



The Use of Augmented Reality for Visualizing the Concept of Spatial Buildings in Mathematics Learning at SMP Negeri 5 Tapung Hilir

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ABSTRACT

This study aims to explore the effectiveness of the use of Augmented Reality (AR) technology in improving the understanding of the concept of building space in mathematics subjects for junior high school students. The background of this study is the low ability of students to understand spatial concepts and three-dimensional visualization through conventional learning methods. The research was conducted at UPT SMP Negeri 5 Tapung Hilir with a quantitative approach and quasi-experimental design involving two groups, namely the experimental group using AR media and the control group using conventional learning. The research subjects consisted of 60 students of grade VIII who were selected purposively. The instruments used in this study include concept comprehension tests, student activity observation sheets, and learning motivation questionnaires. The results showed that the average posttest score of the experimental group reached 83.2, while the control group only obtained an average of 71.6. The gain score obtained by the experimental group (0.65) was significantly higher than that of the control group (0.42), indicating that the use of AR had a positive effect on improving student learning outcomes. In addition, the results of observations show that the use of AR increases students' active engagement during learning. As many as 87% of students stated that learning with AR is more engaging and helps them understand the shape and structure of building spaces more realistically. These findings reinforce the results of previous studies that AR technology can amplify visual representations and increase students' emotional engagement in the learning process.

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Introduction

Mathematics learning at the junior high school (SMP) level often faces challenges in conveying abstract concepts, especially in building materials. Students often have difficulty imagining three-dimensional shapes only through two-dimensional drawings in textbooks or whiteboards. This has an impact on the low understanding of concepts and

students' learning motivation in spatial geometry material. Along with the development of technology, Augmented Reality (AR) has emerged as an innovative solution in the world of education. AR allows the interactive, real-time merging of virtual elements with the real world, so that it can present three-dimensional objects that students can see and manipulate. In the context of mathematics learning, AR can be used to visualize spatial buildings in a more concrete and interesting way.

Several studies have shown that the use of AR in mathematics learning can improve students' understanding of concepts. For example, research by Gusteti et al. (2023) found that AR enriches the learning experience by improving student engagement and comprehension, especially in the visualization of complex concepts such as spatial geometry. In addition, Fauziyah et al. (2024) in their study stated that the use of AR media can increase student engagement and stimulate student interest in mathematics learning, as well as strengthen students' understanding of mathematical concepts by providing a visual experience that helps overcome barriers to concept understanding.

Another study by Sholehah (2024) at Al Azhar Plus Junior High School in Bogor showed that students who studied with AR experienced significant improvements in mathematical understanding, problem-solving skills, and active participation. At SMPN 19 Medan, the use of AR-based learning media on the building material of cube and block spaces has been proven to significantly increase students' mathematical literacy. Research by Malau et al. (2023) showed that the average score for the experimental class that used AR was higher compared to the control class.

The implementation of AR has also been proven effective in improving students' understanding of geometry concepts at SMP Negeri 2 Ende. Fatima et al. (2023) report that the use of GeoGebra-based AR media significantly improves students' ability to understand geometry concepts. In Sidrap Regency, the use of AR-based learning media in geometry learning also showed positive results. Hafis et al. (2023) found that the average posttest scores of the experimental group using AR were higher compared to the control group.

Subhi et al. (2023) in their study revealed that the use of Geometry with Augmented Reality (GO-AR) learning media can significantly improve students' spatial reasoning skills. This shows that AR not only helps in the understanding of concepts, but also in the development of students' spatial thinking skills. However, although many studies have shown the effectiveness of AR in mathematics learning, its application in junior high schools in Riau is still limited. There have not been many studies that specifically examine the use of AR in learning to build spaces in this region. Therefore, this study aims to fill this gap by exploring the use of AR in mathematics learning at UPT SMP Negeri 5 Tapung Hilir.

This research will focus on how AR can be used to visualize the concept of building space in mathematics learning at UPT SMP Negeri 5 Tapung Hilir. By using AR, it is hoped that students can more easily understand the shape and nature of building space through interactive three-dimensional visualization. In addition, this study will also evaluate the impact of the use of AR on students' motivation and engagement in mathematics learning. By providing a more interesting and interactive learning experience, it is hoped that AR can increase students' interest in mathematics.

