching materials.

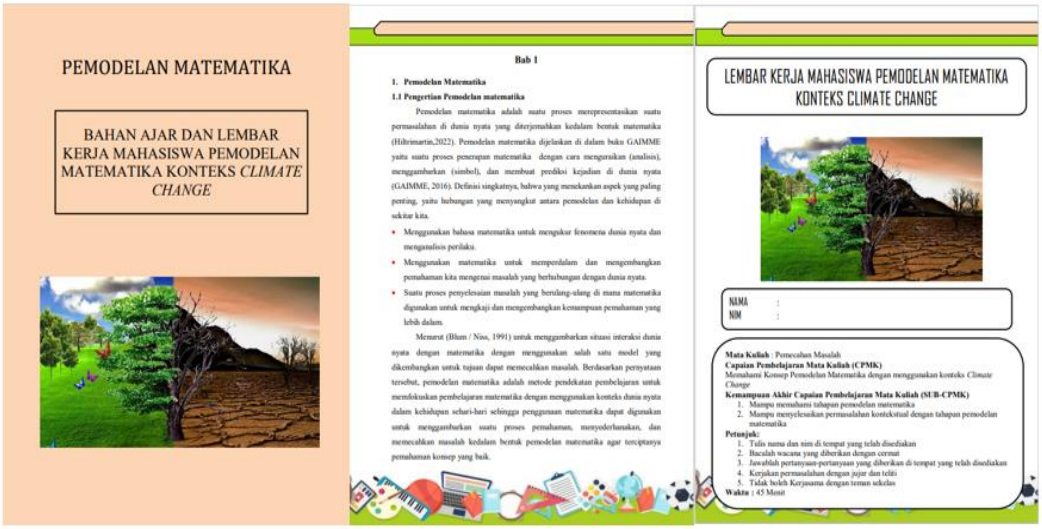


Figure 2. Cover Design, Material, and Activities

Development

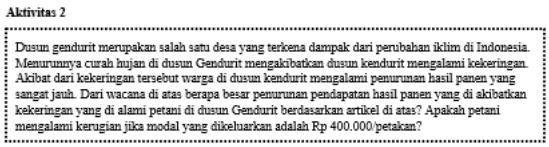
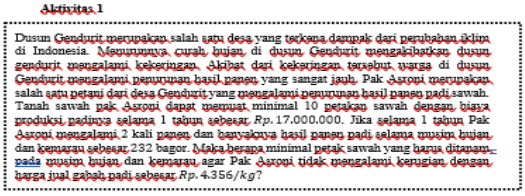
At the development stage, the researcher conducted a media expert test. The first media expert is a mathematics education lecturer who determines the validity of the developed teaching materials based on the suitability of the content, constructs, and language contained in the teaching materials with mathematical modeling. The second is for the biology education lecturer to check the suitability of climate change material in teaching materials based on mathematical modeling in the context of climate change for prospective teachers. The assessment table from media experts is presented in Table 2.

Table 2. Media Expert Assessment

Media Expert Assessment I	Media Expert Assessment II
Change covers	The explanation about climate change is adequate
Add an example question	
Replace the problems found in the MFI	

Assessments from several media experts have been carried out, with several suggestions for improvement. Furthermore, the teaching materials were revised according to the input given. The improvements that have been made are presented in Table 3.

Table 3. Improvement of Teaching Materials

Teaching Materials Before Repair	Teaching Materials After Repair
	
	

After the media expert test, the teaching materials developed were tested on six students, two in the one-to-one stage and four in the small group stage. In the one-to-one stage, two students commented on adding one more problem to the LKM in the teaching materials to assist in solving real problems.

In the small group stage, students comment on correct words that are still wrong, as well as the time available at the LKM. The time given to solve problems at the LKM was initially 30 minutes but changed to 45 minutes. Based on the advice from media experts, one-to-one and small-group trials of teaching materials met the characteristics of validity.

