

THE USE OF AR MEDIA ON MATHEMATICS LEARNING OUTCOMES OF FOURTH GRADE STUDENTS

PENGUNAAN MEDIA AR PADA HASIL PEMBELAJARAN MATEMATIKA SISWA KELAS EMPAT

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Abstract

Lack of performance in mathematics, particularly in geometry, is often associated with students' difficulty in visualizing abstract spatial concepts through conventional instruction. This study examined students' mathematics performance before and after using Augmented Reality (AR) and investigated its effect on grade 4 students at SDN 551 Tampa, Luwu Regency. A pre-experimental one-group pretest-posttest design was employed. Data were collected through observation, pretest and posttest assessments, and document analysis, then analyzed using a paired-samples t-test. The findings revealed that students' mathematics performance was low before the implementation of AR-based learning but improved significantly afterward, reaching a high level of achievement. Statistical analysis confirmed a significant positive effect of AR on students' mathematics performance. These findings suggest that AR-based learning media effectively enhance students' understanding of geometric concepts by providing interactive and immersive visualizations. Teachers are encouraged to integrate AR into mathematics instruction to foster active learning and improve conceptual understanding.

Keywords: *Augmented Reality (AR), Mathematics Learning Outcomes, Spatial Geometry*

Abstrak

Rendahnya hasil belajar matematika, khususnya pada materi geometri, disebabkan oleh kesulitan siswa memvisualisasikan konsep spasial yang abstrak melalui pembelajaran konvensional. Penelitian ini bertujuan menganalisis hasil belajar matematika siswa sebelum dan sesudah penggunaan Augmented Reality (AR) serta menguji pengaruhnya terhadap siswa kelas IV SDN 551 Tampa, Kabupaten Luwu. Penelitian menggunakan desain pra-eksperimen dengan model one-group pretest-posttest. Data dikumpulkan melalui observasi, tes awal dan tes akhir, serta analisis dokumen, kemudian dianalisis menggunakan uji paired-samples t-test. Hasil penelitian menunjukkan bahwa hasil belajar matematika siswa berada pada kategori rendah sebelum penerapan AR, kemudian meningkat secara signifikan hingga mencapai kategori tinggi setelah pembelajaran berbasis AR. Analisis statistik juga membuktikan bahwa penggunaan AR berpengaruh positif dan signifikan terhadap hasil belajar matematika siswa. Oleh karena itu, media pembelajaran berbasis AR direkomendasikan untuk meningkatkan pemahaman konsep geometri melalui visualisasi yang interaktif dan mendukung pembelajaran aktif.

Kata Kunci: *Augmented Reality (AR), Hasil Belajar Matematika, Geometri Spasial*

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1. Introduction

Education is a crucial factor in building a nation's civilization. Through education, individuals can develop their full potential and prepare for the future. In the modern era, education aims not only to produce intellectually capable graduates but also creative, adaptable, and technologically proficient graduates. Therefore, the learning process needs to be managed innovatively to enhance students' interest and enthusiasm for learning. According to Law No. 20 of 2003, education is a deliberate, planned effort to create an environment in which students can develop their potential to the fullest.

According to Masykur, as cited in Kurniawati & Ekayanti (2020), in the field of basic education, mathematics is one of the key subjects that play a crucial role in developing logical, systematic, and analytical thinking skills. However, in reality, field observations show that learning mathematics, particularly concepts related to geometric shapes, is often considered difficult to understand due to the abstract nature of these concepts. At SDN 551 Tampa in Luwu Regency, this issue is particularly evident in fourth-grade lessons on geometric shapes in the fourth-grade. Based on initial observations and interviews with teachers, students have difficulty visualizing geometric shapes in a spatial context. As a result, only about 40% of students meet the minimum passing score of 70 on daily quizzes.

These poor learning outcomes are consistent with Susanto's (2013) findings, which stated that, in general, students in elementary schools still have weak abilities in mathematics and fail to achieve satisfactory results in this subject. On the other hand, Daryanto & Rahardjo (2012) emphasized that mathematics education should help develop critical, logical, systematic, and creative thinking skills. It should also enable students to connect mathematical concepts with the real world. However, a teaching method that relies solely on lectures is no longer effective in addressing these challenges.

