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Project-based learning assisted augmented reality in increasing students' mathematical understanding of concepts

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Abstract

The gap in this study uses Augmented Reality media when the learning system takes place. This research aims to determine the effectiveness of the Project-Based Learning (PjBL)—model in increasing mathematical understanding of concepts assisted by Augmented Reality. The method used in this study uses a quantitative methodology with a quasi-experimental research design with a nonequivalent control group design approach. The random cluster sampling technique was used for sampling in this study. The class used was ten science four class as the control class and ten science five class as the experimental class. Validity and reliability test were carried out with the help of Winstep 3.73 software and data analysis techniques using SPSS 24.0 for Windows software. The total question of the instrument is five, which contains indicators of mathematical understanding concepts. The results of this study are that the experimental class using the Augmented Reality-assisted Project Based Learning (PjBL) model is better than the control class using conventional models. The implications of this research are to assist teachers in improving students' ability to mathematical understanding concepts and improve innovative learning methods in the classroom with the PjBL models and augmented reality.

Keywords: augmented reality; mathematical understanding concept; project-based learning

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Introduction

Mathematical understanding concepts need to be owned by students as an essential capital in their learning outcomes. Mathematical understanding concepts students' ability to explain, understand, and represent existing mathematical concepts in solving problems so that they are easy to understand (Hernández et al., 2020; Kenedi et al., 2019; Purnomo et al., 2017). The mathematical understanding concept is also essential for students to learn mathematics (Al-Mutawah et al., 2019). Mathematical understanding is essential for students to solve problems to deepen them when learning mathematics (Minarni et al., 2016). Therefore, mathematical understanding concepts can be developed based on their experiences completing assignments and learning designed to deepen their knowledge of students (Simamora et al., 2018). Mathematicalunderstandingf ng of concepts is always related to students' assumptions regarding their prior knowledge and reasoning based on previous learning experiences (Simon, 2017).

However, mathematical understanding concepts still need to be improved in learning mathematics. The results of the 2018 PISA study, released in 2019, where Indonesia was ranked 72 out of 78 participants who could mathematical understanding concepts in the low category from several countries (Nurjanah. et al., 2020). Other studies also show that the mathematical understanding concepts of Indonesian students are still at the lowest level because students need help to connect their knowledge with new knowledge gained (Suarsana et al., 2018).

Factors that cause the low ability to understand concepts arise from students' mistakes in writing mathematical symbols. Students only remember a concept if they explore it properly (Mustangin & Setiawan, 2021; Yunita et al., 2020). In addition, the strategy used by the teacher is also influential, such as often forbidding the teacher to solve the problem quickly without knowing the concept of the solution (Palupi et al., 2022). Therefore, The teacher may emphasize understanding concepts so students can elaborate their thoughts on a concept using their language (Cai & Ding, 2017). In addition, the teacher plays an active role in the class to focus on mathematical understanding concepts so the students acquire broader knowledge and skills regarding the material being studied (Yu & Singh, 2018).

Therefore, learning is needed to develop the ability to mathematical understanding concepts such as the Project-Based Learning (PjBL) Model. The PjBL model is an inquiry-based learning strategy involving individuals and groups to construct their knowledge to complete projects and produce products through products, presentations, or performances for a certain period (Guo et al., 2020; Kai et al., 2021). In its application, students become learning centers, and teachers become facilitators by encouraging students to raise questions, discuss with groups about completion time, and solve a problem in the form of a project (Hall & Miro, 2016; Morrison et al., 2021). PjBL instructs students to work on projects independently or in groups based on predetermined steps and rules with a time limit given by the teacher (Hsu et al., 2018; MacLeod & Veen, 2020). The PjBL model can increase a deeper understanding of mathematical concepts and train other skills so students can apply real-life knowledge (Holmes & Hwang, 2016; Ummah et al., 2019).

In addition, a learning media is needed to help innovative learning models such as augmented reality (AR). AR is an innovation with the real-time display directly or indirectly by inserting 3D objects from the virtual world to increase information about existing natural objects (Cahyono et al., 2020; Salinas & González-Mendívil, 2017). The characteristics of AR are the combination of natural and virtual objects that enable the very high usability and creativity required for innovative learning (Coimbra et al., 2015). AR has the advantage of providing different experiences to students by adding virtual and interactive information to understand and explore concepts better than before, leading to good learning outcomes and motivation (Cerqueira et al., 2019; Chen et al., 2016; Demitriadou et al., 2020).

