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The Effect of Augmented Reality Media on Mathematics Learning Outcomes of Elementary School Students

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Abstract: This study aims to test the effect of Augmented Reality (AR) media on mathematics learning outcomes of fifth-grade students at SD Negeri 2 Tibayan, Klaten Regency. The use of Augmenter Reality Media can serve as an alternative in innovative learning activities. The study used pre-experimental research methods, one group pretest, and a posttest design using learning outcomes through pretest and posttest to determine the effect of before and after using Augmented Reality media. The subjects of this study were students of fifth grade SD Negeri 2 Tibayan, totaling 20 students, with 12 male students and 8 female students. This study uses instruments in the form of learning outcomes tests and learning devices in the form of teaching modules. Data analysis techniques in this study are descriptive and infersional analysis techniques. The results of the study before using Augmented Reality (AR) media showed a low level of understanding of the concept, with an average value of 64. After using Augmented Reality (AR) Media obtained an average of 80,450 with a standard deviation of 10,679, as well as the lowest value of 65 and the highest of 100 so that it shows the level of understanding of the concept in the high category. Based on these results, it can be concluded that Augmented Reality (AR) media has a significant influence on students ' math learning outcomes.

Keywords: augmented reality, mathematics learning outcomes.

▪ INTRODUCTION

The main components of the learning process, namely the instructor as the subject of learning, media and learning resources, learning environment, and teaching materials, have a significant influence on the achievement of learning. Since these four elements are essential in the learning process, the learning objectives will not be achieved optimally if one or more of these elements are not fulfilled. Based on this statement, choosing the right learning resources needs to be a top priority in order to achieve the best learning outcomes (Saputra et al., 2020; Krisnajati, Nisa & Zulfiati, 2024). There is a possibility that students do not understand the information or messages conveyed despite the various ways of verbal and nonverbal communication in the classroom. Thus, the delivery of information or messages in the classroom can run smoothly by using the right learning media (Mukhtarkyzy et al., 2022; Nadia, 2022).

Students often find learning math in elementary school difficult and boring. Abstract concepts in mathematics are often difficult for students to understand and visualize, especially students who learn in a visual way (Hui et al., 2024). Based on the results of interviews with fifth-grade teachers who have obstacles in using learning media. The teacher said that the mathematics learning outcomes, especially in geometry of grade fifth students were still below the Minimum Completion Criteria (Value 65), namely 13 out of 20 students or 65% of students; this was due to the lack of student involvement and participation in the classroom, based on observations. Many elements in the learning process are the root cause. One of them is that teachers are less creative in designing

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engaging learning. Therefore, it makes learning feel uninteresting, so it reduces students' motivation to continue learning and ultimately reduces their learning outcomes.

Mathematics is indeed a complex subject and is also a subject in the national exam from elementary school to high school. We often use geometry and other mathematical concepts in our daily lives. Spatial geometry is also learned in school. Some spaces have curved sides, while others have flat sides. A flat space itself is a space whose sides are all flat. A space is not a flat space if one side is curved (Munir, 2024). In 2019, TIMSS report shows that students ' understanding of Mathematics at the elementary level in Indonesia is lower than in other countries. Geometry is an element that shows a low level of understanding. Students in Indonesia only about 34% have "high" geometry skills, much lower than students in countries like Singapore and South Korea who have high scores in this field (Andrew et al., 2019).

Students are more motivated and actively involved in the learning process when faced with fun and engaging learning materials. Learning media is one of the intermediary media that can help deliver material or information with the aim of arousing students' enthusiasm for learning. Technology is currently growing rapidly and sophisticated. In almost every aspect of human life, technology is increasingly easy, efficient, and successful to use. The education sector has benefited from the various advantages and conveniences brought about by the rapid advancement of computer and information technology (Pahmi et al., 2023; Anggraeni et al, 2024).