According to Dinarti (2024), improving students' learning outcomes requires the use of interactive and engaging learning tools that actively involve students in the learning process. One promising innovation is Augmented Reality (AR), which provides immersive learning experiences by integrating three-dimensional virtual objects into the real world in real-time (Cai, Niu, Wen, & Li, 2023). A growing body of research has demonstrated the effectiveness of AR in education. Sari, Mariana, & Siswono (2025) found that AR-based interactive 3D visualizations increase student engagement, stimulate curiosity, and promote independent knowledge construction. Similarly, Cai, Niu, Wen, & Li (2023) and Nindiasari, Pranata, Sukirwan, Sugiman, Fathurrohman, Ruhimat, & Yuhana (2024) reported that AR enhances students' cognitive knowledge construction and supports meaningful learning. In mathematics education, AR has been shown to improve students' understanding of geometric concepts through direct interaction with three-dimensional objects (Ananda & Fauziah, 2022). Moreover, AR improves cognitive abilities and learning outcomes (Yusup, Azizah, Rejeki, Silviani, Mujahidin, & Hartono, 2023) and enhances critical thinking skills among Indonesian elementary school students (Akbar, Herman, Suryadi, Mursalim, Alman, Putra, & Blegur, 2025).

Despite these encouraging findings, several challenges remain in implementing AR in elementary education. Cufuna, Lazaro, & Duart (2025) argued that further research is needed to examine the actual impact of AR on students' learning outcomes, its long-term sustainability in educational settings, and the readiness of teachers and schools to adopt the technology effectively. In addition, many elementary schools still face practical constraints, including limited access to high-specification devices and the availability of inflexible AR applications. Therefore, further research is needed to examine the use of

AR technology in real-world learning environments in elementary schools. This study ensured that AR can truly improve learning quality. Instead of relying on monotonous digital applications, researchers employed a hybrid implementation strategy, using AR cards created through a creative integration of Assemblr Edu and Canva. This innovation results in media that is inexpensive, practical, adaptable, and easy to integrate into existing educational systems.

The use of AR-based media, combined with smartphones in the classroom, is expected to help students understand abstract concepts related to spatial shapes. It also encourages active student interaction and helps eliminate any misconceptions they may have about space. Teachers can carry out teaching activities in these areas without being hindered by limitations related to technology access. Given these issues, this study was conducted to empirically examine the impact of AR-based media on students' math learning in grade 4 at SDN 551 Tampa, Luwu Regency.

2. Research Method

This study employed a quantitative approach using a pre-experimental one-group pretest–posttest design to examine the effect of AR on fourth-grade students' mathematics learning outcomes. The research was conducted at SDN 551 Tampa, Ponrang District, Luwu Regency. The study population consisted of 108 students, while the sample comprised 21 fourth-grade students selected through purposive sampling. The sample included 13 males and 8 females. These students were chosen because their cognitive development was at a transitional stage, and the learning materials were relevant to the content presented through AR technology.

Data collection was conducted through participatory observation, documentation, and pretest and posttest assessments. The main research tools included observation sheets to record students' activities and a written test consisting of 20 multiple-choice questions, all of which were based on indicators of competence achievement. The collected data were then analyzed using inferential statistical methods. Before testing hypotheses, the data were first tested for normality using the Shapiro-Wilk test. Once it was confirmed that the data followed a normal distribution, paired-samples t-tests were used to assess the significance of any differences in scores and to objectively evaluate the impact of using AR technology.

3. Results and Discussion

3.1 Results

3.1.1 Students' Math Learning Results before the Use of AR Technology (Pretest)

Table 1. Descriptive Statistics for Pretest

Statistics	Scores
N	21.00
Minimum	25.00
Maximum	75.00
Mean	50.71
Std. Deviation	15.35

According to table 1, data before the use of AR technology, the overall score was 25-75. In other words, the highest score achieved by students was 75, while the lowest score was 25. The pretest results indicate that students' average academic performance remains quite low, with a significant range in individual scores. This finding indicates that students' initial levels of competence vary greatly. Some students have a relatively good understanding of the material, while others are still at a low level. This situation reveals a gap in students' initial abilities before any learning interventions are implemented.

Table 2. Frequency Distribution of Pretest Scores

Interval Value	Frequency	Percentage	Category
≤ 50	12	57.14%	Low
51 - 75	9	42.86%	Medium
76 - 100	0	0.00%	High
Total	21	100%	

According to table 2, 57.14% of the students fall into the lower category. This result indicates that students' initial abilities remain predominantly low.