Several studies have been conducted regarding the PjBL Model, AR, and mathematical understanding concepts—first, research by Chen and Yang (2019), on the effect of PjBL learning on student academic outcomes, shows that PjBL significantly positively impacts student academic achievement compared to traditional learning models. Second, research by Rensaa (2014), with the theme of learning notes on understanding mathematical concepts, results that when students record material provided by lecturers, it will contribute to good conceptual understanding but can become an obstacle if there are errors in writing, causing students to feel confused or concept error. Third, research by Cai et al. (2020) on using AR in learning mathematics shows that AR-based education positively affects mathematics teaching for junior high school students.

Then the gap in this study uses Augmented Reality media when the learning system occurs. At the same time, the novelty in this study is a Project Based Learning model to increase mathematical understanding of concepts. This research aims to see the PjBL's model effectiveness in increasing the mathematical understanding of concepts assisted by Augmented Reality.

Methods

The method used in this research uses a quantitative method with a quasi-experimental research design with a nonequivalent control group design approach. Quasi experiment is a method that provides and compares the treatment of subjects in a group (Maciejewski, 2020). Two sample classes were randomly selected in this research design: the experimental and the control. As a first step, a pretest will be given to both classes to determine students' prior knowledge before starting learning, then a treatment, and, in the end, will be given a posttest to measure the ability to understand students' mathematical concepts. The Augmented Reality-assisted PjBL model will be used in the treatment stage in the experimental class. In contrast, the conventional model school teachers use will be applied to the control class.

Table 1. Research design pretest and posttest control group design (**Kaleli, 2021**)

Class	Pre-test	Treatment	Post-test
Experimental Class	Mathematical understanding concept test	PjBL model	Mathematical understanding concept test

Class	Pre-test	Treatment	Post-test
Control Class	Mathematical understanding concepts test	Conventional model	Mathematical understanding concepts test

The cluster random sampling technique was used for sampling in this research. The sampling technique is defined as a class sampling method in a random way based on the classes in the study population (Wang & Cheng, 2020). The control class is ten science four classes, whereas the experimental class is ten science five. The research instrument is in essay form test questions with a total of 5 questions which contain indicators of mathematical understanding concepts. In the description, test questions, of course, go through the validation process first. The indicators used in this study are (1) re-expressing the concepts that have been learned; (2) grouping objects according to the concept requirements that have been fulfilled; (3) applying the concept by using logic; (4) analyzing examples and non-examples of concepts based on the material being taught; (5) write down the concept of the material being studied in the form of a mathematical representation (Ardila et al., 2022). The researcher validated each essay test for mathematics education lecturers and high school teachers in the construct validation process. In the content validation process, there were four classes of 11th-grade students with 140 students. Validity and reliability test using the help of Winstep 3.73 software.

Table 2. Misfit item

	Item				
	1	**2**	**3**	**4**	**5**
Measure	0.8	-1.6	-1.1	1.4	0.5
Outfit MNSQ (0.5 - 1.5)	1.4	0.84	0.9	0.8	0.9
Outfit ZSTD (-2.0 - +2.0)	2	-0.5	-0.6	-1.7	-0.9
PTMEA-CORR (0.4-0.85)	0.7	0.47	0.6	0.9	0.8

Table 2 above shows that all items are declared valid because they have fulfilled the two suggested criteria (Sakakibara et al., 2015). A reliability test also measures this instrument to see whether the instrument is reliable or not. Below will be presented a table for the criteria, as follows in Table 3.

Table 3. Reliability in Rasch analysis (**Sumintono & Widhiarso, 2013**)

Statistics	Fit Indices	Interpretation
Cronbach's Alpha (KR-20)	< 0.5	Very bad
	0.5 - 0.6	Bad
	0.6 - 0.7	Enough
	0.7 - 0.8	Good
	> 0.8	Very good
Item and Person Reliability	< 0.67	Weak
	0.67 - 0.80	Enough
	0.81 - 0.90	Good
	0.91 - 0.94	Very good
	> 0.94	Excellent
Item and Person		The higher the value of

Statistics	Fit Indices	Interpretation
Separation		separation, it can be said that the quality of the instrument is better and can identify groups of items and groups of people.

Then the results of the data analysis will be presented in Table 4 below.

