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Developing realistic problem-based mathematics instructional materials to enhance students' conceptual understanding

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ABSTRACT

The purpose of this research was to develop realistic problem-based instructional materials that were both valid and practical in order to assist students in successfully enhancing their conceptual comprehension. We adopted the Borg and Gall's research and development model. During the process, we involved a total of seven teachers and 196 fifth-grade students in a public elementary school in Bandar Lampung, Lampung Province on the Indonesian island of Sumatra. We used several instruments including observation, questionnaire, and tests for data collection followed by descriptive statistics, t-test, and proportion test to test the effectiveness of the instructional materials being developed. The findings suggest that the realistic problem-based mathematics instructional materials that were developed are valid and practical to use. In other words, the instructional materials successfully help fifth-grade students enhance their conceptual comprehension. Following the findings are a discussion of the limitations and suggestions for future research.

KEYWORDS

Mathematics instructional Materials; realistic problems; conceptual comprehension

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Introduction

Lestari et al (2013) teaching materials are learning resources that are carefully organized to attain the core skills. Students can learn a skill methodically so that they can master the competency as a whole. According to Nurhasanah (2017), teaching materials are materials that will be taught to students who have been chosen (selection), and the content must be studied and comprehended by the students. As a result, teaching materials may be defined as learning materials that are organized systematically to master the resources utilized by educators and students in the learning process. As stated by Mulyasa (2006), the principles of producing instructional materials include validity, which is connected to the level of applicability and test ability of the content with competence, significance, utility, and learnability. Regarding the possibilities of studying the content, it aims to urge students to pursue various additional studies.

Mathematics is a topic in primary school that is integrated thematically for lower grades, namely grades I, II, and III, but stands alone or is not integrated with themes for high grades, namely grades IV, V, and VI. Mathematics is one of the subjects taught in elementary, secondary, and higher education. According to Minister of National Education Regulation Number 22 of 2006 establishing content requirements for elementary and secondary education units, mathematics learning should begin with the introduction of issues that are similar to situations encountered in daily life. Students construct concepts and knowledge using intuition, reasoning power, and previously learned notions.

Based on the results of the needs analysis regarding realistic problem-based mathematics teaching materials on 12-15 April 2021 in Cluster I Dahlia, Bumiwaras District, Bandar Lampung with the target of 7 fifth-grade educators consisting of 3 educators at SD Negeri 3 Bumiwaras, 3 educators at SD Negeri 4 Bumiwaras, and 1 Muhammadiyah Elementary School educator, the results are shown in Figure 1.

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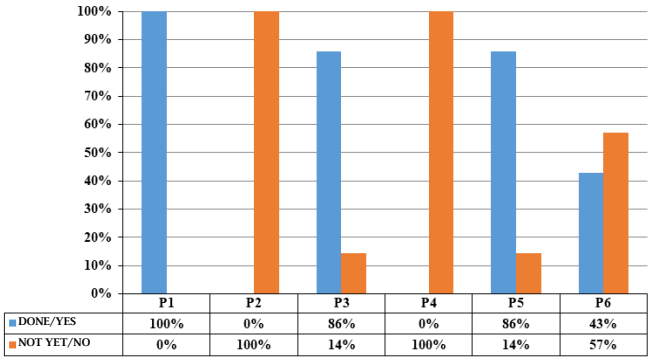


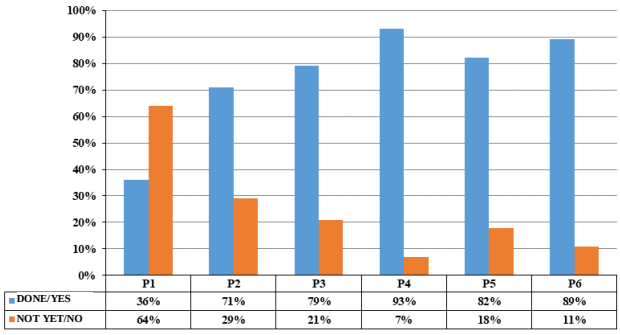
	P1	P2	P3	P4	P5	P6
DONE/YES	100%	0%	86%	0%	86%	43%
NOT YET/NO	0%	100%	14%	100%	14%	57%