Implementation

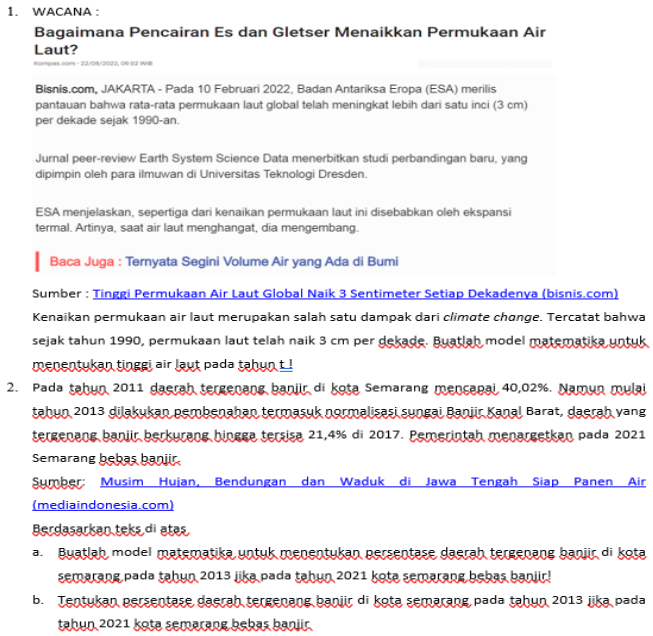
The implementation phase aims to see the practicality of the teaching materials developed. The practicality of teaching materials can be seen when the teaching materials are tested on individuals or groups as well as in trials in real classes; this is in line with several previous studies that looked at practicality based on the results of individual trials and real classes (Nurhusain et al., 2022; Rohmah & Nisa, 2022; Tegeh & Kirna, 2013).

Teaching materials were tried out in real classes on 53 mathematics education students. Teaching materials are given to all students. Learning is done online and offline. There are 14 face-to-face (offline) students and 39 people through zoom meetings. The researcher explained the mathematical modeling in the context of climate change and provided examples of problems in the teaching materials. Furthermore, the researcher asked the students to work on the problems found in the LKM individually.

Three observers assisted the researcher in observing all students in class and those who took part online. Based on the results of observations made by the three observers, students are still confused about solving these problems. In addition, teaching materials that should be done individually are still being worked on together. This can be seen during the learning time when the results they collected were almost identical. The learning process ran smoothly, and from the observations made by the observer, three students were still confused about solving the problems given. The researcher conducted interviews with the three students. The results show that they are still confused when they want to determine the minimum value because they misunderstood the meaning of the problem given.

Evaluation

The last stage is evaluation. The researcher evaluates the results of the development of teaching materials at this stage by administering a two-question test. The problems contained in these questions refer to the context of climate change. The test questions that the researchers gave to the research subjects can be seen in Figure 3.



1. WACANA :

Bagaimana Pencairan Es dan Gletser Menaikkan Permukaan Air Laut?

Bisnis.com, JAKARTA - Pada 10 Februari 2022, Badan Antariksa Eropa (ESA) merilis pantauan bahwa rata-rata permukaan laut global telah meningkat lebih dari satu inci (3 cm) per dekade sejak 1990-an.

Jurnal peer-review Earth System Science Data menerbitkan studi perbandingan baru, yang dipimpin oleh para ilmuwan di Universitas Teknologi Dresden.

ESA menjelaskan, sepertiga dari kenaikan permukaan laut ini disebabkan oleh ekspansi termal. Artinya, saat air laut menghangat, dia mengembang.

Baca Juga : Ternyata Segini Volume Air yang Ada di Bumi

Sumber : Tinggi Permukaan Air Laut Global Naik 3 Sentimeter Setiap Dekadenya (bisnis.com)

Kenaikan permukaan air laut merupakan salah satu dampak dari *climate change*. Tercatat bahwa sejak tahun 1990, permukaan laut telah naik 3 cm per dekade. Buatlah model matematika untuk menentukan tinggi air laut pada tahun t !

2. Pada tahun 2011 daerah tergenang banjir di kota Semarang mencapai 40,02%. Namun mulai tahun 2013 dilakukan pembenahan termasuk normalisasi sungai Banjir Kanal Barat, daerah yang tergenang banjir berkurang hingga tersisa 21,4% di 2017. Pemerintah menargetkan pada 2021 Semarang bebas banjir.