Among the newer technologies is augmented reality. AR is digital content that instantly transforms computer-generated virtual items into tangible objects. Augmented reality allows people to view two- or three-dimensional virtual objects projected onto the real world by utilizing gadgets such as Android phones. Multimedia media includes still images, moving images, and sound animation. A mixture of these elements can be processed, stored, displayed, and transmitted by specific devices. Multimedia refers to media consisting of two or more components. Multimedia, according to the previous research is a collection of several components that create interesting information, such as text, images, audio, or video (Anggraeni, et al, 2024).

Students will learn maths in a more enjoyable and relevant way when AR-based learning resources are used, which will increase their enthusiasm. GeoGebra 3D Calculator is the programme used in this AR application is a platform for producing and disseminating interactive AR-based media or learning resources. Maths is abstract; it takes a lot of focus and seriousness to understand it, and it may even take a long time because symbols and images are still difficult for children to understand. The main goal of the learning process is for students to understand the material. One of the innovations in the use of learning media today is the use of interactive media. Smartphones are the most frequently used technology-based learning tool (Mukhtarkyzy et al., 2022; Chofifah et al, 2024).

Augmented reality, commonly abbreviated as AR, allows for providing interactive and engaging learning experiences that match the real world, where real-world objects are visualized through technology that we can easily hold in our hands. This technology has had a positive impact on various fields, such as industry, entertainment, medicine, tourism, and many more (Çetin, 2022; Permana et al, 2022). However, experts assure us that this is just the beginning and that the future of AR will bring cheaper, more engaging, and more accessible applications. This technology has also had a positive impact on

education. The first 25 AR apps have been developed that are specifically designed for use in education (Hajirasouli & Banihashemi, 2022; Boldaji, 2024).

AR is an emerging technology that blends the real world and the virtual world by using 3D object replacement techniques or human-machine interfaces. This technology simulates real-world experiences for users to see, smell, hear, and feel (Ahmad, 2021; Sungkono et al, 2022).In addition, virtual technology allows users to join in activities. It has emerged that AR can be adapted in various ways to support entrepreneurs. Presumably, it will change the way we perceive the world around us. It will add graphical layers and other sensory enhancements to the real world in real time. AR places virtual objects in a real-time environment that can be viewed through different viewing objects and turns the environment into a digital interface (Kounlaxay et al, 2021; Ivan & Maat, 2024).

Since its launch, various levels of education, various fields of education, and various educational environments have successfully implemented this AR application, benefiting students. However, there are still some pending issues that need to be addressed to have the best technology to enrich education. Moreover, it is important to note that as AR hardware advances, AR applications will also advance, bringing affordability and new challenges to the AR research field. This study provides an overview of AR technology in the Pedagogical Perspective of Primary School Education (Sitorus & Santoso, 2022; Sari et al, 2023).

This age range has cognitive development that is still bound by concrete objects and can be captured by the five senses. Mathematics is abstract, so students need tools to use media and props that can make it easier for teachers to convey material to students and convey it well (Krisma & Setyadi, 2022; Hariyono et al., 2023). The role of a teacher is to motivate students so that they are ready to learn and achieve the learning goals that have been determined (Adam, 2023). Teachers can also utilize various facilities and infrastructure to improve students' understanding and learning outcomes of mathematics. This is because Maths not only improves students' problem-solving and analytical skills but also enhances their logical, functional, and aesthetic skills (Suwito et al, 2023; Victor et al, 2024).

In general, humans are involved in the daily use of mathematics, and this daily application of mathematics drives the human brain to articulate problems, theories, and solutions for the survival of humanity (Lawan, 2020; Kartini & Putra, 2020). Studies on the use of AR in mathematics education have shown that it elicits positive attitudes toward learning content, provides engaging learning experiences, provides teacher-student collaboration, and enhances the learning of geometry and mathematics (Palancı & Turan, 2021; Tolba et al., 2022). An engaging learning model is needed in the learning process because this study aims to see the effect of using Augmented Reality media on students' Mathematics learning outcomes (Sundari, 2024, Zapata et al., 2024).

