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Augmented Reality Learning Media with a Problem-Based Learning Model to Enhance the Students' Comprehension on Mathematical Concepts

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ABSTRACT

The aim of this research is to develop augmented reality learning media with a problem-based learning model and analyze the feasibility, practicality, and effectiveness of augmented reality learning media with a problem-based learning model in improving students' understanding of mathematical concepts. This research uses the research and development method with the ADDIE model (Analysis, Design, Development, Implementation, Evaluation). The sampling technique used is a random assignment, namely random sampling, where the experimental and control groups are chosen randomly from a lottery. The first lottery that came out was used as the experimental class, and the second lottery was used as the control class. Data collection techniques in this research used interview techniques, questionnaires, and tests. The results show (1) augmented reality learning media with a problem-based learning model is suitable for use, (2) augmented reality learning media is very practical to use, (3) understanding of mathematical concepts of students who receive learning with augmented reality media is better than students with conventional learning, and there are significant differences. (4) The augmented reality-based learning media developed is effective in use. The findings imply that the augmented reality learning media with a problem-based learning model can be an alternative and innovative media in assisting the student's comprehension on mathematical concepts.

Introduction

Education is something important in life, this means that every Indonesian has the right to get it and is expected to always develop in it. Education in general, means a life process in developing each individual to be able to live and survive (Rahman et al., 2022). At this time, we have entered the 21st century, where this century is faced with several challenges. Therefore, humans need to be equipped with the skills to solve these challenges. In the 21st century, every individual is required to have both hard and soft skills. Skills that must be possessed in the 21st century are learning and innovation skills, for example, creativity, critical thinking, collaboration, life and career skills, as well as information media and technology skills, for example, digital literacy (Redhana, 2019).

As information technology continues to develop in the 21st century, educational institutions are starting to innovate teaching and learning activities. A new innovation is really needed in the world of education because, with new innovation, the quality of education can be improved. Teaching and learning activities in each educational unit are expected to be based on technology. Augmented Reality technology is a unique system in the field of information technology; Augmented Reality (AR) is a synthesis of real and virtual imagery (Nincarean et al., 2013). The creation of a virtual world is carried out to generate user perceptions to understand information from familiar objects, so this has the potential to provide learning material to students in a different way (Bower et al., 2014). The use of learning tools or media can make abstract teaching materials concrete, make an uninteresting learning atmosphere interesting, and avoid student boredom (Baabdullah et al., 2022). In general, the mathematics learning process in Elementary Schools is still centered on teachers, and the learning media used by teachers is still books only, which makes students bored in learning, thus affecting students' low understanding of mathematical concepts.

In line with this, the ability to understand mathematical concepts is the ability to classify mathematical objects, interpret ideas or concepts, find examples of a concept, and restate mathematical concepts in one's own language (Muna & Afriansyah, 2018). To improve understanding of mathematical concepts, teachers need to help students, one of which is using the scaffolding technique, namely assistance to students when they have difficulty solving problems. Scaffolding techniques can include asking questions and giving instructions.

Elementary school is the main foundation for students to build their knowledge, so teaching knowledge so that students understand and understand it is important (Buchori et al., 2016). The increasing development of technology today also has an influence on education in elementary schools. The ease of accessing technology has made the teaching and learning process begin to adapt in terms of the use of technology, even now the use of digital instruction tools is starting to be used in the world of education (Cozad & Riccomini, 2016).

Based on initial observations made at SD Tunas Harum Bangsa Semarang and SDN Pendrikan Lor 03 Semarang, the schools have adequate facilities and infrastructure, but the learning system still uses books or 2D pictures. This of course makes students bored in following lessons and even understanding learning is still difficult, so understanding mathematical concepts in three-dimensional geometric material is not satisfactory, this is due to the lack of learning media that is interesting, practical and easy to use in learning. Most students only listen to textbooks or use PowerPoint. Because of this method, learning is less effective, uninteresting, and slow to understand.

Based on these problems, it shows that teachers must be able to keep up with existing technological developments. In the learning process, teachers are required to create learning media that can attract students' attention and make the material easy for students to understand. Learning media can be understood as anything that can convey and channel from sources in a planned manner so as to create a conducive learning environment where recipients can carry out the learning process effectively and efficiently messages (Buchori et al., 2017). The teaching and learning process does not only use learning media but must be supported by a learning model that provides more opportunities for students to gain their own knowledge of a concept or formula they are learning to complete the tasks given by the teacher, so that students can collaborate, interact and exchange ideas with other students and have a memory of a material concept. Students can gain knowledge by finding their own concepts or formulas that they learn from problems that arise, so that the concepts and formulas will last a long time in students' minds. This model is Problem Based Learning (PBL) (Ou Yang et al., 2023). PBL is a pedagogical approach that allows students to learn while actively engaging with meaningful problems (Yew & Goh, 2016).