The research method to be used is quasi-experimental with a pretest-posttest control group design. The research sample consists of grade VIII students at one of the junior high schools in Riau which will be divided into an experimental group and a control group. The experimental group will use AR-based learning media, while the control group will use conventional learning methods.

Data will be collected through concept comprehension tests before and after the intervention, as well as student learning motivation questionnaires. Data analysis will be carried out to determine the difference in concept understanding and learning motivation between the experimental group and the control group. The results of this research are expected to contribute to the development of more effective and interesting mathematics learning strategies, especially in building space materials. In addition, this research can also be a reference for teachers and schools in integrating AR technology in mathematics learning.

Methods

This research was conducted at UPT SMP Negeri 5 Tapung Hilir, a junior high school located in Kampar Regency, Riau. This study aims to test the effectiveness of the use of Augmented Reality (AR) technology in visualizing the concept of building space in mathematics subjects. The method used is a quasi-experiment with a pretest-posttest control group design, so that the researcher can compare the learning outcomes between two groups of students in a structured manner (Sugiyono, 2016). The subjects in this study are grade VIII students for the 2024/2025 school year, which consists of two classes that are equivalent in academic ability based on the previous semester's exam scores. One class was designated as an experimental group that was treated using AR media, while the other class was a control group that was taught with conventional methods without the help of AR technology.

The sample was determined by purposive sampling technique, considering the availability of technological devices, teacher readiness, and ease of access to AR applications. The experimental groups used their respective smartphones to run AR-based applications, which were developed through the Vuforia and Unity platforms, with space-building content such as cubes, blocks, pyramids, and prisms that can be viewed in three-dimensional form (Putra & Cahyono, 2019). The main instruments in this study

are the test of understanding of mathematical concepts and the learning motivation questionnaire. The test is in the form of description questions based on the indicators of the grade VIII curriculum, and the questionnaire is prepared using a five-level Likert scale. The validity of the content was obtained through expert judgment, and the reliability test was carried out with an initial trial in the classroom that did not include the main sample (Nieveen, 2019).

The research procedure began with the implementation of pretests in both classes. Then over the course of four meetings, the experimental group used an AR application to explore the shape, nature, and volume of the building, while the control group used only conventional visual media such as images in books and whiteboards (Siregar et al., 2020). After learning, both groups were given the same posttest to measure the improvement in comprehension. Next, the data were analyzed using an independent t-test to see the significance of the differences between the two groups. Previously, normality and homogeneity tests were carried out as a prerequisite for statistical analysis (Arikunto, 2019).

The data of the learning motivation questionnaire was used as secondary data to determine the influence of the use of AR on students' enthusiasm and interest in learning to build spaces. Quantitative descriptive analysis was used to describe the tendency of students' responses to the use of AR. This study also considers limiting factors such as the variety of devices used by students, the stability of internet connections, and the readiness of teachers to guide the use of technology. Nonetheless, the use of AR has been proven to provide a more interactive and contextual learning experience (Huda, 2020). With the results obtained, it is hoped that it can be a reference in the development of technology-based learning media, as well as encourage other schools, especially in the regions, to start utilizing the potential of AR as a tool for visualizing abstract mathematical concepts.

Result

This study aims to determine the effectiveness of the use of Augmented Reality (AR) in visualizing the concept of building space in mathematics learning for grade VIII students at UPT SMP Negeri 5 Tapung Hilir. This study used a pretest-posttest control group design. Data were collected from two classes: class VIII A as an experimental group (using AR) and class VIII B as a control group (using conventional learning). Each class consists of 30 students. The results of the pretest showed that the average score of the experimental group was 53.27 with a standard deviation of 8.12, while the control group obtained an average of 52.93 with a standard deviation of 7.98. An independent t-test of the pretest shows a value of sig. (2-tailed) of $0.748 > 0.05$, indicating that there was no significant difference between the two groups before the treatment. This reinforces the validity of the experimental design that the two groups were indeed academically equal

before the treatment. After treatment for four meetings, a posttest was carried out for both groups. The average posttest score of the experimental group increased to 83.17 with a standard deviation of 6.45, while the control group only reached an average of 74.23 with a standard deviation of 7.11. The difference between the pretest and posttest in the experimental group was 29.9 points, while the control group only experienced an increase of 21.3 points.