Augmented reality technology is not limited to any discipline or age group. Augmented reality apps on first graders have improved their motivation and their math learning outcomes (Reddy & Govindarajan, 2020; Masmuzidin et al., 2022). Given the students ' early math skills, the improvement in their mathematical computational thinking skills was more significant when they learned using augmented reality media compared to conventional learning (Angraini et al., 2024). This shows that each student's initial mathematical ability plays a role in the difference in mathematical computational

thinking ability between those who receive AR learning methods and those who receive conventional learning methods (Ahmad, 2021; Hariyono et al., 2023).

Specifically, this research aims to assess the extent to which the use of augmented reality media with Android-based 3D Applications can improve the understanding of mathematical concepts among students in Grade 5 of SD Negeri 2 Tibayan. Identify differences in math learning outcomes between students who use augmented reality media with students who use conventional learning methods. Knowing the response and motivation of students to the use of augmented reality media in mathematics learning. Assessing the effectiveness of augmented reality media as a learning aid in improving critical thinking skills and solving mathematical problems in Grade 5 students of SD Negeri 2 Tibayan.

▪ METHOD

Participants

This research was conducted at SD Negeri 2 Tibayan Klaten. A total of sixteen students in 5th grade in SD Negeri 2 Tibayan Klaten are the research subjects. Purposive sampling is the sample strategy used in this research. Purposive sampling is the process of choosing a sample based on a predetermined goal or choosing people closest to and best informed about the data or topics under investigation. Thus, researchers often use the intended sampling technique to select informants based on their knowledge and experience regarding the focus of empirical inquiry (Robinson, 2023).

Research Design and Procedures

This research uses a quantitative methodology. This research uses pre-experimental research, which is a research method to find the effect of a treatment on other things under controlled conditions (Aziz et al., 2022; Ermawati et al., 2024). This study aims to see the effect of using Augmented Reality learning media using the 3D Grapher application for building space material and understanding the basic concepts of geometry on the learning outcomes of grade 5th students at SD Negeri 2 Tibayan Kltaen. The research design used is a one-group pretest and posttest design, so this research was conducted on one group of reasons to compare learning before and after treatment (Munir, 2024, p. 151). In addition, this study also uses learning outcomes through pretest and posttest to compare the effect before and after using Augmented Reality media. Before implementing augmented reality in mathematics learning, the researchers administered a pre-test to the students to assess their initial understanding of the material. Then, the researchers conducted mathematics lessons using augmented reality media several times. After completing the mathematics lessons aided by augmented reality media, the researcher administered a final test to the students related to the material that had been previously learned. The researcher then used the students' pretest and post-test results as data in this study for comparison.

Instruments

This research's data collection method is a test method. The test technique uses multiple-choice questions. There were approximately twenty multiple-choice questions in total. Researchers administered this question during the pretest and posttest, using direct observation sheets. Before the research instrument in the form of this test is used in data collection, this instrument has been validated with content validation by experts.

The experts stated that the statements used in the test are in accordance with the indicators used to determine the learning outcomes of students in this research. Here are the validation results from the experts in Table 1.

Table 1. Results of the questionnaire validation

No.	Statement	Significance	Explanation
1.	Statement 1	0.565	Valid
2.	Statement 2	0.575	Valid
3.	Statement 3	0.646	Valid
4.	Statement 4	0.565	Valid
5.	Statement 5	0.565	Valid
6.	Statement 6	0.775	Valid
7.	Statement 7	0.574	Valid
8.	Statement 8	0.575	Valid
9.	Statement 9	0.866	Valid
10.	Statement 10	0.574	Valid
11.	Statement 11	0.901	Valid
12.	Statement 12	0.574	Valid
13.	Statement 13	0.575	Valid
14.	Statement 14	0.667	Valid
15.	Statement 15	0.701	Valid
16.	Statement 16	0.574	Valid
17.	Statement 17	0.646	Valid
18.	Statement 18	0.659	Valid
19.	Statement 19	0.866	Valid
20.	Statement 20	0.730	Valid

The number of students who took the test was 20 people, so the r table in the data validity test was 0.4438 with a significance level of 5%. If the significance value is greater than 0.4438 then the data is declared valid, whereas if the significance value is smaller than 0.4438 then the data is declared invalid. The results of the validity test of the statements on the questionnaire show that the significance value is greater than the r table, so all of the statements are declared valid. Meanwhile, the reliability test result is 0.941 so this statement has high reliability. We can categorize students' understanding of mathematics into five levels: very high, high, medium, low, and very low. The following Table 2 displays the categories of student learning outcomes in mathematics education.

