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Effectiveness of project-based learning with augmented reality on concept understanding and mathematical anxiety of elementary school students

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ABSTRACT

The use of the Project Based Learning model assisted by Augmented Reality in the field of Education aims to improve conceptual understanding and reduce students' mathematical anxiety on spatial building materials. The research subjects consisted of fifth-grade students at SDN Tlogomulyo, divided into two groups: an experimental class with 28 students and a control class with 29 students. This research is a quantitative experiment. Data collected through test and non-test techniques. The test was conducted with a Post-test at the end of the learning session, while the anxiety questionnaire was given before and after the learning session. The analysis results show that the average Post-test score for concept understanding in the experimental class is 81.7, while in the control class it is only 66.96. The average score for the anxiety questionnaire in the experimental class increased from 60 to 73.5, while the control class only experienced a slight increase from 55.1 to 57.9.

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1. INTRODUCTION

Mathematics is one of the subjects studied in all elementary schools, junior high schools, senior high schools, and even in higher education institutions. Mathematics originates from real-world empirical experiences, which are then analyzed in the realm of reason through logical reasoning within cognitive structures, making mathematical concepts easy to understand and manipulate by other (Rahmah, 2018). In everyday life, mathematics is often used for things such as predicting time by looking at the clock on the wall, estimating how long it will take to sleep from night until waking up, measuring the distance from home to school, and many more. Thus, a good understanding of other mathematical concepts not only helps students academically but also prepares them to face practical challenges in the future. However, there are still many students who continue to believe that mathematics is difficult and scary, which will have a negative impact on their academic achievement (Lisgianto & Suhendri, 2021). Spatial awareness is one of the topics considered difficult in mathematics lessons related to everyday life. Sometimes, students find it very difficult to understand the lesson. Some of the problems students face when learning space construction are solving verbal problems, using concepts, and applying principles (Nugroho et al., 2023)..

Mathematics plays a crucial role in real life and in supporting various other fields of science. Given the importance of mathematics, it is hoped that students' understanding of mathematical concepts can be improved. However, the fact is that students still lack understanding of these concepts. One of the causes is the negative perception of mathematics among students (Fahrudin et al., 2018). If students do not understand the concepts correctly, they may answer the same questions incorrectly. This situation should be used effectively by teachers to apply the correct concepts to elementary school students (Radiusman, 2020).

The Project Based Learning (PjBL) learning model in collaboration with Augmented Reality (AR) was used for several reasons. Some students still had difficulty understanding concepts and experienced mathematical anxiety. In addition, during observations at the school, teachers still used learning models that seemed boring and lacked innovation in the media used, so that students were often not involved in the teaching and learning process. One type of digital media innovation that can be integrated with learning models is Augmented Reality, which is a type of 21st-century digital media (Ilham, 2023). Therefore, teachers must use learning models that support students to be more creative and express themselves more freely, both individually and in groups. Among the models that can be applied is the Project-Based Learning model in collaboration with Augmented Reality digital media.

The Project-Based Learning model is known as project-based learning. A project is a complex and challenging task based on a theme that involves students in the process of designing, problem solving, decision making, and research. This project provides students with the opportunity to work within a specified period of time to produce a product (Sumilat et al., 2023). The PjBL model has significant advantages and benefits for students. However, the implementation of this model is still rarely done by teachers because it requires careful preparation and takes a long time to complete (Hamidah & Citra, 2021).

The Project-Based Learning model has characteristics that distinguish it from other learning models, including: (1) Projects are at the core of the learning process, (2) Learning is focused on problems or questions that encourage students to solve problems related to specific ideas, (3) Students independently build their knowledge, (4) Students act as problem solvers, and (5) Student activities are directed toward experiences similar to real-life situations (Sulistyorini, 2020). Considering that the Industrial Revolution 4.0 is influencing education today, often referred to as "Education 4.0," and has several key characteristics. Education 4.0 refers to the use of digital technology in the teaching and learning process. Therefore, it is very important for teachers to have the skills to integrate technology into learning, one of which is by utilizing the digital media Augmented Reality (Wati et al., 2023).

