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DEVELOPMENT OF TEACHING MATERIALS LINEAR PROGRAM BASED ON PROBLEM-BASED LEARNING ASSISTED BY GEOGEBRA APPLICATIONS

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ABSTRACT

This study aims to develop teaching materials for linear programming based on Problem Based Learning assisted by GeoGebra applications that are valid, practical, and effective. The type of research used is a type of development research using the 4-D development model. The 4-D development model consists of the Define, design, develop, and disseminate phases. This study only reached the development stage. The research subjects were class XI SMA Negeri 2 Toma students. The instruments used were material expert and media expert validation sheets as well as student response practicality sheets and mathematical problem-solving ability tests. Based on the results of the research that has been done, it is found that the analysis of the validation results of material experts is 3.65 with a percentage of 73.06% in the valid category, and media expert validation is 4.08 with a percentage of 81.67% in the valid category. In the limited test, analysis of the results of the practicality sheet of 10 students obtained an average percentage of 73.73% in the practical category, and in the broad test of 29 students obtained an average percentage of 89.33% in the very practical category. In the effectiveness test, it was found that 71.25% was in good category. Thus, it can be concluded that the linear program teaching materials based on problem-based learning assisted by the GeoGebra application meet valid and practical criteria and are suitable for use in learning, and can be effective in facilitating mathematical problem-solving skills.

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INTRODUCTION

Problem-solving ability is one of the abilities that must be mastered by students in learning mathematics because it can accustom students to thinking systematically, critically, and logically, facilitates an understanding in learning mathematical concepts, and makes it easier for students to solve everyday problems (Imannia, et al. 2022; Sitorus & Sutirna, 2021; Sari, 2021). Hidayatsyah (2021) solving mathematical problems is a complex cognitive activity, as a process to overcome a problem that is encountered and to solve it requires a number of strategies. Problem-solving abilities provide opportunities for students to develop and train their mindset (Lestari et al., 2022). Siregar et al. (2021) state that students who are taught problem-solving skills will be skilled in gathering relevant information, analyzing information, and aware of the importance of re-examining the results that have been obtained. When students can solve a problem, then these students already have new abilities (Hidayatsyah, 2021).

Linear programming is one of the material topics studied by class XI high school students that has something to do with everyday life. Monariska & Komala (Ali, 2022) linear programming is a method of determining the optimum value (maximum and minimum) of a linear problem, which results from the value in a set of linear problem solutions. However, in reality students' mathematical problem solving skills in linear programming material are still relatively low (Fahda & Amin, 2019). In line with Liyana & Ferdianto (2018) in applying linear programming material, students still have difficulty identifying and planning problem solving procedures. Ekadiarsi & Khusna (2022) students cannot solve linear programming word problems because they do not understand the questions given. In addition, students have difficulty describing the graph of the settlement set area and determining the optimum value of the objective function (Rahayu & Naila, 2019).

The problem of students' difficulties can be overcome by having an innovative learning model for solving linear programming questions, one of which is with linear programming teaching materials. Teaching materials are all types of materials used to support teachers in carrying out teaching and learning activities in class (Fitriyana et al., 2021). The teaching materials developed in this study are in the form of student worksheets. Pranata et al., (2021), Student worksheets contain a series of activities that must be carried out by students to maximize understanding and aim to build basic abilities according to the indicators of achievement of learning outcomes that have been determined. According to Purwasi & Fitriyana (Styasih et al. 2021) The success of the mathematics learning process in class can be achieved optimally, one of which is through the use of a device in the form of worksheets that are adapted to the characteristics and needs of students, thereby helping students overcome their difficulties.

Student worksheet teaching materials developed based on problem-based learning models. The Problem Based Learning learning model is a learning model that uses problems as the first step in acquiring new knowledge (Salenussa, et al. 2022). According to Arend (Manfaati, et al.,2021), Problem Based Learning is a model designed to help students develop their thinking, problem-solving, and intellectual skills. In line with the results of research by Ulva et al. (2020) that the ability to solve mathematical problems using problem-based learning models is better than those using conventional models. In problem-based learning, students are given the opportunity to learn actively and independently to build their skills according to

their experience and knowledge where the teacher's role is more of a facilitator in the learning process (Angelius, et al. 2022).

In addition to innovative learning models, learning applications also support success in the mathematics learning process. The learning application in question is one of the GeoGebra applications. Geogebra is dynamic software that combines geometry, algebra, and calculus which can be used as a tool in learning mathematics (Bernard & Sunaryo, 2020). The use of the GeoGebra application can help students understand material concepts and solve linear programming problems because it makes it easier for students to describe graphs of the set of settlement areas.