Table 3. Frequency Distribution of Pretest Scores

Criteria	Value Range	Student	Percentage
Mastery	>70	5	23.81%
Non-Mastery	<70	16	80.95%
Total		21	100%

Table 3 illustrates the percentage of students who achieved the required standards before the use of AR technology was extremely low and did not meet the desired standards. The majority of students fell below the minimum acceptable level. This result confirms that students had significant difficulties in students' understanding geometric concepts due to the limitations of the learning materials used before the introduction of AR technology.

3.1.2 Students' Math Learning Outcomes after Using AR Technology (Posttest)

Based on the posttest results for 21 students, students' learning outcomes improved significantly after using AR-based learning materials. The lowest score achieved by the students was 75, while the highest was 100. Most students scored above 90, indicating that their understanding of geometric shape concepts improved significantly.

Table 4. Descriptive Statistics for Posttest

Statistics	Scores
N	21.00
Minimum	75.00
Maximum	100.00
Mean	88.81
Std. Deviation	7.89

Table 4 shows that the use of learning media has effectively eliminated the gap in students' abilities. The lowest scores achieved by students now meet the minimum standard requirements. The high average scores and the fact that some students scored perfectly indicate that students of all ability levels can effectively absorb the material. This finding confirms that the interventions implemented have succeeded in creating a level and consistent understanding of the material across the entire class.

Table 5. Frequency Distribution of Posttest Scores

Interval Value	Frequency	Percentage	Category
≤ 50	0	0.00%	Low
51 - 75	2	9.52%	Medium
76 - 100	19	90.48%	High
Total	21	100%	

Table 5 shows that 90.48% of the students fell into the high category, while 9.52% fell into the medium category. This result indicates that after using AR technology, students' abilities improved significantly, with the high category being the predominant one.

Table 6. Frequency Distribution of Posttest Scores

Criteria	Value Range	Student	Percentage
Mastery	>70	21	100%
Non-Mastery	<70	0	0%
Total		21	100%

Table 6 indicates that the results are very positive. After using AR technology in the learning process, students' overall mastery rate reached 100%. This significant improvement indicates that the 3D visualizations provided by AR technology help students understand the material more easily. As a result, all grade 4 students met or exceeded the established proficiency standards.

This improvement shows that AR technology can help students understand spatial concepts that were previously abstract and difficult to comprehend. AR also increases students' engagement in the learning process, thereby contributing to overall improved learning outcomes. The results of observing students' learning activities are shown in the table below.

Table 7. Observations Results

No	Total	Percentage	Category
1	27	67.50%	B
2	30	75.00%	B
3	33	82.50%	A
4	26	65.00%	B
5	30	75.00%	B
6	29	72.50%	B
7	36	90.00%	A
8	27	67.50%	B

No	Total	Percentage	Category
9	34	85.00%	A
10	31	77.50%	B
11	24	60.00%	C
12	34	85.00%	A
13	28	70.00%	B
14	36	90.00%	A
15	29	72.50%	B
16	30	75.00%	B
17	27	67.50%	B
18	33	82.50%	A
19	25	62.50%	B
20	34	85.00%	A
21	36	90.00%	A

Based on table 7, students' learning activities were predominantly classified as good (B) and very good (A). Empirically, these findings are consistent with and strongly support the students' cognitive learning outcomes in meeting the predetermined mastery criteria. The high conversion scores obtained across the ten observed indicators demonstrate that students' active engagement during classroom learning served as a key foundation for the substantial improvement in learning achievement. This finding is reflected in the increase in the mean score from 50.71 on the pretest to 88.81 on the posttest, with the classical mastery level reaching 100%.

3.1.3 The Effect of AR Media on the Mathematics Learning Outcomes

The effect of AR media on the mathematics learning outcomes of fourth-grade students at SDN 551 Tampa was examined using inferential statistical analysis. Before hypothesis testing, the data were assessed for normality to verify that the assumptions for parametric analysis were satisfied and to determine whether there were statistically significant differences in students' learning outcomes before and after the implementation of the AR-based learning intervention.

Table 8. Normality Test Results

	<i>Kolmogorov-Smirnov</i>		<i>Shapiro-Wilk</i>	
	df	sig	df	sig
<i>Pretest</i>	21	0.20	21	0.26
<i>Posttest</i>	21	0.14	21	0.14

Table 8 presents the results of the Shapiro-Wilk normality tests, with significance levels of 0.26 for the pretest and 0.14 for the posttest. Since both values are greater than $\alpha = 0.05$, it can be concluded that the student performance data follows a normal distribution. Therefore, the analysis can proceed with hypothesis testing using the paired sample t-test.