Augmented Reality is a technology that integrates elements from the real world with the virtual world. The use of AR in education creates many new opportunities for the learning process. The application of AR technology in interactive learning emphasizes active student participation. With AR, students can explore three-dimensional objects and visualize abstract concepts. This results in a more engaging learning experience and motivates students to think critically, collaborate, and hone their problem-solving skills (Indahsari & Sumirat, 2023).

The results of the study Dringu et al. (2022) support this research, showing that there was an increase in student learning outcomes and creativity with the Project Based Learning approach combined with Augmented Reality in second grade elementary school. Another study Fatahillah & Faradillah (2023) explains that the Project Based Learning model with Augmented Reality improves student understanding using a quasi-experimental method.

This study combines the project-based learning model with AR technology, which is an update from previous studies. The dual aspects examined in this study are concept understanding and mathematical anxiety, making this study unique compared to previous studies. Additionally, this study views AR as a visualization tool that can enhance cognition and make learning comfortable and enjoyable for students experiencing mathematical anxiety.

The results of the study indicate that collaborating between the Project Based Learning learning model and Augmented Reality digital media has the ability to visualize the concepts of fifth grade elementary school spatial geometry material. This shows an urgent need to explore this topic. Therefore, this study addresses whether the PjBL learning model combined with AR is effective in improving concept understanding and reducing mathematical anxiety among students. The results of this study are expected to provide positive engagement toward achieving student learning outcomes and serve as a reference for future research

2. METHOD

This quantitative study uses an experimental method. This method is based on the students' need to understand concepts and help reduce mathematical anxiety towards the impact of the models and media used.

Table 1. Validity Test of Question Instruments

No Question	r count	r table	Description
1	0,4200	0,3809	Valid
2	0,5507	0,3809	Valid
3	0,3836	0,3809	Valid
4	0,5739	0,3809	Valid
5	0,7785	0,3809	Valid
6	0,4662	0,3809	Valid
7	0,4522	0,3809	Valid
8	0,0434	0,3809	Invalid
9	0,4493	0,3809	Valid
10	0,6827	0,3809	Valid
11	0,6903	0,3809	Valid
12	0,3336	0,3809	Invalid
13	0,4984	0,3809	Valid
14	0,4219	0,3809	Valid
15	0,3824	0,3809	Valid

Table 2. Reliability Test of Question Instruments

Reference value	*Cronbach's Alpha*	Description
0,75	0,758	Reliable

The research design used was an experimental design with a *Post-test Only Control Design* according to Sugiyono (2013) in Saputra (2017), where R is the type of group being studied. Furthermore, the research involved two unrelated groups of subjects, namely the experimental group that received treatment and the control group that did not receive treatment. O refers to the *output* of the *post-test* for both groups.

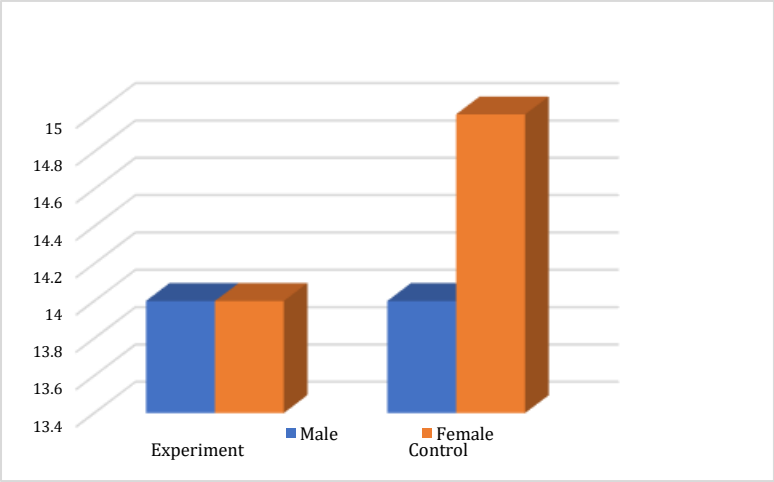

Figure 1. Data on Grade V at Tlogomulyo Elementary School

The population of this study consisted of 57 fifth-grade students at SDN Tlogomulyo, divided into two groups: an experimental group and a control group. The sample was taken using the simple random sampling technique, where students were selected randomly to ensure representativeness in responding to AR-based PjBl learning.