In addition, the validity and reliability that have been tested, there are several categories of mathematics learning outcomes of Grade 5 students, namely if students obtain grades 0-54, then the category of learning outcomes is very low. When obtaining grades 55-64, then obtaining the category of low learning outcomes, and values 65-79 obtaining the category of medium. Then, grades 80-89 obtained the category of high learning outcomes, while grades 90-100 got the category of very high learning outcomes. This category of learning outcomes also helps in seeing the development of student learning outcomes to be able to draw conclusions from this study.

Data Analysis

This research uses descriptive and infomercial data analysis; the analysis of this research is determined through the level of student understanding in mastering the

learning material. Meanwhile, to test the hypothesis of this study using the SPSS programme. The normality test was conducted first before conducting hypothesis testing. The normality test using the SPSS program is based on the One Sample Shapiro Wilk test with a significance value > 0.05 for normally distributed data, while a significance value < 0.05 for data that is not normally distributed. After knowing that the data is normally distributed, then hypothesis testing is carried out using the paired sample t-test. If the p-value <0.05, then H0 is rejected, and H1 is accepted, which means that Augmented Reality Media has a significant effect on students' Mathematics learning outcomes. If the p-value > 0.05, then H0 is accepted and H1 is rejected, which means that Augmented Reality Media does not have a significant effect on students' Mathematics learning outcomes.

▪ RESULT AND DISSCUSSION

In the first stage, the researcher gave an initial test (pretest) of Mathematics about the concept of building space in grade 5th students. Based on calculations using the SPSS application obtained the results of the initial test (pretest) math scores before using augmented reality media with a total of 20 students, obtained an average of 64.050 with a standard deviation of 8.721, and the lowest value of 50 and the highest 80. The average score before using augmented reality media showed in the low category. The following is a description of the level of understanding of students towards the concept of spatial:

Table 2. Level of understanding of geometric concepts in the pre-test

Interval	Frequency	Percentage Valid	Percentage Category	Result
0 - 54	2	10%	10%	Very Low
55 - 64	11	55%	55%	Low
65 - 79	6	30%	30%	Medium
80 - 89	1	5%	5%	High
90 - 100	0	0%	0%	Very High

After conducting the pretest, the treatment is continued, namely the process of learning Mathematics about the concept of Building Space using Augmented Reality media, namely using the GeoGebra 3D Calculator application that can be accessed using an Android cellphone. Then after the learning is carried out out out posttest at the evaluation stage, the researcher gives the final test (posttest) Mathematics about the concept of building space in grade 5th students. Based on calculations using SPSS application data obtained final test results (posttest) mathematical values after using augmented reality media with a total of 20 students, obtained an average of 80.450 with a standard deviation of 10.679, and the lowest value of 65 and the highest 100. The average score after using augmented reality media showed in the high category. The following is a description of the level of understanding of students towards the concept of spatial:

Table 3. Level of understanding of geometric concepts in the post-test

Interval	Frequency	Percentage Valid	Percentage Category	Result
0 - 54	0	0%	0%	Very Low
55 - 64	0	0%	0%	Low
65 - 79	11	55%	55%	Medium

80 - 89	5	25%	25%	High
90 - 100	3	15%	15%	Very High

Before conducting hypothesis testing, a normality test is carried out to determine whether the data is normally or abnormally distributed. Table 4 with the one sample Shapiro Wilk method below shows that both pretest and posttest data are normally distributed with a significant value > 0.05. Here are the results of the normality test in more detail.

Table 4. Normality test (shapiro wilk)

	Statistic	**df**	**Sig.**
Before using Augmented Reality Media	0.958	20	0.510
After using Augmented Reality Media	0.908	20	0.059

Both data have shown normal distribution, because the pre-test and post-test exhibit significance values of 0.510 and 0.059. Both calculated significance values are greater than the table significance value, 0.051 > 0.05 and 0.0059 > 0.05. Then, we can test the hypothesis using the paired sample t-test method in the SPSS 30 application. The results of the calculations using the SPSS application can be seen in Table 5.