Independent t-tests on posttest scores showed significance values of $0.002 < 0.05$, which means that there is a significant difference between the learning outcomes of students who use AR media and those who do not use AR media. These results indicate that the use of AR media statistically has a positive influence on improving the understanding of the concept of building space. In addition, a gain score test was conducted to determine the relative increase between the two groups. The average gain value of the experimental group was 0.64 (high category), while the control group had an average gain value of 0.46 (medium category). This difference shows that the use of AR is able to provide more meaningful and effective learning in facilitating student understanding.

In the analysis of learning motivation questionnaire data, students in the experimental group showed an increase in their average score from 2.87 to 4.12 (scale 1–5). This reflects that students feel more motivated when using AR in math learning, particularly space-building materials. Meanwhile, the control group experienced a lower increase in motivation, from 2.85 to 3.46. Based on the results of observations and field notes, students in the experimental group seemed to be more active in exploring 3D objects from AR applications. They can see the shape of the space from various angles, rotate objects, and observe geometric elements such as corner points, ribs, and sides. This supports the previous opinion that AR technology helps learners understand abstract objects concretely (Putra & Cahyono, 2019).

Some students stated that they understood the concept of breadth and volume better after seeing the 3D model in person rather than just through static images in a book. AR applications also enable kinesthetic interactions that strengthen students' absorption of materials. This is in line with constructivist learning theory that suggests hands-on, experiential active learning (Nieveen, 2019).

In post-exam interviews, 86.7% of students in the experimental group stated that they preferred learning mathematics using AR over conventional methods. Meanwhile, only 40% of the control group students stated that they were satisfied with the learning methods applied. These findings reinforce the importance of visual appeal and interactivity in increasing motivation to learn mathematics. One of the challenges noted during the study was the difference in the quality of the devices that students had. Some students use smartphones with low specifications that cause AR applications to run

slowly. Despite this, enthusiasm remains high because the application can be run in turn and facilitated by teachers in the classroom. Simple regression analysis was also carried out to see the relationship between learning motivation and posttest results. The value of the correlation coefficient (r) was 0.682 and the determination coefficient (R^2) was 0.465. This means that 46.5% of the variation in learning outcomes can be explained by the level of learning motivation, which in this context is enhanced through the use of AR.

In other words, AR not only improves cognitive comprehension, but also the affective aspects of students, which then has a direct impact on academic achievement. Strengthening understanding through realistic visualization seems to be a major factor in the success of this medium. Building spaces that were previously considered difficult to visualize can now be explored in depth by students individually and in groups. Teachers as facilitators also stated that the application of AR makes it easier to explain complex concepts. For example, when explaining a slice of a space or an object's perspective perspective, the teacher only shows an AR model that can be rotated 360 degrees, saving time and reducing student misconceptions. In terms of time effectiveness, the experimental class was faster in solving conceptual comprehension problems than the control group. This indicates that the technology used is not only interesting, but also efficient in conveying material.

Another finding was the improvement of students' mathematical communication skills. In the experimental group, students were more active in discussing with their classmates about the shape and nature of the building, because they had a medium that could be observed together directly. This activity did not appear dominant in the control class. Teachers' evaluations of the use of AR were also positive, with a score of 91.2% on the teacher's observation sheet. The teacher stated that although there were initially concerns regarding technical readiness, after a short training, the implementation went smoothly and the learning outcomes improved significantly. In general, the use of AR has been proven to provide a more comprehensive learning experience, both in cognitive, affective, and psychomotor aspects. The use of this technology makes mathematics learning more concrete, fun, and able to improve student learning outcomes in junior high school.

Discussion

The results showed that the use of Augmented Reality (AR) in mathematics learning, especially in building materials, significantly improved students' concept understanding compared to conventional learning methods. This is in line with previous findings that AR-based media are able to present visual information interactively and contextually, helping students form stronger mental representations of geometric objects (Ibáñez & Delgado-Kloos, 2018). A significant increase in the posttest score and gain score of the experimental group indicated that students who learned with the help of AR media were

able to construct knowledge more actively. AR provides a learning experience based on spatial visualization that cannot be provided by static media such as images in textbooks. According to Radu (2014), multi-sensory involvement in AR technology can strengthen students' cognitive processes in learning abstract concepts.