Data were collected using test and non-test methods, which included a post-test to assess students' understanding of spatial concepts after learning, as well as a mathematical anxiety questionnaire to assess students' mathematical anxiety levels before learning and to obtain feedback on their learning experiences. According to Holmes in (Julya & Nur, 2022), the mathematical anxiety instruments used in this study included the following main indicators: 1) Feelings of anxiety and tension; 2) Lack of confidence in one's abilities; 3) Fear of failure; 4) Headaches; and 5) Loss of enthusiasm and interest in learning.

The research began by determining the population and selecting the sample. All students were given a questionnaire to determine their initial anxiety levels. The experimental group received treatment, while the control group did not. After the treatment, both groups took a post-test and filled out a final questionnaire to evaluate the changes that occurred. Next, data from the initial and final tests were analyzed using appropriate statistical methods to test the research hypothesis, enabling the researcher to draw conclusions about the effect of the treatment on the variables studied.

3. Result and Discussion

The results show that the PjBL model and AR digital media can prepare students to face learning problems, including difficulty understanding concepts and feeling anxious in spatial geometry. Conceptual understanding can be seen from the post-test results, while analysis of the questionnaires given to students shows mathematical anxiety among students.

These findings are in line with constructivist theory, which states that learning is more meaningful when students are active in the process of constructing their own knowledge through direct and contextual experiences. When compared to the control group, students in the experimental group scored better on the test than the control group. This shows that the project-based approach helps students learn better.

Students became more engaged, active, and motivated to understand concepts in depth through PjBL syntax such as project setting, planning, implementation, and evaluation. With the help of AR media, the visualization of abstract spatial objects became more real and easier to understand, making it easier to understand ideas.

These results support the findings of Dringu et al. (2022), who found that adding AR to PjBL can improve student learning outcomes and creativity. This also applies to Fatahillah & Faradillah (2023), who found that PjBL with AR media significantly improved students' understanding of experiences.

Additionally, the results of this study indicate that the experimental group experienced a significant level of mathematical anxiety. Most students were in the moderate or anxious category before learning, but most became non-anxious after learning. These results support the claim Nugroho et al. (2023), which states that enjoyable, contextual, and non-monotonous learning methods can help reduce mathematical anxiety.

Theoretically, project-based learning supported by digital visualization, such as AR, has the ability to shift students' focus from learning pressure to curiosity and achievement. Students are more confident and less anxious when they can complete projects in a fun and collaborative way. This is in line with the emotional domain approach in learning, which emphasizes the importance of managing students' emotions and desire to learn. Thus, the research flow and process can be summarized as follows:

Project Learning Flow

In this study, it is divided into six syntactic (1) Project determination, (2) Planning steps, (3) Schedule preparation, (4) Project development, (5) Report and presentation, (6) Project assessment. Each syntax is designed to provide a structured and in-depth learning experience, enabling students to actively engage in the learning process. The implementation of project-based learning can encourage students to be more creative.

Experimental Group Research Process

In the initial stage of the research, students were given a preliminary mathematical anxiety questionnaire to determine the initial conditions of both groups. This questionnaire is designed to assess students' anxiety levels towards mathematics comprehensively, covering various aspects such as confusion, fear, worry, lack of confidence, and even physical symptoms such as frequent dizziness when facing mathematical problems, cold sweats, and so on. At this stage, the results obtained from both classes before the treatment were grouped as follows:

Table 3. Initial Mathematical Anxiety Questionnaire Scores

Category	Frequency	Percentage	Frequency	Percentage
	Experiment		Control	
Anxious	3	12%	5	20%
Moderate	22	88%	20	80%
Not anxious	0	0	0	0
Total	25	100%	25	100%

Referring to Table 3, it can be concluded that in the initial anxiety stage, the experimental group had a moderate level of mathematical anxiety. This can be seen from the fact that 22

students were in the moderate category, three students were in the anxious category, and no students had low anxiety. Meanwhile, in the control group, there were 20 students in the moderate category, five students in the anxious category, and no students in the low category. The difference in the moderate level or category between the experimental group and the control group was only 8%.