Table 5. Hypothesis test (paired sample t-test)

Pair- 1	**Paired Differences**			**t**	**df**	**Significance**	
	Mean	**Std. Deviation**	**Std. Error Mean**			**One-sided-p**	**Two Sided-p**
Before – After using Augmented Reality Media	16.400	5.345	1.195	13.722	19	< 0.001	< 0.001

Based on the calculation of the hypothesis test above, a significant difference was found between before and after using Augmented Reality media, namely with a p-value that shows <0.001 on both sides. Based on the criteria for hypothesis testing in this study, the p-value <0.05, so H0 is rejected, and H1 is accepted; this indicates that Augmented Reality Media has a significant effect on student learning outcomes in mathematics.

This research uses pre-experimental research, using learning outcomes through pretest and posttest to compare the effect of before and after using Augmented Reality media. The application used in this study is the GeoGebra 3D Calculator, which can be downloaded through PlayStore on each student's smartphone. Here is a look at the application used to explain the concept of Build Space:

Through several stages of research and data processing, we can see the difference in learning outcomes of grade 5th students of SD Negeri 2 Tibayan from the pretest and posttest showed positive results. Table 3 shows data from the initial test results (pretest) of mathematics scores before using augmented reality media with a total of 20 students, obtained an average of 64.050 with a standard deviation of 8.721, as well as the lowest score of 50 and the highest score of 80. Based on the level of understanding, only 1 student with a high level of understanding, while the overall average score before using augmented reality media shows in the low category.

