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INFLUENCE AUGMENTED REALITY BUILDING SPACE AGAINST MATHEMATICAL SPATIAL VISUALIZATION ABILITY CLASS VIII STUDENTS ON THE TUBE MATERIAL

Dea Indriani[1], Reflina[2]
[1,2] Universitas Islam Negeri Sumatera Utara, Sumatera Utara, Medan, Indonesia
e-mail: dea0305213047@uinsu.ac.id

Abstract

Spatial visualization ability is very important in learning geometry of solid shapes because it allows students to imagine, manipulate, and represent three-dimensional objects, but many students still have difficulty in imagining the shape of solid shapes in mathematics learning due to the lack of learning media based on mathematical spatial visualization. This research aims To examine the impact of Augmented Reality (AR) media on spatial visualization of students' mathematical spatial visualization abilities. The study was conducted at Mts Darul Ulum Budi Agung Medan with a quantitative approach and one group pretest - posttest design. Class samples were randomly selected, namely class VIII-2, totaling 32 learners. The instruments used were test and student questionnaires response questionnaires. Data were analyzed through normality tests, homogeneity, N - Gain, and paired sample t - test. The results of the study showed that the average student score increased from 42.91 to 75.19. The t test showed a significance value of 0.000 <0.05, which means that the use of AR has a significant effect on students' spatial visualization b most students experienced an increase in the moderate category. A total of 91% of students also responded positively to AR-based learning. Thus, AR media has proven to be an effective learning alternative for improving mathematical spatial visualization skills in geometric geometry.

Keywords: Athematic Learning, Augmented Reality, Geometry, Spatiall visualization, Three dimensional shapes

Abstrak

Kemampuan visualisasi spasial sangat penting dalam pembelajaran geometri bangun ruang karena memungkinkan siswa membayangkan, memanipulasi, dan merepresentasikam objek tiga dimensi, namun banyak siswa masih kesulitan dalam membayangkan bentuk bangun ruang dalam pembelajaran matematika karena kurangnya media pembelajaran yang berbasis visualisasi spasial matematis. Penelitian ini bertujuan untuk mengetahui pengaruh media Augmented Reality (AR) Bangun Ruang terhadap kemampuan visualisasi spasial matematis siswa. Penelitian dilakukan di Mts Darul Ulum Budi Agung Medan dengan pendekatan kuantitatif dan desain one group pretest – posttest. Sampel kelas dipilih secara acak yaitu kelas VIII-2 yang berjumlah 32 siswa. Instrumen yang digunakan berupa tes dan angket respon siswa. Data dianalisis melalui uji normalitas, homogenitas, N – Gain, dan paired sampel t – test. Hasil penelian menunjukkan rata – rata nilai siswa meningkat dari 42,91 menjadi 75,19. Uji t menunjukkan nilai signifikansi 0,000 < 0,05, yang berarti penggunaan AR berpengaruh signifikan terhadap kemampuan visualisasi spsasial siswa. Hasil uji N-Gain menunjukkan sebagian besar siswa mengalami peningkatan pada kategori sedang. Sebanyak 91% siswa juga memberikan respon baik terhadap pembelajaran berbasis AR. Dengan demikian, media AR terbukti dapat menjadi alternative pembelajaran yang efektif dalam meningkatkan kemampuan visualisasi spasial matematis pada materi bangun ruang.
Kata kunci: Augmented Reality, Bangun ruang, Geometri, Pembelajaran matematika, Visualisasi spasial

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INTRODUCTION

Spatial ability is one of the important abilities that is beneficial to human life (Cholilah, 2023). Spatial ability is related to an individual's capacity to understand and remember spatial relationships between geometric objects (Taylor & Tenbrink, 2013). According to Nugroho (2017), spatial visualization ability is a very important skill in learning geometry, this ability allows students to imagine, manipulate, and represent objects in three-dimensional space.