Figure 1. Educator Needs Analysis

On April 14, 2021, information was acquired through an interview with the principal of SD Negeri 3 Bumiwaras that educators had employed teaching materials with genuine difficulties in the mathematics learning process in class, specifically, students were given challenges relating to the actual world in everyday life. Educators used actual situations as teaching materials, although the teaching materials were obtained from government-manufactured teachers' books.

Student characteristics associated with poor student motivation The parents of students at SDN 3 Bumiwaras are usually busy fishermen who do not have time to urge their children to study at home. As a result, to improve kids' motivation at home and at school, instructional materials that are relevant to everyday life are required.

Figure 2 shows the findings of the needs analysis for instructional materials that are relevant to students' everyday lives in the actual world.



	P1	P2	P3	P4	P5	P6
DONE/YES	36%	71%	79%	93%	82%	89%
NOT YET/NO	64%	29%	21%	7%	18%	11%

Figure 2. Analysis of Student Needs

The results of the observation that the average daily test score of fifth-grade students at SDN 3 Bumiwaras in the 2021/2022 academic year was 55. The test score had not yet reached the KKM, while the KKN value set for mathematics learning was 60. This data is shown in Table 1.

Table 1. List of Average Daily Test Scores for Class V SDN 3 Bumiwaras Academic Year 2021/2022 Semester 2

No	Subject	KKM	Average Score of The Class
1	Indonesian Language	75	78
2	Civics Education	70	77
3	Mathematics	60	55
4	Social Science	70	71
5	Natural Science	70	70

Source: Documentation of Class V Educators at SDN 3 Bumiwaras

Therefore, actual problem-based mathematics teaching resources are one of the tools available to educators. Good teaching resources for learning mathematics are the ones that provide students with the most opportunities to answer problems. Based on the above description, this study will create realistic problem-based mathematics teaching materials to help students enhance their conceptual comprehension skills.

Methods

Types of research

The type of research method used was the Research and Development method according to Borg & Gall (1983). According to Borg and Gall (1983), research and development is research aimed toward producing a certain product. The product was created after doing a requirements study in the area. First, the produced product is validated. The product is then changed to provide a high-quality, relevant product. The research outcome is realistic problem-based mathematics teaching materials for class V of elementary school, which may later be utilized as learning resources for students.

In this study, researchers only carried out steps one to seven, namely research and information gathering, planning, developing the preliminary form of the product, preliminary field testing, main product revision, main field testing, and operational product revision.

This study's subjects were divided into two groups: product trial subjects and use trial subjects. Expert validation, which includes material specialists, media experts, and linguists, is the topic of product testing. The participants in the usage experiment were fifth-grade elementary school teachers and students from Cluster I Dahlia, Bumiwaras sub-district. The goal of this development research is to provide realistic problem-based mathematics teaching materials to help students comprehend concepts better.

The population in this study consisted of all educators and students from the class V SDN Bumiwaras sub-district, with as many as 7 educators and 196 students. According to Sugiyono (2016), a population is an object or subject that has certain qualities and characteristics that are set to be studied and conclusions are drawn.

This study employed non-probability sampling with a purposive sampling technique, that is, defining the sample based on certain criteria. This study involves determining the sample based on the preliminary study's questionnaire results, namely SDN 4 Bumiwaras as a small group trial sample comprising 12 students and three educators from class V. Then, at SDN 3 Bumiwaras, a large group trial was conducted with 28 students from class V A (experimental class) and 28 students from class V B (control class). According to Sugiyono (2016), the sample is a subset of the population's size and characteristics.