Table 9. Paired Samples t-Test Results

Mean	critical t-value	t-value	Sig. (2-tailed)	Decision
-38.095	21.458	2.086	0.000	Significant

Table 9 shows that the paired-samples t-test yielded a calculated t-value of 21.458, while the critical t-value was 2.086. Since the calculated t-value exceeded the critical t-value ($t = 21.458 > 2.086$), the null hypothesis (H_0) was rejected and the alternative hypothesis (H_a) was accepted. Furthermore, the obtained two-tailed p-value was 0.000, which is well below the 0.05 significance threshold, indicating that the observed difference was statistically significant. These findings demonstrate that the use of AR media had a significant positive effect on the mathematics learning outcomes of fourth-grade students at SDN 551 Tampa, Luwu Regency. This conclusion is further supported by the substantial increase in students' mean scores, which improved from 50.71 on the pretest to 88.81 on the posttest.

3.2 Discussion

Before the implementation of AR technology, students in grade 4 at SDN 551 Tampa achieved math learning outcomes below expected standards. This finding indicates significant difficulties in students' cognitive understanding of geometric concepts taught traditionally. The low scores at this initial stage can be attributed to the nature of geometric concepts, which require high levels of abstraction and spatial visualization skills. Before the use of AR technology, students relied solely on static, two-dimensional images in textbooks and on teachers' verbal explanations. As a result, they had difficulty understanding spatial structures, including the number of sides and angles. These findings are consistent with Jean Piaget's theories of cognitive development (Ilhami, 2022). It is stated that children in elementary school are still at the concrete operational stage of thinking. Therefore, it is difficult for them to understand abstract concepts without visual aids. This study aligns with cognitive load theory, which suggests that presenting traditional geometric concepts in a verbal/abstract manner often results in excessive cognitive load for elementary school students (Suwarno, 2020). This finding is consistent with results from Nurapidah, Nasrun, & Sirajuddin (2025), who reported an average value of 9.50 during the initial stages of their research. It shows that there is a common pattern of problems across various elementary schools in teaching mathematics without innovative media.

The use of AR-based learning media, through applications like Assemblr Edu and Canva, led to significant improvements in students' learning outcomes. Based on posttest data, there was a substantial increase in average scores, reaching 88.81. Notably, the overall achievement rate increased to 100%, and all 21 students achieved high scores. This improvement demonstrates that AR-based media can create a more meaningful learning experience by providing interactive 3D visualizations. This result allows students to observe three-dimensional objects on the smartphone screen as if they were actually present in front of them. Achieving such positive results demonstrates that integrating AR technology into the classroom can revolutionize the way students acquire information. Theoretically, this success can be explained through the dual-coding theory. The coding theory, proposed by Allan Paivio, states that the human brain processes information through two separate yet interconnected channels: the verbal channel (words) and the visual channel (images) (Listiyani, Hidayah, Khoerotunisa, Athoillah, Efendy, & Atmaja, 2025). AR-based media that combine visualizations with 3D graphics activate both of

these processing channels in the learner's brain. This combination enhances long-term memory retention and minimizes misunderstandings. The results of Lintiasri, Nisa, Masjid, & Cahyani (2025) also support this finding, showing that AR effectively improved students' comprehension levels across all categories. In addition, this increase in scores is similar to the results obtained by Rahmaveira & Ardianti (2024), who reported a posttest score of 85.40. The success of SDN 551 Tampa confirms that the use of AR technology has a tangible impact on reducing misconceptions about geometric shapes and on helping students grasp these concepts more quickly through visualizations.

After implementing this medium, significant changes were observed in both students' behavior and the classroom learning atmosphere. The learning process, which previously relied heavily on one-way instruction from the teacher, became more interactive and engaging. Students showed great enthusiasm and curiosity as they explored every detail of the three-dimensional objects presented to them. This change also had a positive effect on students' confidence, as they became more willing to ask critical questions, discuss ideas with their peers, and express their findings in their own words. The visualization capabilities made possible by AR technology help students understand abstract geometric concepts more easily. This includes understanding the locations of vertices, edges, and faces. Without having to rely on manual visualization, which can be confusing, students can grasp these concepts more clearly. This creates a much more positive, engaging, and effective learning environment. As a result, the understanding gained is not just short-term memorization; it becomes a deep, meaningful understanding that remains firmly ingrained in the student's long-term memory. In other words, AR technology does not merely change the numbers on grade sheets; it truly revolutionizes the way students interact with knowledge.