The novelty in this research is that linear program teaching materials in the form of worksheets are developed using the problem-based learning model assisted by GeoGebra applications that are oriented to improve and train students' mathematical problem-solving abilities. Thus, this article examines the development of problem-based learning-based linear program teaching materials assisted by GeoGebra applications to improve students' mathematical problem-solving abilities.

METHOD

This research is development research with a 4-D model. 4-D stands for Define, Design, Develop, and Disseminate. This study aims to develop teaching materials for linear programming based on problem-based learning assisted by the GeoGebra application to improve high school students' mathematical problem-solving skills so that the 4-D development model fits perfectly with the products produced.

The subjects in the study were 10 students of class XI-MIPA for the limited test and 29 students of class XI for the broad test. The instruments used were questionnaires for the practicality of the teaching materials produced and tests in the form of description questions regarding students' mathematical problem-solving abilities.

The development of teaching materials for linear program material based on problem-based learning assisted by the GeoGebra application follows the 4-D development steps, namely as follows:

1) Define

This stage is carried out to analyze needs or define development requirements. In developing a product, development needs to refer to development requirements and analyze and collect information to what extent development needs to be done. At this stage, it is necessary to analyze the initial conditions, learning, concepts, tasks, and learning objectives.

2) Design

At this stage, the initial design of teaching material products in the form of student worksheets is carried out, namely the selection of the media to be used, the format of the contents of teaching materials, and the initial design.

3) Develop

At this stage, developing teaching materials, validating teaching materials, and making improvements and improvements to teaching materials according to the validator's suggestions.

4) Disseminate

The final stage in the development of the 4-D model is dissemination. In this study, it only reached the development stage.

The validation of teaching materials is carried out by experts consisting of material experts and media experts. Based on suggestions from material experts and media experts, improvements were made to the teaching materials. Practicality is measured by giving students questionnaires, while effectiveness is obtained based on the results of tests of mathematical problem-solving skills that are carried out after learning using teaching materials that have been developed.

Validity and practicality data analysis techniques use a Likert scale of 1, 2, 3, 4, and 5. The average score of the percentage of validity and practicality criteria is calculated using the formula:

$$p = \frac{f}{N} x\ 100\%$$

Information:
p : percentage
f : score obtained
N : maximum score

The results of the validity and practicality percentages are then interpreted according to table 1 below.

Table 1. Interpretation of the Validity and Practicality of Teaching Materials

Interval (%)	Validity
0 – 20	Invalid/Not Pratical
21 – 40	LessValid/Less Pratical
41 – 60	Fairly Valid/Quite Pratical
61 – 80	Valid/Pratical
81 – 100	Very Valid/Very Pratical

Source : Riduwan dan Sunarto (Nabilla et al., 2022)

The results of the mathematical problem-solving ability test scores consisting of 5 (five) questions are used to determine the effectiveness of linear program teaching materials based on problem-based learning assisted by the GeoGebra application. The scores obtained by students on the test used the formula:

$$p = \frac{f}{N} x\ 100\%$$

Information:
p : percentage
f : score obtained
N : maximum score

The percentage score of the mathematical problem-solving ability obtained is then interpreted using the following interpretation.

Table 2. Categories of Solving Ability Mathematical Problems

Score	Interpretation
86 – 100	Very Good
71 – 85	Good
56 – 70	Fairly Good
40 – 55	Less Good
0 – 39	Not Good

Source : Nasoetion (Khotimah et al., 2016)

RESULTS AND DISCUSSION

Result

The research results are presented based on the stages of the 4-D development model. However, the research only reached the development stage and did not carry out the dissemination stage due to limited time and costs. The development research phase is described as follows:

The first stage is defined. This step is carried out for the purpose of determining and analyzing learning needs and criteria. Researchers conducted initial and final analyses, learning, assignments, concepts, and learning objectives. In the initial analysis stage, the researcher identified the problems encountered in learning linear programming material. The problem obtained at this stage is that the learning process is still teacher-centered by explaining the material and students only listen and understand it. In addition, the teaching materials and media used are less attractive and do not motivate students to learn linear programming material. The learning analysis stage is carried out by identifying the characteristics of students in order to determine the appropriate learning media to be used in teaching materials.

The task analysis stage is carried out by identifying the abilities obtained from learning using problem-based learning linear program teaching materials assisted by the GeoGebra application. Based on the results of interviews with mathematics teachers, information was obtained that teachers rarely gave to students and students' mathematical problem-solving abilities were still low. The concept analysis stage is carried out by identifying the concepts of the material being taught, then systematically compiling the teaching materials in the form of formulation of learning objectives.