Learning media that is interesting and capable of displaying three-dimensional animated objects will make it easier for students to understand spatial material, this learning media is Augmented Reality. By using Augmented Reality (AR) software, students will be more interested in paying attention to the teacher's explanation in front of them because Augmented Reality (AR) software has the function of creating three-dimensional interactive animations (Sahin & Yilmaz, 2020). In terms of output, Augmented Reality (AR) software is capable of producing files with the extension .APK (Android Package), which can be embedded in smartphones with the Android operating system (H. Y. Chang et al., 2022).

Based on the aforementioned description, this research highlights the implementation of augmented reality learning media by focusing in the following research question: How is the effect of augmented reality learning media with a problem-based learning model on the student’s comprehension on mathematical concepts?

Research Methods

This research was carried out at SD Tunas Harum Bangsa Semarang and SDN Pendrikan Lor 03 Semarang in class VI in the even semester of the 2023/2024 academic year. The type of research carried out is research and development research with the ADDIE model (analysis, design, development, implementation, evaluation). The research design used was Quasi-Experimental with Pretest-Posttest Control Group Design. The sampling technique used is a random assignment, namely random sampling, where the experimental and control groups are chosen randomly from a lottery. The first lottery drawn was used as the experimental class, and the second lottery was used as the control class (Sugiyono, 2016). The group that is treated is called the experimental group, and the group that is not treated is called the control group. In this research, SD Tunas Harum Bangsa Semarang, as an experimental group, was given augmented reality learning media with a problem-based learning model, and SDN Pendrikan Lor 03 Semarang, as a control group, used conventional learning.

Data collection techniques in this research used interview techniques, questionnaires, and tests. Interviews were conducted with sixth-grade elementary school teachers to collect initial data to identify problems and find out problems in learning activities that occur in the classroom. The purpose of this interview is to provide the right solution through product design that is developed to suit the problems faced in class VI elementary school. A media feasibility questionnaire was given to media experts and material experts to obtain suggestions and input at the development stage of augmented reality learning media. The following examples of interview questions can be seen in Table 1.

Table 1 Class VI Teacher Interview Questions Regarding Learning Needs

No	Question
1	What learning media are used in the teaching and learning process in class VI?
2	Does the learning media used make students motivated to participate in learning?
3	What do you think about application-based learning media installed on smartphones when applied in class VI?
4	What do you think about application-based learning media installed on smartphones that can display 3-dimensional animation (based on augmented reality)?
5	What do you think about learning activities carried out using group discussions to solve a problem?
6	What do you think about using smartphones during learning?

A practicality questionnaire was given to students and teachers after carrying out learning activities to determine the practicality of augmented reality learning media with a problem-based learning model. The following example of a student and teacher practicality questionnaire can be seen in Table 2.

Table 2 Example of a Student and Teacher Practicality Questionnaire.

No.	Statement
1	Text or writing in Augmented Reality-based media is easy to read
2	Don't use too many letter combinations
3	The image presented is clear (not blurry)
4	There is a description of each image presented in this Augmented Reality-based media
5	The images presented are interesting
6	Images presented in Augmented Reality-based media can motivate
7	The images presented correspond to the material
8	The images presented make it easier to understand the content of the material
9	Presentation of material in Augmented Reality-based media according to class conditions
10	The material presented in Augmented Reality-based media is easy for me to understand
11	This Augmented Reality-based media uses examples of questions related to everyday life problems
12	The presentation of material in Augmented Reality-based media encouraged me to discuss it with other friends
13	There are no sentences that give rise to double meanings in this Augmented Reality-based media
14	I can easily understand the sentences used in this Augmented Reality based Media
15	I can improve students' cognitive scores
16	I feel motivated to learn with this Augmented Reality-based media
17	I find it easier to learn by using Augmented Reality-based media
18	I am very interested in using this Augmented Reality based media
19	I study more diligently by using Augmented Reality-based media

The test is used to determine the increase in students' understanding of mathematical concepts. It consists of multiple-choice questions whose validity was first tested at Sultan Agung 01 Islamic Elementary School, Semarang. The validity result is 40 questions were declared valid and the reliability result is 0.959. Those results imply that multiple-choice questions are valid and reliable as the instrument of this current research.

The test was carried out on two groups twice, namely Pretest questions and Posttest questions with the same questions to determine changes before and after being given treatment.