Spatial ability involves a person's ability to perceive, store, remember, and create mental images of shapes and spaces (Sudirman, 2020). According to Mix & Cheng (2018), spatial ability plays a crucial role in facilitating students' understanding of abstract concepts that often require mental visualization, such as geometry, algebra, and measurement. Students with good visualization skills tend to understand geometry more easily than those with poorer visualization skills (Teapon, 2023).

However, various studies show that many students experience difficulty in visualizing spatial figures (Yusra, 2024). This is due to several factors, such as limited teaching aids in schools, low spatial abilities, and a lack of learning methods that support spatial visualization (Saputri, 2020). This is supported by the results of Programme for International Student Assessment (PISA) 2022 on content Space and Shape, where Indonesia obtained an average score 367, still far below the OECD average standard which is at 490 (OECD, 2023). These findings indicate that students' understanding of geometry in Indonesia is still relatively low compared to other countries. This reflects that many students in Indonesia still struggle to grasp geometric concepts comprehensively (Fauzi, 2020).

This condition is in line with research results that also indicate weak spatial visualization abilities in students. One such study by Mananeke (2017) revealed that in geometry learning there are still various problems related to students' visual-spatial abilities. Many students experience difficulty in thinking conceptually in pictorial patterns, so they are unable to connect various pieces of information obtained (Narpila, 2024). In addition, they also face obstacles in depicting and describing geometric shapes, have low skills in drawing and using tools to create three-dimensional images, and experience difficulty in understanding images (Harum, 2022).

The development of digital technology has brought various innovations to the world of education, one of which is Augmented Reality(AR). AR technology enables integration between the real world and the digital world by displaying three-dimensional (3D) objects through devices such as smartphone or tablet cameras (Rozi 2021). In contrast to Virtual Reality (VR) AR, unlike AR, completely replaces reality; it simply adds digital elements to the real world to enrich students' learning experiences (Sofyah, 2024). On the other hand, various forms of technology-based learning media have also begun to be utilized in mathematics learning, such as Android-based educational games (Alfiyanti, 2023). However, the direct application of AR-based technology in mathematics learning in Indonesia is still very rare.

In fact, one of the advantages of using AR is minimizing students' misconceptions because they cannot visualize a material (Karunia, 2021).Using AR allows students to learn through direct interaction with virtual objects displayed on the physical environment and can see, understand, and interact with three-dimensional geometric models in real-time, so they can more easily understand geometric concepts that were previously considered abstract (Ibáñez & Delgado-Kloos, 2018).By using AR, students' interest in learning and the learning process can be increased. learning itself (Ilmawan & Kurniawan, 2022)

In various developed countries, the application of AR in education has grown rapidly (Gusteti, 2023), particularly in visual-based and interactive learning. However, in Indonesia, the application of AR in education remains limited. While the use of Android-based technology in education has shown progress in the adoption of digital applications in mathematics education, more advanced technologies such as Augmented Reality have not yet been widely adopted (Siregar, 2025). According to Sukma (2023), although AR has been widely used in learning in developed countries, its use in Indonesia, particularly in vocational education, is still minimal. The use of AR is still largely focused on science and engineering, while other fields are still rare. Therefore, development is needed for other learning areas to achieve broader AR utilization (Arwanto, 2023). According to Khairunnisa and Aziz (2021), the use of AR technology in mathematics learning in Indonesia is still very limited. This is due to a lack of understanding and adequate supporting facilities. However, the use of AR in learning can help overcome various challenges in understanding abstract mathematical concepts, including in material geometric shapes in geometry

Although several studies have shown that digital media such asAugmented Reality(AR) is effective, but research specifically examining the influence of AR on mathematical spatial visualization skills in spatial geometry is still limited. Furthermore, few teachers utilize AR as a learning medium to develop mathematical spatial visualization skills, which are abstract and difficult to observe directly. Therefore, this study aims to analyze the influence of AR use.Augmented Realityon students' spatial visualization abilities in learning spatial structures