Table 4. Review of output summary

Statistics	Value
Person Reliability	0.70
Item Reliability	0.98
Person Separation	1.51
Item Separation	6.59
Cronbach's alpha (KR-20)	0.73

Table 4 shows KR-20s' value is 0.73, with high criteria. The person reliabilities value is 0.70 with sufficient criteria, and the highest value shown by item reliability is 0.98 with particular criteria. If the separation value produces a high value, it can result in better instrument quality to identify item and person groups. The instrument is reliable based on the data obtained because the KR-20 value exceeds 0.7 (Sakakibara et al., 2015)—data analysis techniques using descriptive analysis and inferential. Descriptive analysis was used to explain the results of the pretest and posttest data on mathematical understanding concepts in the control or experimental classes. T-test and N-gain were used in inferential statistical analysis. In testing the hypothesis using a paired sample t-test to see if there is a comparison of students' average ability to mathematical understanding concepts in both classes. The N-gain purpose is to determine the student's ability to improve mathematical understanding of concepts after treatment (Juleha et al., 2019) in data analysis techniques using SPSS 24.0 for Windows software.

Results

Normality Test

The Kolmogorov-Smirnov test is used for data testing. The Kolmogorov-Smirnov test is a test that compares the distribution of data from two different samples to find differences and behavior of data at different time intervals (Porwik & Dadzie, 2022). In this test, there are criteria, namely if the significance value of probability (Sig.) < α (0.05), then H_0 is rejected, which indicates abnormal data then if the significance probability value (Sig.) > α (0.05), then H_0 is accepted so that it indicates normal data (Kelidbari et al., 2016; Zeydabadi et al., 2019). The data will be presented in Table 5 below.

Table 5. Normality test

	Kolmogorov-Smirnov			
	Class	**Statistic**	**df**	**Sig.**
Results of Students' Mathematical Understanding Concepts	Pre-test of experimental class (PjBL)	0.132	35	0.131
	Post-test of experimental class (PjBL)	0.129	35	0.150
	Pre-test of control class (Conventional)	0.097	35	0.200
	Post-test of control class (Conventional)	0.119	35	0.200

Based on the experimental class analysis results, the value of Sig. The pre-test was 0.131, the post-test was 0.150, and the control class obtained a Sig. on the pre-test of 0.200 and the post-test of 0.200. Because of the four Sig. > 0.05, the data is categorized as normal. After the normality test, the homogeneity test will be carried out.

Homogeneity test

The type of homogeneity test used in this research is the Levene test. The Levene test is an inferential statistic that aims to assess the equality of variance in a data group (Desu et al., 2016). For the Levene test, there is a provision that if the Sig's value > α(0.05), then it produces homogeneous data, and vice versa on Sig's value < α(0.05), then produces non-homogeneous data (Gao et al., 2017). Below is presented Table 6 of homogeneity based on the pretest of the two classes.

Table 6. Test of homogeneity of variance pretest

	Mean	**Median**	**Median and with adjusted df**	**Trimmed mean**
Levene Statistic	0.54	0.456	0.456	0.563
df1	1	1	1	1
df2	68	68	67.97	68
Sig.	0.465	0.502	0.502	0.456

Based on Table 6, it is found that the value of Sig. of 0.465. Because the Sig value > 0.05, the decision is to accept H_0. This condition means there are similarities in the variance in the posttest data group for the experimental class, and the control data is homogeneous. After testing the pretest data, we will test the post-test data to determine whether the data is homogeneous. Below will be presented Table 7 of homogeneity based on the posttest of two classes as follows.

Table 7. Test of homogeneity of variance posttest

	Mean	Median	Median and with adjusted df	Trimmed mean
Levene Statistic	0.258	1	68	0.613
df1	1	1	1	1
df2	68	68	67.11	68
Sig.	0.613	0.649	0.649	0.624

Based on Table 7, it is found that the value of Sig. of 0.613. Because the Sig value > 0.05, the decision is to accept H_0. This condition means there are similarities in the variance in the posttest data group for the experimental class, and the control data is homogeneous.

Paired sample t-test

After obtaining normally distributed and homogeneous data, the next step is testing the paired sample test to see the average comparison in the two classes (Ramadurai et al., 2019). In the t-test, the control class in the paired sample statistics output table gets an average pretest of 38.14. The average post-test value is 72, the post-test standard deviation is 09.05, and the pretest is 10.06. For the standard deviation of errors, the pretest mean was 1.70, and the posttest was 1.52. this deviation occurred because the average value is 38.14, which means less than the post-test value of 72. It proves this similarity with the learning outcomes average compared to the conventional method. Then in the correlation output table, there is a correlation value of 0.288 with a Sig value of 0.093. then there is a probability value 0.05 as a significance level (Dehghanzadeh & Jafaraghaee, 2018). Value 0.093 > probability 0.05 proves that there is no correlation between the pretest and posttest variables. Then on the paired samples test, Sig's value is 0.00 less than 0.05. then we conclude that H_1 is accepted.