Figure 1. Augmented Reality Learning Media

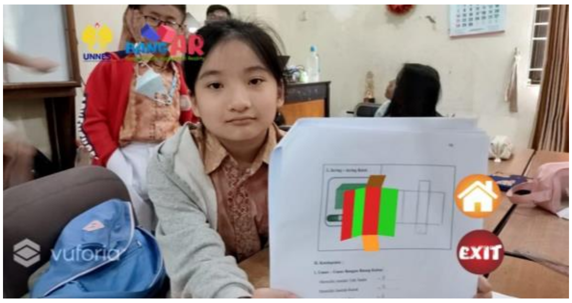

Figure 2. Example of Augmented Reality Scan Results

Findings

The results of the research are in the form of feasibility questionnaires, practicality questionnaires, and data on student pretest-posttest scores before and after learning. The feasibility questionnaire was given to media expert validators and material experts before implementation in schools. Testing the validity of the questions was carried out at SD Islam Sultan Agung 01 Semarang before carrying out the pretest and posttest. Furthermore, research data was obtained from two sample classes, namely class VI SD Tunas Harum Bangsa Semarang as an experimental group totaling 22 students, who were given treatment in the form of providing augmented reality-based learning media with a problem-based learning model during teaching and learning activities. Meanwhile, class VI of SDN Pendrikan Lor 03 Semarang, as a control group of 27 students, was not given treatment or only used conventional learning.

Test the feasibility of augmented reality learning media with a problem-based learning model by media experts and material experts. Obtaining assessment scores from validators consists of 5 assessment criteria; then, from three media experts and three material experts, the scores are averaged to be interpreted using a table of learning media suitability categories (Sukarjo, 2014). The following is Table 3 of the feasibility categories for augmented reality-based learning media and Table of results of the feasibility analysis of learning media. The results obtained are shown in Table 4 and Table 5.

The practicality test of augmented reality-based learning media was given by providing a response questionnaire of agree (1) and disagree (0) during the implementation stage.

Practicality test questionnaires were given to three teachers and class VI students at SD Tunas Harum Bangsa Semarang. This data collection was preceded by providing augmented reality-based learning media, after which data collection was carried out directly by distributing a questionnaire with 19 response items. Testing the practicality of this research, the response results were obtained as in Table 6.

Table 3. Learning Media Eligibility Category

NO	RANGE	QUANTITATIVE CATEGORIES	QUALITATIVE CATEGORIES
1.	$\bar{x}i + 1{,}8\,S < \bar{x} \leq \bar{x}i + 3\,S$	4,21 – 5,00	Very Worth It
2.	$\bar{x}i + 0{,}6\,S < \bar{x} \leq \bar{x}i + 1{,}8\,S$	3,41 – 4,20	Worthy
3.	$\bar{x}i - 0{,}6\,S < \bar{x} \leq \bar{x}i + 0{,}6\,S$	2,61 – 3,40	Not Worth It
4.	$\bar{x}i - 1{,}8\,S < \bar{x} \leq \bar{x}i - 0{,}6\,S$	1,81 – 2,60	Not feasible
5.	$\bar{x}i - 3\,S < \bar{x} \leq \bar{x}i += -1{,}8\,S$	0 – 1,80	Totally Not Worth It

Table 4. Recapitulation of Media Expert Validation Results

Expert	Assessment Aspects		Average	Criteria
	Graphics	Content		
Media Expert 1	4,67	4,93	4,83	Very Worth It
Media Expert 2	4,67	4,87	4,79	Very Worth It
Media Expert 3	4,67	4,80	4,75	Very Worth It

Table 5. Recapitulation of Material Expert Validation Results

Expert	Assessment Aspects			Average	Criteria
	Content	Language	Contextual		
Materials Expert 1	4,79	4,64	4,75	4,72	Very Worth It
Materials Expert 2	4,79	4,64	4,25	4,66	Very Worth It
Materials Expert 3	4,86	4,64	5	4,79	Very Worth It

Table 6. Recapitulation of Teacher and Student Response Results

Validator	Indicator	Score	Average
Teachers (3 people)	Appearance Presentation of Material Benefit	53	17,67
Students (22 people)	Appearance Presentation of Material Benefit	383	18,09

According to M. Singarimbun, (2014) if the Reproducibility Coefficient (Kr) score is > 0.90, it is declared to meet the requirements and is confirmed in the Scalability Coefficient (Ks) test with the criteria for meeting the requirements, namely > 0.60. The following is Table 7, a summary of the Kr and Ks scores for the practicality test by teachers and students.