METHODS

This research uses a quantitative approach with a pre-experimental design method, namely the type*one-group pretest-posttest design*. According to Saputra (2017),*one-group pretest-posttest design*is an experimental method conducted on only one group without a comparison group. The population in this study were all eighth-grade students at MTs Darul Ulum Budi Agung Medan, consisting of five classes. The class sample was randomly selected, namely class VIII-2, which consisted of 32 students. The selection of class VIII-2 took into account the level of academic heterogeneity and active participation of students in mathematics learning. Based on initial observations and the results of the diagnostic assessment, students in this class showed varying levels of spatial visualization abilities, so they were considered representative of the characteristics of the population and worthy of being used as a sample in this study

The AR technology used in this research is the Augmented Reality Bangun Ruang application version 2.0, developed by Ape Dev and downloaded from the Google Play Store. This application allows students to view three-dimensional geometric objects in real time.real-timeThrough the Android device's camera. The application is used on an Android device and works by utilizing the camera's features to scan special markers. Once the marker is scanned, the application will display a 3D geometric object, such as a cylinder, in real time.real – timeon the screen. Students point the camera at the marker to observe the shape and structure of the object from various angles, making the learning process more interactive and concrete.

The data collection technique in this study used tests in the form of pretests and posttests, as well as student response questionnaires. The test instrument consisted of five questions arranged based on indicators of mathematical spatial visualization abilities. Meanwhile, the student response questionnaire consisted of fourteen statements that describe students' responses after using AR media. The results of the instrument test showed that all questions and student response questionnaires were declared valid based

on the validity test using the Pearson Product Moment formula, with a calculated r value > r table. The reliability test using Cronbach's Alpha showed that the question instrument had a reliability of 0.652 and the questionnaire of 0.894, both of which were in the reliable category. The discrimination test showed that all questions had a correlation index between 0.531 - 0.865 and was classified as very good. The level of difficulty of the questions varied from easy, medium, to difficult, so the instrument was declared suitable for use in research.

This data analysis was conducted statistically based on the approach described by Sugiyono (2019) in his book, Statistics for Research. The initial stage of data analysis involved normality and homogeneity tests to determine whether the pretest and posttest data were normally distributed and homogeneous. After conducting the normality and homogeneity tests, the hypothesis was tested using a paired-sample t-test.software IBM SPSS16. The hypothesis criteria will be accepted if the results of the paired-sample t-test are < 0.05, then H_0 rejected and H_1 accepted, meaning there is a significant difference between the pretest and posttest results. As supporting data, the N-Gain test was also used to measure the improvement in students' mathematical spatial visualization abilities after using AR on the geometric shapes material using pretest and posttest data. The formula for calculating the N-gain value is as follows.

$$\mathrm{N}_{\mathrm{gain}} = \frac{\text{skor posttest} - \text{skor pretest}}{\text{skor maksimal} - \text{skor pretest}}$$

The effectiveness criteria interpreted from N – Gain are as follows:

Table 1 N-Level Criteria – gain

Criteria	Skor N-gain
Less	$g < 0{,}30$
Medium	$0{,}30 \leq g \leq 0{,}70$
High	$g \geq 0{,}70$

Source: (Oktavia, 2019)

Additionally, descriptive analysis was used to interpret student responses to the use of AR (Dunleavy & Dede, 2014), providing additional insight into the potential and challenges of implementing this technology in geometry learning.

RESULTS AND DISCUSSION

Mathematics learning on curved-sided solid shapes (cylinders) in this study was implemented using Augmented Reality (AR) for Solid Shapes through the Discovery Learning model. This integration aims to improve students' spatial visualization skills through active, contextual, and exploration-based learning experiences.

The learning process is designed in two sessions. In the first session, students use the AR Bangun Ruang application to observe 3D objects of cylinders and their nets. This process allows students to identify the elements and properties of cylinders, as well as construct their own formulas for surface area and volume based on visual observation. All activities refer to the Discovery Learning stage: stimulation, problem identification, data collection, analysis, and conclusion. With this approach, learning becomes more meaningful because students do not simply receive information passively, but construct their own knowledge through direct and collaborative experiences.