In this development research, data was collected using expert observation guidelines in the form of quantitative data based on the results of a score of questions about the suitability of teaching materials, and qualitative data based on comments or suggestions about the feasibility of developed teaching materials. Documentation is utilized to gather information about students and school profiles. Documentation is derived from the term document, which signifies written products, according to Arikunto (2013). A questionnaire is a data collection instrument. According to Sugiyono (2016), a questionnaire is a data collection tool in which respondents are given a set of questions or written statements to answer. The questionnaire was used in this study to examine educators' and students' demands, to test theoretical feasibility (expert validation), and to test the practicality of educators' and students' responses. Data collection was performed through the use of a test procedure in the form of a written test. The test was repeated twice, once before and once after learning with realistic problem-based mathematics teaching materials and once after learning with teaching materials routinely utilized by educators. Giving tests is a good way to assess students' conceptual comprehension before and after using teaching materials.

Data Analysis Techniques

Expert validation analysis was conducted to determine the theoretical feasibility of the developed mathematics teaching materials. This expert validation analysis was carried out by descriptive analysis of the percentage with the following formula:

$$P = \frac{n - m}{M - m} x100\%$$

where:
P = Aspect Percentage Level
n = Total Aspect Score Obtained
M = Maximum Quantity
m = Minimum Quantity

Table 2. Expert Validation Assessment Criteria

Level of aspect presentation	Criteria
81 % - 100 %	Strongly Feasible
61 % - 80 %	Layak
41 % - 60 %	Quite Feasible
21 % - 40 %	Less Feasible
0 % - 20%	Not Feasible

Source: Riduwan (2009)

The practicality of the generated instructional material products was determined using questionnaire responses from educators and students. The percentage findings of this educator response questionnaire were descriptively analyzed using the following formula:

$$P = \frac{n - m}{M - m} x100\%$$

where:
P = Aspect Percentage Level
n = Total Aspect Score Obtained
M = Maximum Quantity
m = Minimum Quantity

Table 3. Practical Criteria for Responses of Educators and Students

Level of Aspect Percentage	Criteria
81 % - 100 %	Strongly Practical
61 % - 80 %	Praktis
41 % - 60 %	Quite Practical
21 % - 40 %	Less Practical

0 % - 20%	Not Practical

Source: Riduwan (2009)

Product Effectiveness Analysis is used after getting the data from the pretest and post-test results, calculations are carried out to determine the increased score (gain) understanding of students' concepts in both classes. According to Hake (1998) the amount of increase is calculated by the normalized gain formula, namely:

$$g=\frac{posttest\ score-pretest\ score}{maximum\ possible\ score-pretest\ score}$$

The gain data is then interpreted using the interpretation of Hake (1998) as shown in Table 4:

Table 4 Interpretation of Gain Value

Interval Indeks Gain (g)	Interpretation
$0{,}71 \leq g \leq 1{,}00$	High
$0{,}30 \leq g \leq 0{,}70$	Medium
$g \leq 0{,}29$	Low

Results

Based on the findings of research and development of realistic problem-based mathematics teaching materials to improve conceptual understanding of fifth-grade students at SDN 3 Bumiwaras using development procedures based on Borg and Gall (1983), the following results were obtained with the main steps of development research:

Research and Information Collection

The preliminary stage of the study consists of field observations and literature studies. Field studies are conducted by undertaking curriculum analysis, learning condition analysis, and needs analysis. Furthermore, a literature evaluation is conducted by evaluating books and sources relevant to the research to be conducted. In the introduction chapter, the results of observations, interviews, surveys on field needs, and specialized literature studies have been explained in the context of the topic. Preliminary study findings concerning the description or conditions of continuous learning. The following are the preliminary findings:

a. The ability related to understand students' concepts has not become the main focus of learning.
b. Limited learning tools and instructional materials stifle the inventive learning process.
c. Students are still focused on textbooks and are unable to link challenges encountered in daily life.
d. There are no complimentary books available in the learning process that can serve as a reference for textbooks for teachers.