Table 7. Summary of Practicality Test Kr and Ks Scores by Teachers and Students

Validator	Indicator	Kr score	Ks score	Conclusion
Teachers	Appearance Presentation of Material Benefit	0,930	0,837	Very Practical
Students	Appearance Presentation of Material Benefit	0,912	0,785	Very Practical
	$\bar{x}$ Average Score	**0,921**	**0,811**	**Very Practical**

Based on the results of Table 7, the average score of the Reproducibility Coefficient and the average score of the Scalability Coefficient consisting of teachers and students, the average score of the practicality test, the Reproducibility Coefficient $\bar{x}$ = 0.921 > 0.90 and the average score of the practicality test of the Scalability Coefficient $\bar{x}$ = 0.811 > 0.60, it can be concluded that augmented reality-based learning media is very practical to use as learning media in class VI elementary school.

Test the prerequisites before carrying out the effectiveness test using the normality test and data homogeneity test. Next, to test the effectiveness of the augmented reality-based learning media, it was tested using the N-Gain score calculation and the independent sample t-test. Testing data analysis requirements is needed to determine whether the data in this research can be used or not. The normality test aims to determine whether the data used in both the experimental class and the control class is normally distributed or not, with a significance level of 0.05, if the significant score is > 0.05 then the data is normally distributed. The data normality test was carried out using IBM SPSS software according to Shapiro Wilk. The results of the pretest and posttest data normality test for the experimental class and control class can be seen in Table 8.

Table 8. Pretest and Posttest Normality Test Results for Control & Experimental Groups

Class		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Learning Outcomes	Control Pretest	.162	27	.065	.956	27	.301
	Control Posttest	.140	27	.189	.967	27	.518
	AR Experiment Pretest	.153	22	.197	.958	22	.459
	AR Experiment Posttest	.169	22	.103	.915	22	.060

Based on Table 8, it is known that the normality test for the use of augmented reality-based learning media has a significance value (Sig.) Shapiro Wilk experimental class obtained a pretest score of 0.459 > 0.05 and for the posttest group 0.060 > 0.05. So it can be concluded that in the Shapiro normality test wilk is normally distributed so that testing can be carried out at a later stage.

The homogeneity test is carried out to determine whether the population taken from the sample is homogeneous or not. This homogeneity test uses the homogeneity of variances test with a significant α = 0.05. The acceptance criteria are if the significant score is > 0.05 then the data is homogeneous and if the significant score is < 0.05 then the data is not homogeneous (Markamah et al, 2018). The following is Table 9 Homogeneity Test Results.

Table 9. Pretest and Posttest Homogeneity Test Results for Control & Experimental Groups

No	Category	Test	Levene's test	Sig	Conclusion
1	Eksperiment	Pretest	1.516	.224	Homogeneous
	Control	Pretest			
2	Eksperiment	Posttest	3.261	.077	Homogeneous
	Control	Posttest			

Based on Table 9, the results of the homogeneity test on the based of mean Pretest show a significant value of 0.224 > 0.05, so it can be concluded that the data is homogeneous, while the score on the based on mean Posttest shows a significant value of 0.077 > 0.05, so it can be concluded that the data is homogeneous.

The prerequisite test results show that the data is normally distributed and homogeneous, then the N-Gain test is carried out to show the effectiveness of augmented reality learning media with a Problem Based Learning model. The results of the N-Gain test calculations with the help of the SPSS program in percentage form are summarized in Table 10.

Table 10. N-Gain Test Results for Augmented Reality-based Learning Media Scores

Calculation	Experimental Class *N-Gain Score (%)*	Calculation	Control Class *N-Gain Score (%)*
Average	78,03	Average	42,42
Minimal	68,00	Minimal	00.00
Maximum	90,00	Maximum	80.95

Based on the results of the N-Gain Score test calculations in this research, it shows that the average N-Gain score for the experimental class is 78.03 with the minimum N-gain score for the experimental class being 68.00 and the maximum N-gain score being 90.00. Then for the control class it was 42.42 with a minimum control class score of 00.00 and a maximum N-gain score of 80.95. The score is then interpreted using Table 11, which is an interpretation of the effectiveness of N-Gain in the following percentages.

Table 11. N-Gain Score Interpretation

Percentage %	Interpretation
<40	Ineffective
40-55	Less effective
46-75	Effective enough
>76	Effective

Based on Table 10 and Table 11, the interpretation of the effectiveness of the N-Gain score above can be concluded that the average Gain score for the experimental class is 78.03%, so it can be concluded that the application of augmented reality-based learning media is effective in increasing students' understanding of mathematical concepts. Meanwhile, the conventional method shows that the average Gain score for the control class is 42.42%, which is less effective in increasing students' understanding of mathematical concepts.