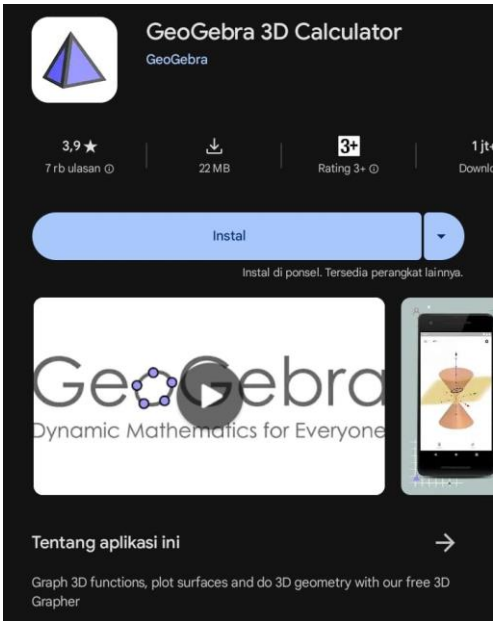

Figure 1. GeoGebra 3D calculator application on playstore

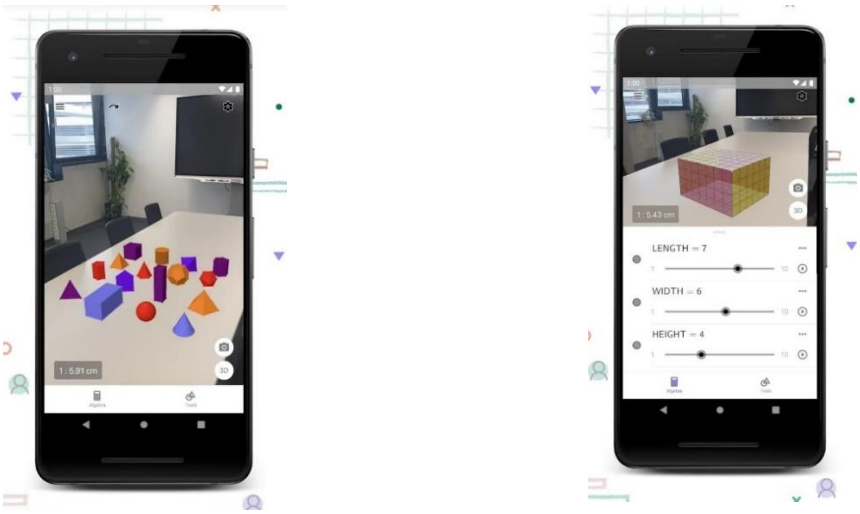

Figure 2. Example of using the GeoGebra 3D calculator application

After the pretest, learning is done using the GeoGebra 3D Calculator application as Augmented Reality media. So, the posttest results shown in Table 5 with mathematics learning outcomes after using augmented reality media obtained an average of 80.450 with a standard deviation of 10.679, as well as the lowest value of 65 and the highest of 100. The average value after using augmented reality media shows in the high category at the level of understanding of the concept of Build Space. The difference can be seen in Figure 3.

Then, through the normality test stage it was also found that both data showed typically distributed data with a significant value > 0.05. So, hypothesis testing can be done on both data, and the results obtained p-value < 0.05, so H0 is rejected, and H1 is accepted; then, Augmented Reality media has succeeded in having a significant effect on the learning outcomes of fifth-grade mathematics students of SD Negeri 2 Tibayan. The

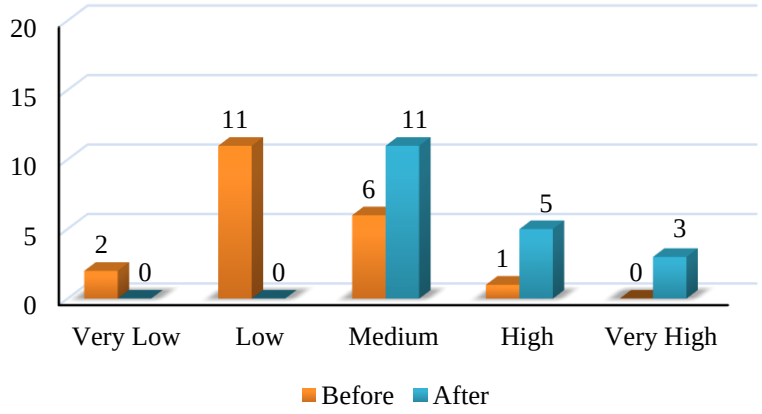

Figure 3. Data before and after the implementation augmented reality

results of this study indicate a significant effect of the use of Augmented Reality learning media compared to conventional learning media. This is in line with several previous studies that also explain the positive influence of the use of Augmented Reality (AR) learning media that can improve student learning outcomes and motivation (Guntur & Setyaningrum, 2021; Nadzeri et al., 2024).

According to other research findings, students who learn using augmented reality media are better at mathematical computational thinking compared to conventional learning methods (Ivan & Maat, 2024; Yahya et al., 2024). This suggests that each student's early mathematical ability contributes to the difference in their mathematical computational thinking ability compared to students who receive conventional learning (Prihatin et al., 2022; Masmuzidin et al., 2022). It also shows that student's early math skills affect the difference in their ability to think mathematically computationally between students who receive AR learning and students who receive conventional learning. Next, it is necessary to study how AR learning affects other math skills, especially high-level thinking skills (Zimmerman et al., 2023).

This research also supports Ramhawat et al (2022) research which states that learning media has been proven to be able to help achieve learning objectives well, especially in visualizing the material being studied. Furthermore, the use of this media can also improve learning outcomes from cognitive, affective and psychomotor aspects (Sutrisno & Nisa, 2023).

▪ CONCLUSION

Based on the formulation of the problem and the research methods used, using data processing and valid instruments, several conclusions were obtained. Namely, the results of research in the early stages showed the level of understanding of student concepts before using Augmented Reality (AR) media in the low category. Then, after using Augmented Reality (AR) media, the level of understanding of student concepts is in the High category. In addition, after testing the hypothesis, it was obtained that the results of Augmented Reality media succeeded in having a significant influence on the learning outcomes of fifth-grade mathematics students of SD Negeri 2 Tibayan. The researcher

hopes that through this study, it can inspire other teachers to utilise Augmented Reality media in learning, not only in learning Mathematics.

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