The average pretest experimental score in the paired sample statistics output table is 43.44. Then the posttest average result gets the value of 85.71, for the pretest standard deviation value of 9.09 and posttest of 9.71. The Standard Deviation Error Mean value at the pretest is 1.53, and the post-test is 1.64. Because the average pretest score is smaller than the posttest score, meaning 43.44 < 85.71, it proves a deviation in the average student learning outcomes in the PJBL model. Then in the output table of paired samples correlations, there is a relation coefficient value of 0.333 with a Sig value of 0.051. Sig's value 0.093 > probability 0.05, proving there is no correlation between the pretest and the posttest variable. Then on the paired samples test, Sig's value is 0.00 less than 0.05. Then we conclude that H_1 is accepted

N-gain test

The n-gain purpose is to determine the student's ability to improve mathematical understanding of concepts after treatment (Juleha et al., 2019). Then in Table 8 will present the N-gain analysis in both classes using SPSS 24.0 software

Table 8. Analysis of gain score

Class	N-Gain	Criteria
Experimental class	0.74	High
Control class	0.54	Medium

Based on Table 8, the N-gain value is 0.74 with high criteria in the experimental class and 0.54 with medium criteria in the control class.

Categorization of students' ability to understand mathematical concepts

Then, a student's mathematical understanding of concepts will be categorized in both classes based on predetermined criteria. In this study, there were 10 test instruments based on students' mathematical understanding concepts, with a minimum score of 0 and a maximum score of 4 for each indicator. Then for the value $X_{min} = 0 \times 10 = 0$ then for the value $X_{max} = 4 \times 10 = 40$. Then we get Xmax – Xmin = 40 – 0 = 40 for the range. The mean value is $(X_{max} - X_{min})/2 = (40 + 0)/2 = 20$, and the standard deviation is range/6 = 20/6 = 3.33. Next, the criteria for categorizing the ability to understand students' mathematical concepts will be presented in Table 9

Table 9. Categorization of students' mathematical understanding concept

Grouping category	Category
X < logit mean – 1.SD X < 20 – 3.33 X < 16.67	Low
(logit mean – 1. SD) ≤ X < (logit mean +1.SD) 20 – 3.33 ≤ X < 20 + 3.33 16.67 ≤ X < 23.33	Medium
X ≥ logit mean + 1.SD X ≥ 20 + 3.33 X ≥ 23.33	High

After students are given questions in the form of posttest understanding of students' mathematical concepts, then the work results are processed using SPSS 24.0 for Windows. The outcome of the low, medium, and high categorization in the two classes is in Table 10 below.

Table 10. Output categorization of students' mathematical understanding concept

	Experiment Class	Control Class	
Categorization	High	Medium	High
Frequency	35	2	33
Percent	100	5.7	94.3
Valid Percent	100	5.7	94.3
Cumulative Percent	100	5.7	94.3

Based categorization of mathematical understanding concepts in Table 10, overall, students in the experimental class get a high category in the ability to understand concepts through the PjBL treatment model assisted by Augmented Reality. In contrast, in the control class, two students in the medium category and 33 students in the high category with treatment using conventional learning models.

Discussion

Based normality test in Table 5, Sig's value of the experimental pretest is 0.131, then Sig's value post-test is 0.150. The control class gets a Sig's value on the pretest is 0.200, and the posttest of 0.200. we conclude that because of all four Sig. > 0.05, the data is categorized as normal. After the data shows normal, the homogeneity test will be carried out. Then, based on the homogeneity of variance pre-test from Table 6, the Sigs' value is 0.465. Because of the Sig value > 0.05, the decision is to accept H_0. This condition can explain the variance similarity in two classes is homogeneous. Table 7 has found the Sig value of 0.613. Because of the Sig value > 0.05, the decision is to accept H_0. This condition can explain why the variance similarity in the two classes is homogeneous.

The outcome from the paired sample test shows an average result deviation between both tests learning, so there is an impact from using the PjBL strategy in learning mathematics assisted by Augmented Reality. It improves students' understanding of mathematical concepts more than the conventional method. The PjBL model will build students' curiosity and understanding of concepts in solving problems (Zhao & Wang, 2022).