Based on the preliminary research findings, it is vital to create realistic problem-based mathematics teaching materials to increase students' conceptual comprehension.

Planning

Planning for the development of realistic problem-based mathematics teaching materials to improve students' conceptual understanding skills is as follows:

a. Formulating the Purpose of Using Mathematics Teaching Materials

Core competencies and basic competencies are used as the basis for research and develop mathematics teaching materials. Meanwhile, the learning indicators are used as the basis for achievement in the process.

b. Analyzing the Curriculum and Determining the Material

Curriculum analysis activities must be carried out to define the objectives required for designing mathematics teaching materials and conceptual comprehension tools. According to Permendikbud Number 24 of 2016, the implementation of the 2013 curriculum as a stand-alone topic for high grades such as grades IV, V, and VI at the primary school level. Permendikbud Number 8 of 2016 states that teaching materials are a learning tool for teachers and students so that students can improve basic knowledge for higher education levels. Based on this explanation, the mathematics teaching materials developed in this study are teaching materials that can improve students' understanding of concepts as evidenced by tests. The materials used in this study are plans and scales.

c. Determining the KD and Indicators

The basic competencies used in this study are basic competencies in floor plans and scale materials.

Developing the Initial Product

The processes of product development of realistic problem-based mathematics teaching materials to improve conceptual comprehensions are the outcomes of the original product generated in this research. This process was carried out by product mapping, which includes determining the elements of

mathematics instructional materials, which include: 1) title; 2) instructions for use; 3) KI, KD, and product development goals. After the product of mathematics teaching materials is arranged, the next step is to review the product by validation of material, media, and language experts consisting of 2 lecturers from the University of Lampung. The expert's assessment is used as the basis for making revisions. The expert assessment was carried out by submitting a product that had been adjusted to the indicators contained on the validation sheet. The recapitulation of the validation assessment of material experts, media experts, and linguists is presented in Table 5.

Table 5. Expert Validation Results

No	Validator	Score
1	Material Expert	69,69 81,81
2	Media Expert	70,37 85,18
3	Language Expert	71,42 76,19
Average		**75,77**
Criteria		**Layak**

Source: Research Results

Based on table 5, shows that the results of the validation of experts who assess the design of realistic problem-based mathematics teaching materials to improve the ability to understand concepts have met the criteria with an average value of 75.77% of eligible criteria.

Preliminary Field Testing

The product of mathematics teaching materials has been revised based on the advice of experts, so the next step is an initial field trial to determine the practicality of realistic problem-based mathematics teaching materials to improve students' conceptual understanding. The subjects were students of SDN 4 Bumiwaras. The initial field test practitioner test was carried out in two stages, namely trials on educators and students.

The results of the educator response questionnaire are as follows.

Table 6. Results of Initial Field Trial Educator Responses

No	Educators' Score	Percentage	Category
1	52	100	Strongly Practical
2	52	100	Strongly Practical
3	51	97,44	Strongly Practical
Total		297,44	
Percentage Average		**99,14**	Strongly Practical

According to Table 5, the results of the teacher response test in the first field for practicality acquired an average value of 3 educators with a percentage of 99.14% extremely practical criteria.

Then, it was followed by student testing. The trial was conducted on students, with a total of 12 students participating. The following are the findings of the student response questionnaire:

Table 7. Results of Student Responses for Initial Field Trials

No	Students' Score	Percentage	Criteria
1	36	100	Strongly Practical
2	34	92,59	Strongly Practical
3	35	96,3	Strongly Practical
4	31	81,48	Strongly Practical
5	31	81,48	Strongly Practical
6	29	74,07	Praktis
7	28	70,37	Praktis
8	31	81,48	Strongly Practical
9	29	74,07	Praktis
10	29	74,07	Praktis
11	28	70,37	Praktis
12	33	88,89	Strongly Practical
Total		985,2	
Percentage Average		**82,1**	**Strongly Practical**

According to Table 7, the results of the student response test in the initial field for the students' practicability, the average value of 12 students with a percentage of 82.1% is the extremely practical criterion. This demonstrates that mathematics teaching materials have a degree of practicality that may be classified as extremely

practical based on the responses provided by educators and students, indicating that it is feasible to progress to the next step.