During the treatment stage, students in the experimental group carried out project-based learning during four meetings. In the first and second meetings, students were divided into several groups for project-based learning. Then, students were taught about spatial figures using *Augmented Reality* media, including cubes, blocks, prisms, and tubes. Each spatial figure was explained and evaluation questions were given. In the third meeting, students were asked to design a project to be made together with group members within a specified time. In the fourth meeting, students completed their unfinished projects, which were then presented in front of the class together with their groups. After all presentations, the teacher and students conducted an evaluation together during the project-based learning process. On the other hand, in the control group, learning was only conducted using conventional methods, with material provided during two meetings. No media or teaching aids were used.

In the final stage of the research, after the experimental group received treatment and the control group did not, both groups were given a *post-test* on their understanding of the concepts and a final anxiety questionnaire to determine the results of the learning process. At this stage, the results obtained from both classes were presented as follows:

Table 4. Post-test Scores for Understanding

Experimental Group			
N	*Post-test Concept Understanding*		
25	**Minimum**	**Maximum**	**Average**
	64	98	81.68

Control Group			
N	*Post-test Concept Understanding*		
25	**Minimum**	**Maximum**	**Average**
	42	88	66.96

Based on Table 4, the average concept understanding score of students in the experimental group was 81.68. The highest score was 98 and the lowest score was 64. Meanwhile, the average concept understanding score of students in the control group was 66.96. The highest score was 88 and the lowest score was 42. This proves that the experimental group that received treatment had a higher average than the control group that did not receive treatment. This indicates that the learning model used in the experimental group was more effective in improving students' concept understanding, suggesting that the method used not only improved individual learning outcomes but also had the potential to increase student motivation and engagement in the overall learning process. The results of the post-test concept understanding scores obtained by students were tested using an independent sample t-test as follows:

Table 5. Results of the *Post-test* Hypothesis Test of Conceptual Understanding

Independent Sample T-Test					
Levene's Test for Equality of Variances		**T- Test for Equality Means**			
		F	**T**	**Df**	**Sig. (2.tailed)**
Post-test	Equal variances assumsed	2.330	4.350	48	<,001
	Equal variances not assumsed		4.350	44.906	<,001

Table 5 shows that there is a relevant difference in the average *Post-test* scores between the experimental group and the control group. The t-value is 4.350 with df = 48 and Sig. (2-tailed) < 0.01. This means that there is a difference between the experimental group that received treatment and the control group that did not receive treatment, where the experimental group showed higher results.

Figure 1. Project-based learning

In the picture above, students are conducting an experiment on the material they have learned, namely spatial figures. Students work in groups to create real spatial figures. Each group creates a different spatial figure. The material is presented using AR media as follows:

Figure 2. *Augmented Reality* media as a learning aid for students

Based on the image above, students are conducting PjBL learning assisted by an Android application called Augmented Reality (AR). Each student uses their Android device to access

media independently, so that with this tool, virtual elements can be combined with the real world, making learning more interactive, interesting, and fun (Rofi et al., 2023). The use of AR applications can also increase student motivation and engagement. Students who are active during the learning process usually understand the material being taught more quickly and easily because they can see real applications of the abstract concepts being taught (Ridlwaniyyah, 2024).

This indicates that a project-based learning model combined with AR yields significant results in improving students' conceptual understanding. Constructivist theory states that active student involvement in relevant and contextual activities makes learning more meaningful. Paivio's theory (1986) suggests that students find it easier to understand and remember information presented visually and verbally simultaneously when AR media is used.

As seen from the comparison of average scores between the experimental group, which was higher than the control group, it shows that the project-based learning model and AR can facilitate students to achieve their maximum potential in understanding the concepts taught.