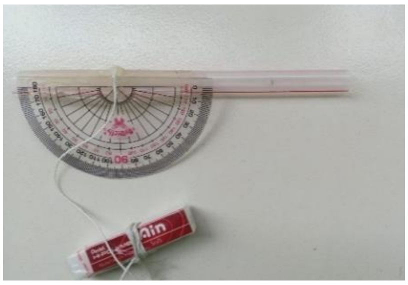

Figure 1. Clinometer

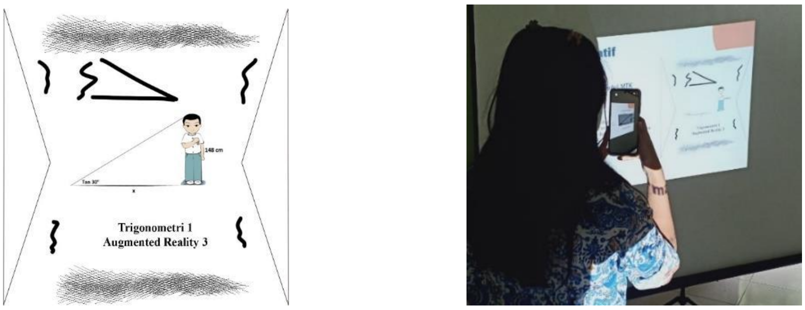

Figure 2. (a) Barcode of augmented reality; (b) Application of augmented reality

In the PjBL model, researchers use visual aids, namely clinometers and Augmented Reality. Figure 3a is a barcode code students will scan through the software on their smartphones. Then a 3D display will appear, as shown in Figure 3b. Based on the results obtained, the researcher hopes that teachers can utilize AR learning media to support students during the mathematics learning process using technology and innovative learning models (Gargrish et al., 2020).

From the N-gain score result in Table 8, the experimental class result average is 0.74 with high criteria. Meanwhile, the control class shows a result of 0.54 with moderate criteria. It shows that the analysis of student scores results by implementing the PjBL model is superior to the control class. The PjBL model, assisted by Augmented Reality, can improve students' mathematical understanding of concepts when applied in the learning process. Augmented reality can help enhance the mathematical understanding of concepts for the better (Cai et al., 2019; Wang, 2017). The PjBL model can help students process their knowledge and develop a mathematical understanding of concepts when completing projects (Holmes & Hwang, 2016).

Based on the categorization of understanding mathematical concepts in Table 10, overall, students in the experimental class get a high category in understanding concepts through the PjBL treatment model assisted by Augmented Reality. In the experimental class, all students answered each posttest item correctly according to indicators of conceptual understanding ability. Students understand mathematical concepts better due to project assignments, such as measuring surrounding objects using a clinometer. Besides that, students are also very enthusiastic and meaningful in using augmented reality to help complete projects given by the teacher. In addition, it can show that the PjBL model assisted by Augmented Reality can improve the student's mathematical understanding of concepts (Anjarwati & Pujiastuti, 2020; Cahyono et al., 2020). In the control class, several students were still in the medium category because the answers to the posttest questions still contained errors and had not been able to meet the criteria for indicators of ability to understand mathematical concepts. Even though most students can get the high category, in the learning process, students feel bored and need time to understand the concepts in trigonometry material. When students feel bored, students will need to help understand a concept during learning (Bailey, 2019).

Conclusion

The experimental class using the Augmented Reality-assisted Project-Based Learning (PjBL) model has a positive impact compared to the conventional model on the control class when reviewed from the N-gain score. The N-gain score shows the average in the experimental class with high criteria, while the control class shows medium standards. Then in the paired sample test, when viewed from each pretest and posttest value in both classes. In conclusion, there is an average deviation between the pretest and post-test learning outcomes, so there is an improvement in using strategies in learning mathematics using the PjBL model better in improving students' mathematical understanding concepts than the control class using conventional models. Then, categorizing students' mathematical understanding concepts indicates that all students in the experimental class belonged to the high criteria of 35 students. Then in the control class, the results showed that two students out of a total of 35 students belonged to the medium category while the other students were in the high sort. The hope for future researchers is to use the PjBL model with the help of Augmented Reality to train other mathematical abilities.

This research had several limitations, such as making the clinometer tool created by the researcher took much work. Then it was found that students' handphones did not support downloading Augmented Reality-based software, so only a few students downloaded the software and made them group representatives. The implications of this research are to assist teachers in improving students' ability to mathematical understanding concepts and improve innovative learning methods in the classroom with the PjBL models and augmented reality.

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Conflicts of Interest

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

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Author Contributions

Axl Ferrari Fatahillah: Conceptualization, writing – original draft, formal analysis, editing, and visualization; **Ayu Faradillah:** Review, validation, and supervision.

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