The effectiveness of the implementation was then analyzed through a test of students' mathematical spatial visualization abilities. Based on the research results and descriptive statistical analysis, data were obtained on the spatial visualization ability test results of students taught using Augmented Reality (AR). The data were analyzed to obtain the highest, lowest, and average scores, and compared with the completion criteria that students must achieve. The results of the pretest and posttest data analysis can be seen in Table 2 below.

Table 2 Results of Pretest and Posttest Data Analysis

Statistik	Results	
	Pretest	**Posttest**
Highest Score	57	95
Lowest Score	27	42
Mean	42,91	75,19

KKM	75	75

Based on Table 2, the highest score in the pretest was 57, while the posttest was 95, indicating a significant increase. The lowest score in the pretest also increased, from 27 in the pretest to 42 in the posttest. Furthermore, the average student score also increased from 42.91 in the pretest to 75.19 in the posttest. These results indicate that Augmented Reality (AR) is effective in improving students' spatial visualization abilities.

Next, an assumption test is carried out as an initial step before conducting a hypothesis test, namely a normality and homogeneity test for the data. The normality test is carried out.to determine whether the data generated comes from a normally distributed population or not (Hajaroh & Raehanah, 2021). This test is carried out usingSofware IBM SPSS 16 , using the Shapiro-Wilk analysis technique. The basis for making decisions in the normality test is that if the significance value is >0.05, it is considered normal. The results of the normality test can be seen in Table 3 below.

Table 3 Normality Test Results

Data	**P (sig). Shapiro-Wilk**	**Taraf Signifikansi**	**Hasil**
Pretest	0,757	0,05	Normal
Posttest	0,283		Normal

Based on Table 3 above, it is known that the significant value for the pretest is 0.757, while the significant value for the posttest is 0.283, because both significant values are > 0.05, it can be concluded that the pretest and posttest data in this study are normally distributed.

Table 4 Results of Homogeneity Test

	P (sig). L evene-Statistic	**Taraf Signifikansi**	**Hasil**
Pretest Posttest	0,178	0,05	Homogen

Based on Table 4 above, it shows that the significance level in the homogeneity test calculation is 0.178. The sample criteria can be said to be homogeneous if the significance level is > 0.05.

Table 5 N-Gain Test Results

Category	Number Of Student	N-Gain Range
Less	10	$g < 0{,}30$
Medium	18	$0{,}30 \leq g \leq 0{,}70$
High	4	$g \geq 0{,}70$

Table 5 shows that eight students had an N-gain level above 0.70, indicating significant improvement in spatial visualization skills. Meanwhile, nineteen students were in the moderate category, and eight students experienced no improvement. These results indicate that the majority of students experienced moderate improvement, indicating that the treatment—in terms of learning methods, media, and approaches—was quite effective in improving spatial visualization skills.

Table 6 Results of Paired Sample T-test

	T	Df	Sig (2-tailed)
Pretest Posttest	14,981	31	0,000

Based on Table 6 above, it shows that the significance value is 0.000 <0.05, so H_o is rejected and H_1 is accepted. Thus, there is an effect of the use of Augmented Reality on mathematical spatial visualization abilities in the material of spatial figures. Based on the results of the study, it shows that the use of Augmented Reality (AR) has a significant effect on improving students' mathematical spatial visualization abilities in the material of spatial figures. This is proven through the results of the pretest and posttest which were analyzed using normality, homogeneity, and t-tests, with all statistical assumptions met.

The average pretest score of 42.91 increased sharply to 75.19 in the posttest. This improvement was consistent across all spatial visualization indicators. For example, in the indicator of imagining shapes from a specific perspective (question 3), the score increased from 6.09 to 16.81, while the highest increase occurred in the indicator of investigating geometric objects (question 5), from 7.88 to 75.19. The 3D visualization offered by AR helps students understand spatial concepts in a concrete and interactive way, which is difficult to achieve through conventional media. Thus, AR has proven to be an effective innovative learning medium in improving students' understanding of spatial geometry. These findings align with research by Endarto and Martadi (2022) and Hernanda (2019), which concluded that the use of AR can increase interest, understanding, and learning effectiveness through direct interaction with three-dimensional objects.