The paired-samples t-test showed a significant difference between students' pretest and posttest scores ($t = 21.458$, $p < .001$), confirming the effectiveness of AR in supporting geometry learning. Compared with conventional teacher-centered instruction, AR enabled students to better understand geometric concepts by transforming abstract representations into interactive and concrete three-dimensional visualizations. These findings suggest that AR provides meaningful learning experiences that facilitate students' conceptual understanding of geometry.

The improvement in students' learning outcomes is supported by Ronald Azuma's theory of concrete visualization, which explains that AR technology enhances learning by integrating virtual objects into real-world environments (Widani, Karlimah, & Kosasih, 2020). This capability helps elementary school students overcome difficulties in visualizing abstract geometric concepts by providing concrete, interactive three-dimensional representations. The findings are also consistent with constructivist learning theory, which emphasizes that students actively construct knowledge through meaningful learning experiences (Casfian, Fadhilah, Septiaranny, Nugraha, & Fuadin, 2024). Through the Assemblr Edu application, students explored and interacted directly with AR objects, thereby developing a better understanding of spatial concepts. Furthermore, the results align with Edgar Dale's Cone of Experience theory, which states that learning becomes more effective when students are actively involved in direct experiences (Sari, 2019). In this study, students' interaction with AR cards and three-dimensional objects created concrete learning experiences that facilitated their understanding of abstract mathematical concepts.

The results of this study are consistent with previous research demonstrating the positive impact of AR on mathematics learning. Amalia, Amril, & Mawardini (2024)

reported that AR-based digital media significantly improved students' learning outcomes ($p = .031$), while the present study showed an even stronger level of significance ($p < .001$). Similar findings were reported by Akbar, Herman, Suryadi, Mursalim, Alman, Putra, & Blegur (2025), who found that AR enhanced students' critical thinking skills, and by Fathuloh, Sutama, Kholid, & Minsih (2025), who concluded that integrating digital technology with visual learning media created more engaging and meaningful mathematics instruction. Rahmaveira & Ardianti (2024) also reported significant improvements in students' learning outcomes following the implementation of AR-assisted learning. Although the present study similarly demonstrated positive effects, the extent of improvement varied among students, which was likely influenced by their initial abilities, individual characteristics, and classroom learning conditions. These findings indicate that although AR is an effective learning medium, its implementation should take into account learners' characteristics and the learning environment.

An important contribution of this study lies in the implementation of AR cards developed through the integration of Assemblr Edu and Canva. Unlike conventional digital learning media that rely solely on screen-based applications, the combination of printed learning cards and smartphone-based AR technology provides an accessible, practical, and cost-effective learning solution that can be implemented without specialized equipment. This approach makes AR more feasible for elementary schools with limited technological resources, particularly in rural areas, while maintaining the quality of three-dimensional visualization needed for geometry learning.

4. Conclusion

This study demonstrates that AR-based learning media significantly improve the mathematics learning outcomes of fourth-grade elementary school students, particularly in learning geometry. The findings indicate that conventional instruction was insufficient to support students' visualization in abstract spatial concepts. In contrast, the implementation of AR cards developed using Assemblr Edu and Canva substantially enhanced students' conceptual understanding through interactive three-dimensional visualization. The integration of printed learning cards with smartphone-based AR technology provides an accessible, practical, and cost-effective instructional innovation that can be implemented without specialized equipment, making it particularly suitable for elementary schools with limited technological resources. These findings contribute to the growing body of evidence supporting the use of AR in elementary mathematics education by demonstrating a practical and scalable approach to technology-enhanced geometry learning. Nevertheless, the findings should be interpreted with caution because the study employed a one-group pretest–posttest design without a control group, involved a relatively small sample from a single school, and focused only on short-term learning outcomes. Therefore, future research should employ more rigorous experimental or quasi-experimental designs with larger and more diverse samples, examine additional variables such as spatial ability, learning motivation, student engagement, technology acceptance, and long-term retention, and evaluate the effectiveness of AR-based learning across different mathematical topics and educational settings.

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