Sumber: Musim Hujan, Bendungan dan Waduk di Jawa Tengah Siap Panen Air (mediaindonesia.com)

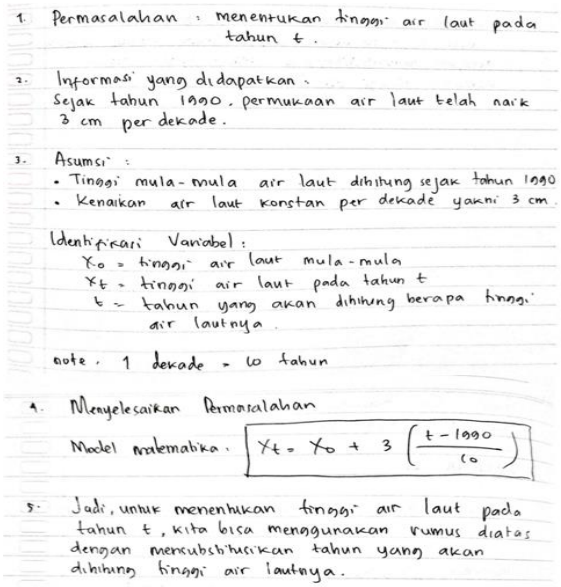
Berdasarkan teks di atas,

a. Buatlah model matematika untuk menentukan persentase daerah tergenang banjir di kota semarang pada tahun 2013 jika pada tahun 2021 kota semarang bebas banjir!

b. Tentukan persentase daerah tergenang banjir di kota semarang pada tahun 2013 jika pada tahun 2021 kota semarang bebas banjir.

Figure 3. Climate Change Context Test Questions

The test results show that students can answer the problems correctly. The results of student answers to problem one are presented in Figure 4.


1. Permasalahan : menentukan tinggi air laut pada tahun t.

2. Informasi yang didapatkan :
Sejak tahun 1990, permukaan air laut telah naik 3 cm per dekade.

3. Asumsi :
- Tinggi mula-mula air laut dihitung sejak tahun 1990
- Kenaikan air laut konstan per dekade yakni 3 cm

Identifikasi Variabel :
X_0 = tinggi air laut mula-mula
X_t = tinggi air laut pada tahun t
t = tahun yang akan dihitung berapa tinggi air lautnya.

note : 1 dekade = 10 tahun

4. Menyelesaikan Permasalahan
Model matematika : $X_t = X_0 + 3\left(\frac{t-1990}{10}\right)$

5. Jadi, untuk menentukan tinggi air laut pada tahun t, kita bisa menggunakan rumus diatas dengan mensubstitusikan tahun yang akan dihitung tinggi air lautnya.

Figure 4. Student Answers to Problem 1

In the first problem, students can solve test problems correctly. Students solve problems coherently according to the steps contained in the LKM that have been implemented during class. Based on the results of the answers that have been analyzed, all students can identify the problem correctly, make assumptions, identify variables, make mathematical models correctly, solve the problems given correctly, and draw conclusions from the results of the answers they have obtained correctly. Furthermore, the results of the second problem are presented in Figure 5.