Beyond simply improving scores, the results of this paid-sample t-test have important implications for the overall approach to geometry learning. The use of AR media provides students with a constructivist learning experience, allowing them to construct their own spatial visualization knowledge based on direct visual experiences. This not only enhances cognitive knowledge but also develops higher-order spatial thinking skills such as metal rotation, visualization from multiple perspectives, and shape transformation. Furthermore, AR-based learning encourages active student engagement through more enjoyable and interactive exploration. This experience brings students closer to the concrete meaning of abstract concepts in geometry, while reinforcing the characteristics of 21st-century learning that integrates technology to improve the effectiveness and quality of learning.

To understand students' responses and experiences during the learning process, we collected data through a response questionnaire. The questionnaire was administered to students after the lesson. This questionnaire aimed to gauge their responses to the Augmented Reality (AR)-based learning on spatial geometry. The results of the questionnaire are presented in the following graph.

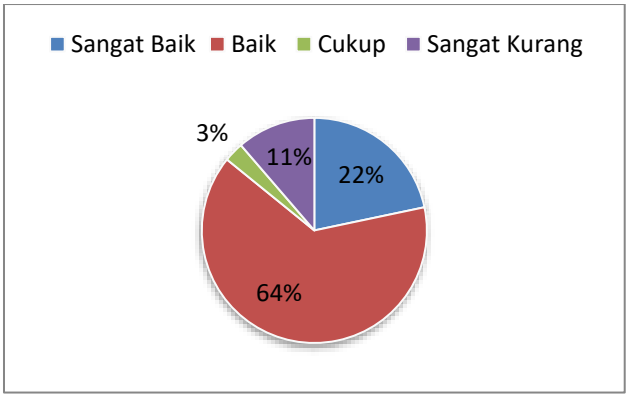

Figure 1 Results of Student Response Questionnaire

Based on the questionnaire results, the majority of students responded positively to learning using Augmented Reality (AR) on the material of geometric shapes. As many as 22% of students rated it very good, 64% good, 3% sufficient, and 11% very poor. This means that 91% of students responded positively to the use of AR media in geometry learning. This positive response was also seen from the four aspects assessed, namely interest in learning, ease of understanding the material, media display, and implementation of learning. The aspect of interest in learning received the highest score, namely 94% in the very good category, indicating that the use of AR can significantly increase student interest in learning. This finding is in line with the results of Salsabilah's research (2018), which showed that 84.6% of respondents also gave a positive response to the use of AR.

Students scan AR markers to display geometric objects.

Students use AR media to understand the elements of geometric shapes such as base, surface, and height.

Figure 2 Student Activities in Learning Using Augmented Reality

Based on the description above, the Augmented Reality (AR) media for spatial figures is an innovation that can improve students' mathematical spatial visualization abilities in learning spatial figures.

CONCLUSION

Based on the data analysis, it can be concluded that the use of Augmented Reality (AR) media in mathematics learning, particularly in spatial geometry, has a significant effect on improving students' spatial visualization abilities. This is indicated by the increase in students' average score from 42.91 in the pretest to 75.19 in the posttest, as well as the results of the experimental test.paired sample t-testwhich shows a significance of 0.000 < 0.05. The data also shows that the majority of students are in the moderate improvement category based on the N-Gain test, and 91% of students gave a positive response to AR-based learning. Thus, AR media is proven not only to improve student learning outcomes quantitatively, but also to be able to increase student motivation and engagement in the learning process, as well as being an effective solution in delivering abstract geometry material.

As a follow-up to the use of Augmented Reality (AR) media in geometric geometry materials, it is recommended to complement it with physical teaching aids, such as real cylinder models, to strengthen students' understanding of three-dimensional structures directly. Furthermore, AR can be combined with interactive software such as GeoGebra to dynamically visualize geometric geometry nets, making learning more contextual, engaging,

and meaningful. Teachers are expected to begin integrating AR into various geometric materials and participate in independent learning technology training

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