Initial Product Revision

The next stage is the revision of the initial product, at this stage, there are no improvements submitted by the educator on the questionnaire sheet, so the next stage is carried out.

Main Field Trial

The main field trial was carried out at SDN 3 Bumiwaras, Bumiwaras District, Bandar Lampung City, with 28 students for the experimental class and 28 students for the control class.

Effectiveness Test

The product effectiveness test was conducted to see a significant difference in the students' understanding of concepts. This is based on the indicator aspect of students' conceptual understanding, namely by using a test sheet that has been tested for validity with 6 valid questionnaire items. The results of the effectiveness of understanding students' concepts, meanwhile, can be known through a statistical test, namely the T-Test. The requirement for the T-test is that it is necessary to test for normality and homogeneity first.

a. Normality test

The normality test was used to assess whether or not the data originated from a population with a normal distribution. The results of the normalcy test were performed using the Lilliefors test. M < M0.05 was acquired from the study of the normality test data from the experimental and control classes. As a result, the data in this research were normally distributed.

b. Homogeneity Test

A homogeneity test is conducted to determine whether the population variance is homogeneous or not. The results of the analysis of the homogeneity test obtained $F_{count} < F_{critical}$. Therefore, the data gained an understanding of the concepts of students in the experimental class and control class has a homogeneous variance.

c. Paired Sample T-Test

Based on the normality test, it is known that the data obtained by the students of the two groups came from a normally distributed population with homogeneous variance, hence the hypothesis test was performed using the T-test. The T-test analysis yielded the result $_{count\ t} > t(1- \alpha)$. Thus, the average gain in the conceptual understanding of students in the experimental class is greater than the gain in the conceptual understanding of students in the control class.

Based on the results of the posttest data analysis of the conceptual understanding of students who participated in learning in the experimental class, it was determined that 89.2% of the 28 students who completed the posttest had good conceptual comprehension. A proportion test was performed to determine whether or not the percentage of students in the experimental class who have high conceptual comprehension reaches 60%. Based on the proportion test results, $z_{count} = 3.152$, and it is known that the value of $z_{count} > z_{table}$, H0 is rejected. This means that the percentage of students who have good conceptual comprehension is more than 60% of the number of students who take lessons with realistic problem-based mathematics teaching materials.

d. Test Result Product Improvement

Based on the findings of the effectiveness test, it is determined that the student's grasp of the topic improves and that there is a substantial difference between the pretest and posttest scores.

Discussion

Validity of Realistic Problem Based Mathematics Teaching Materials

The purpose of developing the resulting mathematics teaching resources is to help students learning process in school. Preliminary research and information gathering are the first steps in developing realistic problem-based mathematics teaching materials. Preliminary research was undertaken at the SD Negeri Bumiwaras sub-district to identify difficulties in the field through documentation and interviews. The second step is to create a product development plan that includes the creation of realistic problem-based mathematics teaching materials to boost students' conceptual comprehension. The third phase is to create the initial product by putting together a product design for mathematics teaching materials based on real-world challenges. Mathematics teaching materials are organized based on previously specified aims and objectives, and the outcome is then validated by experts.

The original product was created based on the results of expert validation performed in the third level of (Borg and Gall, 1983). Product development is considered valid since it employs a validation test conducted by three

experts: material experts, media experts, and language experts.