The second stage of design. At this stage, it is carried out the design of teaching material products is developed in accordance with the results of an analysis of student characteristics, assignments, concepts, and learning objectives. The initial appearance of teaching materials can be seen in Figure 1 below.

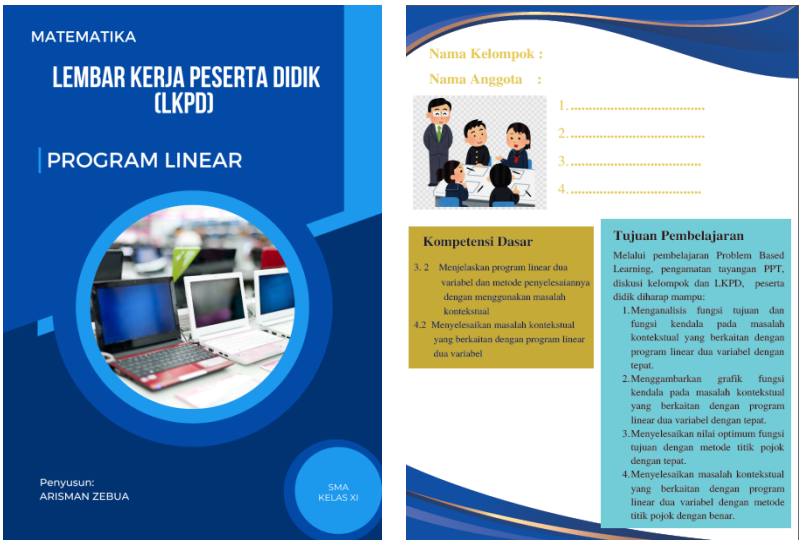

Figure 1. Linear Program Teaching Materials

The third stage of develop. After the initial design of the product has been completed, then at this stage validation of the teaching material product that has been designed is carried out, by providing teaching material to the validator consisting of the material expert validator and the media expert validator. The validator will provide an assessment through a validation sheet, then the researcher will make improvements to the teaching materials (if any) until a valid product is obtained and then tested on learning. The results of the material expert validation of teaching materials can be seen in the following table.

Table 3. Scores of Material Expert Validation Results

Total Score	Average Score	Percentage	Interpretation
219	3,65	73,06%	Valid

Based on the results of the material expert validation in table 3 above, the average score of the material expert validator is 3.65 with a percentage of 73.06% and is in the valid category. Suggestions and input for improvements from the material validator, namely learning objectives, and assessments must be clear and add a student identity column.

The results of the assessment of 2 media expert validators can be seen in table 4 below.

Table 4. Scores of Material Expert Validation Results

Rated Aspect	Average Score	Percentage	Interpretation
Persentation of Content	4,25	85%	Very Valid
Construct	4,00	80%	Valid
Graphic	4,00	80%	Valid
Average	**4,08**	**81,67%**	**Valid**

Based on the score of the media expert validation results in table 4 above, it can be seen from the content presentation aspect that a score of 4.25 is obtained with a percentage of 85% in the very valid category, the constructed aspect is 4.00 with a percentage of 80% in the valid category and the graphical aspect is 4.00 with a percentage of 80% is in the valid category. The overall media rating with an average of 4.08 and a percentage of 81.67% is in the valid category. The suggestion from the media expert validator is that the worksheet teaching materials should be added with instructions for using the GeoGebra application and the appearance of the teaching materials is arranged in a balanced manner.

Based on the results of the material expert validator and media expert, an overall conclusion was obtained that the worksheet teaching materials developed were in the valid category, from the aspect of the presentation of content, constructs, and graphics. Thus, the teaching materials for linear programming based on problem-based learning assisted by the GeoGebra application that has been developed are feasible to be tested in the field after being revised according to suggestions and input from material expert validators and media experts.

After the repairs were completed according to the validation results of material experts and media experts, then limited tests and broad tests were carried out to know the practicality of problem-based learning-based linear program teaching materials assisted by the GeoGebra application. Based on the results of data processing on the practicality questionnaire in the limited test presented in table 5 below.

Table 5. Practicality Results in the Limited Test

Rated Aspect	Average Score	Percentage	Interpretation
Usefulness	123	77%	Praticaly
Convenience	146,8	73%	Praticaly
Help	115,6	72%	Praticaly
Attractiveness	144,8	72%	Praticaly
Average	**133**	**73,73%**	**Praticaly**

Based on the results of the practicality of the limited test table 5 above shows that the aspects of usefulness, convenience, assistance, and attractiveness are in the practical category. Overall the practicality of the teaching material products in the test is limited to the practical category.

After conducting a limited test, the researcher made product improvements and then carried out a broad test. The results of the practicality of teaching materials in the broad test are presented in table 6 below.