Table 6. Final Mathematical Anxiety Questionnaire Scores

Category	Frequency	Percentage	Frequency	Percentage
	Experiment		Control	
Anxious	0	0	4	21%
Moderate	11	44%	21	79%
Not anxious	14	56%	0	0
Total	25	100%	25	100%

Referring to the table above, it is known that in the final anxiety test, 11 students in the experimental group were in the moderate category, 14 students were in the non-anxious category, and there were no students who felt high anxiety. Meanwhile, in the control group, there were 21 students in the moderate category, four students still in the anxious category, and no students in the low category. This indicates a reduction in anxiety levels in the experimental group after receiving treatment in the moderate category in Table 1. The percentage decreased from 88% to 44%. In the control group, there was only a slight decrease from 80% to 79%.

This decrease in anxiety levels can be explained through the theory of emotional control in learning, which states that learning strategies that are interesting, interactive, and tailored to students' learning styles can reduce emotional pressure and increase comfort (Zhao et al., 2021). In this context, AR media provides an immersive learning experience, which helps students shift their focus from fear of mathematics to curiosity and enthusiasm for exploration.

These results are also supported by Nugroho et al. (2023), who state that math anxiety can be reduced through innovative and enjoyable learning approaches. When students feel more capable and confident, their anxiety scores improve. The final anxiety questionnaire scores were tested using the Paired Sample T-Test, as follows:

Table 7. Hypothesis Test of Mathematical Anxiety in the Experimental Group

Paired Differences	
	95% Confidence Interval of the

Experimental group	Mean	Std. Deviation	Std.Error Mean	Difference Lower	Difference Upper	t	df	Sig. (2-tailed)
Pre test Post test	-10.040	6.560	1.312	**-12.748**	**-7.332**	-7.652	24	**<,001**

Based on the output table above, the values obtained are Lower -12.748 and Upper -7.332, and Sig. (2-tailed) < 0.05, so Ho is rejected and Ha is accepted. It can be concluded that there is a difference in mathematical anxiety between students in the experimental group before and after receiving treatment using the AR-assisted PjBL learning model.

Table 8. Hypothesis Test of Mathematical Anxiety in the Control Group

Control Group	Paired Differences Mean	Std. Deviation	Std.Error Mean	95% Confidence Interval of the Difference Lower	Upper	t	df	Sig. (2-tailed)
Pre test Post test	-2.280	5.719	1.144	**-4.641**	**.081**	-1.993	24	**.058**

Based on the output table above, the values obtained are Lower -4.642 and Upper 0.081, and Sig. (2-tailed) > 0.05, so Ho is accepted and Ha is rejected. It can be concluded that there is no difference in mathematical anxiety between students in the control group using conventional learning methods. Therefore, before and after learning using conventional methods, students still experience anxiety towards mathematics.

The success of the *Project Based Learning* model supported by *Augmented Reality* can be seen from the increase in the conceptual understanding of fifth-grade elementary school students, who became more active and creative in the learning process. In addition, there was a decrease in the level of mathematical anxiety, which helped students overcome challenges in spatial construction material and create a product.

4. Conclusion

The results of this study indicate that the implementation of the *Project-Based Learning* (PjBL) model supported by Augmented Reality (AR) media significantly enhances students' conceptual understanding and reduces mathematical anxiety, particularly in spatial geometry topics at the elementary school level. Students engaged in this learning model became more active, motivated, and deeply involved in the learning process. The use of interactive AR visualizations made abstract concepts more concrete and easier to comprehend, thereby increasing students' confidence and comfort in learning mathematics.

A comparison between the experimental and control groups showed that students who received the PjBL-AR treatment achieved higher conceptual understanding scores and experienced a greater reduction in anxiety levels than those who learned through conventional methods. These findings align with constructivist theory and emotional control theory in

learning, both of which emphasize the importance of active engagement and contextual approaches in creating meaningful and enjoyable learning experiences.

Therefore, integrating the PjBL model with AR technology represents an effective instructional innovation to improve the quality of mathematics education in elementary schools while also helping students overcome emotional barriers in understanding complex material.

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