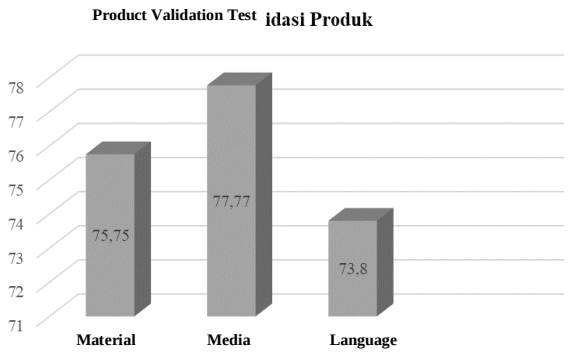


Figure 3. Validation Results of Material, Media, and Language Experts

According to Figure 7, the average validation of material experts is 75.75%, media experts are 77.77%, and language experts are 73.8% with proper criteria. Based on the validation of the three experts, an average value of 75.77% with proper criteria was obtained. As a result, the generated instructional materials are viable and valid for usage in the learning process to facilitate students' conceptual comprehension.

Practicality of Realistic Problem Based Mathematics Teaching Materials

The findings of initial field testing employing practicality response questionnaires by educators and students show the practicality of realistic problem-based mathematics teaching materials. With very practical standards, the percentage on the educator practicality answer sheet with the replies of three small group educators is 99.14%. With very realistic criteria, the results of the student response sheet with 12 students in small and big groups obtained an average percentage of 82.1%. The responses of educators and students show that mathematics teaching materials are based on practical, realistic problems that help students understand concepts. Thus, an assessment of the practicality of teaching materials is obtained using extremely practical criteria, or it can be stated that realistic problem-based mathematics teaching materials are employed to improve students' conceptual comprehension.

Effectiveness

The effectiveness test was carried out to examine the usefulness of actual problem-based mathematics teaching materials that had been integrated with the learning process. The results provided showed that students' learning outcomes improved in the pretest and posttest. After the product has been declared legitimate and practical, the effectiveness of the product must be determined. Test the efficacy with a concept comprehension test that is constructed and scored based on concept understanding indicators such as restating a concept, presenting the concept in the form of a mathematical representation, and using the notion of an algorithm in problem-solving. The effectiveness was evaluated using statistical methods, specifically the T-test and the proportion test.

A prerequisite test, consisting of normality and a homogeneity test, was performed before the T-test. Following the normality and homogeneity tests, it was discovered that the gain data used to comprehend the notion of the two groups came from a population that was normally distributed and had homogeneous variance. In this situation, a T-test should be performed if it demonstrates a substantial difference in students' knowledge of mathematical ideas between those who use practical problem-based mathematics teaching materials and those who do not. The next test was the proportion test which found that the percentage of students who have a good understanding of mathematical concepts is more than 60% of the number of students who take learning with problem-based mathematics teaching materials.

Conclusion

Based on the results of research and discussion, the following conclusions are obtained:

a. In practice, realistic problem-based mathematics teaching resources for a better comprehension of established topics are viable. This is demonstrated in the early field testing by educators' and students' practical replies to extremely practical criteria.
b. Realistic problem-based mathematics teaching tools help increase concept knowledge. The effectiveness of the T-test with the findings of the criterion for effective achievement demonstrates this. This indicates that practical problem-based mathematics teaching materials can be used correctly and successfully to improve students' conceptual comprehension.

Implication

The implications of this research and development are:

a. Students can learn the topic better if realistic problem-based mathematics teaching tools are used to improve conceptual comprehension. Furthermore, these mathematics teaching tools may be utilized as a replacement for supporting teaching materials, allowing educators to give more practical material.
b. Realistic problem-based mathematics teaching materials to improve understanding of the concepts

developed can be a reference for further research in developing mathematics teaching materials, especially at the elementary school level.

c. Realistic problem-based mathematics teaching materials to improve understanding of developed concepts can be used by schools as a learning innovation to provide opportunities for educators to develop their creativity in developing mathematics teaching materials, particularly at the elementary school level.

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