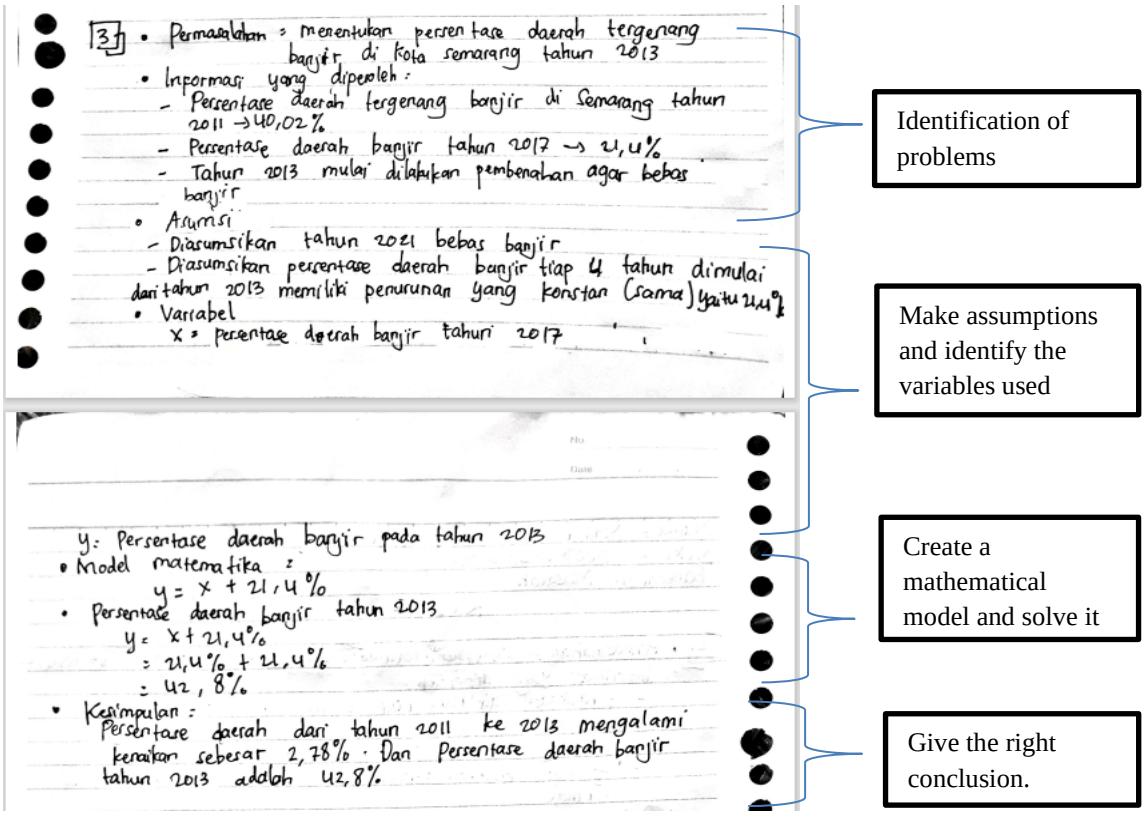


Figure 5. Student Answers to Problem 2

In the second problem, several students were able to identify problems, make assumptions, identify variables, make mathematical models correctly, solve problems given correctly, and provide conclusions from the results of the answers obtained and correctly. But there are still many students who are not right in solving the second problem. This can be seen from the results of the answers to question 2, which are presented in Figure 6.