Next, to find out whether there is a significant difference, the method used in the post-test scores in the experimental class and control class is by using the independent sample t-test. This test was carried out on the post-test learning results of the experimental class and post-test of the control class. The results of the independent sample t-test can be seen in the attached table of independent sample t-test output results. Based on calculations using the SPSS program for the post-test, the results obtained are as shown in Table 12. The results of the pretest and post-test t-tests for the control and experimental classes are as follows.

Tabel 12 Hasil t test Kelas Kontrol dan Eksperimen

No	Group	N-Gain	Levene Test	t	Sig. (2-tailed)	Conclusion
1	Experiment	78.03	0.077	5.77	0.000	There are significant differences
2	Control	42.42				

Based on the output table above, it is known that the significance score (Sig) in Levene's Test for Equality of Variances is 0.077 > 0.05, so it can be concluded that the variance of the N-Gain data (%) for the experimental class and control class is the same or can be said to be homogeneous. The results of the t-test calculation obtained a sig (2 tailed) value of 0.000 < 0.05. Because the sig (2 tailed) value is < 0.05, it can be concluded that there is a significant difference between the posttest of the experimental class and the control class or it can be interpreted that there is a significant difference between classes that use augmented reality-based learning media and conventional classes.

Discussion

From the results of the feasibility test, it can be concluded that the augmented reality learning media is very suitable for use, and from the results of the practicality test, N-Gain test, and independent sample t-test, it can be concluded that the augmented reality learning media with the problem-based learning model is very practical to use, and the results of the N-Gain shows that augmented reality-based learning media is effective in use and is strengthened by the independent sample t-test which shows a significant difference between the posttest of the experimental class and the control class or it can be interpreted that there is a significant difference between classes that use augmented reality learning media and conventional classes. The results of this research agree with research conducted by S. C. Chang & Hwang, (2018), Kaji et al., (2018), Barsom et al., (2016), Yusa et al., (2023), Selfia, (2022), Kurniawan & Kusuma, (2021) and Ilma et al., (2022) state that augmented reality-based learning media can significantly increase the cognitive value of students' understanding of mathematical concepts.

The learning outcomes of students who use augmented reality learning media with the Problem Based Learning model are better than students who receive conventional learning. For students who use augmented reality learning media with the Problem Based Learning model in the experimental class, students play an active role and exchange ideas, learn to express opinions, seek information from other group partners, this is in line with research conducted by Hwang et al., (2016) stated that students who received learning using augmented reality-based educational games showed positive attitudes and improved learning outcomes compared to students who used conventional learning. Learning with the Problem Based Learning model can motivate, process and improve student achievement. This is also in line with research conducted by Rahmadani & Anugraheni, (2017) that the Problem Based Learning model is able to increase mathematics learning activities through solving problems related to the real world. Apart from that, Gün & Atasoy, (2017) also revealed the same thing in their research that the use of augmented reality applications can significantly increase students' academic achievement scores.

Augmented reality-based learning media can be used as a learning medium for students individually or in groups and augmented reality-based learning media is practical and can increase students' enthusiasm and interest in learning (Kharisma et al., 2023). In this way, students will not feel that their learning media is less interactive and monotonous, thereby turning off their interest in learning (Hasbi et al., 2020). Augmented reality-based learning media developed by researchers based on an Android application. The use of online media or multimedia-based media is one solution to enable students to understand the subject matter well. This is in line with the research results of Saltan & Arslan, (2017) which show that there is a positive influence of the use of augmented reality on student motivation and learning achievement.

The learning outcomes of students who use the Problem Based Learning (PBL) learning model with the help of augmented reality learning media are better than students who receive conventional learning. This is because the Problem Based Learning (PBL) learning model with the help of augmented reality learning media both have advantages during the learning process so that the combination of the two can produce maximum learning results.

Conclusion

The results of the research show that (1) augmented reality learning media with a problem-based learning model is suitable for use, (2) augmented reality learning media is very practical to use, (3) understanding of mathematical concepts of students who receive learning with augmented reality media is better than students with conventional learning, and there are significant differences. (4) The augmented reality-based learning media developed is effective in use. This is based on effectiveness tests in the form of the N-Gain score test and the independent sample t-test. The independent sample t-test showed that the experimental class and control class were the same or homogeneous before being treated using augmented reality-based learning media, and in this research, the data used was normally distributed. Then, after being tested, the t-test concluded that it was effective and significant.

This research is still limited to a small scale, involving only one control class and one experimental class, so it is still limited to Quasi-Experimental research. For further research, it is hoped that a larger sample can be used to make the data obtained more valid and consistent.

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