Table 6. Practicality Results in Extensive Test

Rated Aspect	Average Score	Percentage	Interpretation
Usefulness	420	91%	Very Praticaly
Convenience	510	88%	Very Praticaly
Help	430	93%	Very Praticaly
Attractiveness	500	86%	Very Praticaly
Average	**465**	**89,33%**	Very Praticaly

Based on the results of the practicality of the broad test table 6 above shows that the aspects of usefulness, convenience, assistance, and attractiveness are in the very practical category.

Overall, the practicality of teaching material products in the broad test is in the very practical category. Thus, because it meets the valid and practical requirements, the linear program teaching materials based on problem-based learning assisted by the GeoGebra application are appropriate for use in learning mathematics.

In the next stage, the researcher implemented the teaching materials that had been developed for teaching mathematics in class XI and at the end of the meeting, students were given tests to measure the effectiveness of the teaching materials that had been developed. The test is in the form of a description of 5 questions arranged according to indicators of mathematical problem-solving ability. The results of the mathematical problem-solving ability test are presented in table 7 below.

Table 7. Mathematical Problem Solving Ability Test Results

No	Indicator	Percentage	Interpretation
1	Identify the elements that are known, asked and the adequacy of the elements	78%	Good
2	Build a mathematical model	70%	Good
3	Implement strategies to solve problems	65%	Good
4	Check the correctness of the results or answers	72%	Good
	Average	**71,25%**	**Good**

In table 7 above it can be seen that the overall test results for students' mathematical problem-solving abilities were 71.25% and were in a good category. This shows that the developed teaching materials can develop and improve students' mathematical problem-solving abilities.

Discussion

This study developed teaching materials in the form of student worksheets on linear program material based on the problem- based learning model assisted by the GeoGebra application to improve students' mathematical problem-solving abilities by using a 4-D model development design. The first stage in this development is define, namely analyzing the initial conditions, learning, concepts, tasks, and learning objectives. The second stage is design, namely the design of teaching material products that will be developed according to with the results of an analysis of student characteristics, assignments, concepts, and learning objectives. The third stage is develop, namely developing teaching materials, validating teaching materials, and making improvements and improvements to teaching materials according to the validator's suggestions. The last stage is disseminated namely product distribution. In this study, the dissemination stage was not carried out only until the develop stage.

The development of this teaching material was carried out because it was based on the lack of innovation by the teacher in classroom learning, the use of learning media that was less innovative or not based on ICT, and learning resources that only expected textbooks and information from the teacher. Teaching materials are developed using the problem-based learning model assisted by the GeoGebra application so that students are independent and active, making it easier to understand the material being taught and to solve mathematical problems (Faizah, hanim; Astutik, 2017). Thus, student worksheet teaching materials are designed to be as attractive as possible and easily understood by students and can direct students to construct their knowledge.

This study used a data collection instrument in the form of a questionnaire for the practicality of the resulting teaching materials and tests in the form of description questions regarding

students' mathematical problem-solving abilities. The results of the validation of material and media experts show that the teaching materials developed meet valid criteria and are suitable for use in learning. Furthermore, the results of the practicality assessment based on student responses obtained that the teaching materials for linear programming based on Problem-based learning assisted by the GeoGebra application were practical.

After the teaching materials meet the feasibility and practicality criteria, then measure the effectiveness of the teaching materials that have been developed by giving students mathematical problem-solving ability test questions and the results of these tests can develop and improve students' mathematical problem-solving abilities. Kharisma & Asman (2018) problem-based mathematics teaching materials can facilitate or develop and train students' problem-solving skills and achievement in learning mathematics. Improving students' problem-solving abilities by using problem-based learning teaching materials is a natural thing. This is because students themselves find the concept and master the findings correctly, while the role of the teacher guides students by giving directions (guided) and students are encouraged to think for themselves so they can find principles. generally based on directions/questions given by the teacher and to what extent students are guided depends on their abilities and the material being studied (Nasution & Rangkuti, 2019).

CONCLUSION

Based on the results of research data analysis, it can be concluded that the development of problem-based learning-based linear program teaching materials assisted by the GeoGebra application has valid, practical, and effective qualities, so it is suitable for use in mathematics learning, especially linear program material in class XI.

The use of problem-based learning-based linear programming materials assisted by the GeoGebra application can improve students' mathematical problem-solving skills and can help students overcome their difficulties. This is because the students themselves construct their own knowledge, while the teacher is only a facilitator. Suggestions from researchers are that this teaching material can be used in learning mathematics, and for future researchers, this teaching material can be developed into other materials and other learning applications.

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