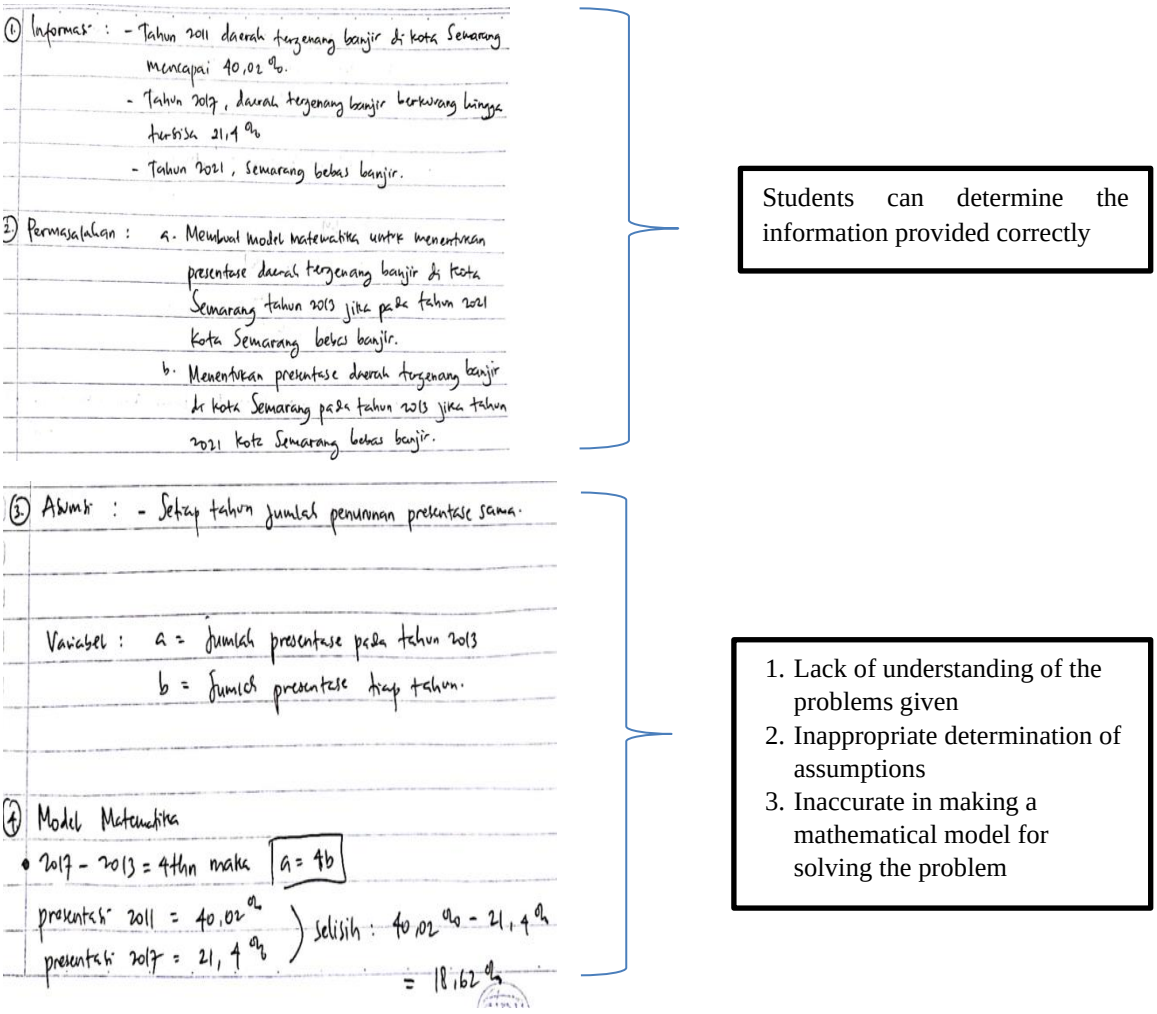


Figure 6. Answers to Question 2

From the test results, it can be seen that there are still many students who have not been able to solve these problems properly. The researcher interviewed several students to ask about their problems in solving them. The results of the interviews the researchers conducted with the two students were that the information in the question fooled them. They also did not properly analyze that the 2013-2017 period is the same as the 2017-2021 period. After the researcher explained the problem, they understood and said that the given problem was not too difficult but required reasoning and a good understanding of concepts.

Their understanding of mathematical modeling skills strongly influences student success in solving contextual problems. Students will be better trained in solving contextual problems to improve their mathematical modeling skills. Similar research conducted by Nurussaniah (2016) states that using teaching materials based on mathematical modeling can affect problem-solving abilities, which along with increasing problem-solving abilities, also develop

conceptual understanding abilities, especially in contextual problems. Therefore, prospective teachers must be creative and innovative in developing teaching materials based on mathematical modeling, which can develop other mathematical abilities.

CONCLUSION

Based on the research that researchers have done, it can be concluded that teaching materials based on mathematical modeling in the context of climate change for prospective teachers already meet the valid and practical categories of mathematical modeling abilities for prospective teacher students. The test results showed that almost all students could solve problems in question 1**,** and some could solve problems in question 2. Because students' reasoning abilities and understanding to make assumptions were still relatively low, they made mistakes. The problems given in teaching materials and during tests are problems that contain the context of climate change. The researcher realizes that there are still many shortcomings in this study, so the results of this study can be considered for further research.

AUTHOR CONTRIBUTIONS STATEMENT

NS, as the main researcher, contributed to generating research ideas and designing the development of teaching materials based on mathematical modeling. AE is in charge of analyzing and developing teaching materials. AA is in charge of preparing product trials. All authors read and agree with the final manuscript.

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