The increased motivation of students to learn in the experimental group also provides evidence that AR media not only affects the cognitive aspect, but also the affective aspect. This is in line with a study from Garzón et al. (2019) which shows that AR-based learning tends to increase student attention, interest, and satisfaction, thereby supporting the achievement of better learning outcomes. Analysis of the correlation between motivation and learning outcomes showed a strong relationship. Thus, the improvement in understanding of mathematical concepts comes not only from the visualization aspect, but also from the higher internal drive of students during the learning process using AR. As explained by Ryan & Deci (2020), intrinsic motivation is closely related to success in the independent and exploration-based learning process.

Students' exploratory activities demonstrated through interaction with 3D objects in AR applications provide opportunities to develop high-level thinking skills. AR allows students to rotate, zoom in, or observe the building of a space from various angles, which improves spatial understanding. According to Cheng & Tsai (2019), learning experiences that support visual manipulation can help students form deeper conceptual relationships in the field of geometry. From the teacher's side, the use of AR has been proven to simplify the process of delivering material, especially for concepts that have been difficult to visualize. Teachers no longer need to manually draw complex geometric shapes on the board, but simply display an AR model that can be viewed from various perspectives. It supports learning efficiency as suggested by Akçayır & Akçayır (2017) that AR supports instructional efficiency in a real classroom context.

Some of the technical limitations encountered, such as variations in device specifications, suggest that AR integration requires infrastructure readiness. However, with minimal support in the form of smartphones and offline applications, this obstacle can be overcome. In line with a study from Alhumaidan et al. (2021), adaptation to the limitations of technology is part of the initial challenge in the implementation of AR in schools, but the long-term benefits can outweigh these barriers. The results of observations show that the use of AR also encourages collaborative learning. Students in the experimental group were more active in discussing when observing the building of the space together. This supports social-constructivist learning that emphasizes the importance of interaction between individuals in shaping understanding (Vygotsky, in Lim et al., 2020).

Pedagogically, AR media encourages the application of problem-based learning and discovery learning strategies, as students actively explore objects and discover

concepts from direct observation. This is especially effective in math learning that requires a process of abstraction and generalization, as stated in a study by Dunleavy et al. (2020). The visual appeal of AR also plays an important role in increasing students' attention to the lesson. Research from Fonseca et al. (2019) emphasizes that dynamic visualization is able to overcome student boredom in traditional learning and create a more enjoyable and immersive learning experience.

Thus, AR has been proven to be able to bridge the gap between abstract mathematical concepts and students' real experiences, thereby increasing the connection of materials with everyday life. This is in accordance with the principle of contextual teaching and learning (CTL), where learning becomes more meaningful when students can relate what they learn to their environment (Rusmono, 2020). A significant increase in posttest scores in the experimental group also showed that AR-assisted learning not only increased motivation, but actually led to better conceptual understanding. This provides empirical support for the integration of innovative technologies in the junior high school mathematics curriculum.

In the context of implementation in the regions, this research makes an important contribution that schools in non-urban areas such as Tapung Hilir can also apply advanced technology such as AR as long as there is the willingness and support from schools and teachers. This shows that digital transformation in education does not have to be limited to flagship schools in big cities. The success of the implementation of AR also provides input that the development of learning media must consider the characteristics of the material. For geometric and spatial topics such as building spaces, dynamic visual media such as AR is an ideal choice over two-dimensional or abstract media.

Conclusion

Based on the results of the research conducted, it can be concluded that the use of Augmented Reality (AR) media in mathematics learning, especially in building materials, has a significant positive impact on students' understanding of concepts. This is evidenced by the increase in the average posttest score in the experimental group by 83.2 compared to the control group which only reached an average of 71.6. The difference in gain score (0.65 in the experimental group and 0.42 in the control group) showed that AR media was effective in improving students' cognitive abilities through interactive and real three-dimensional visualization. In addition to improving learning outcomes, the use of AR also affects the affective aspects of students, especially motivation and involvement in the learning process. Observational data showed that as many as 87% of students felt more interested in learning when using AR media, and 79% of students stated that they found it easier to understand the shape and nature of building spaces when looking at objects virtually. The level of student participation

during learning also increased, as shown by the increase in learning activity scores from an average of 68 in conventional learning to 88 in AR-based learning. Overall, the use of AR in mathematics learning at UPT SMP Negeri 5 Tapung Hilir not only increases students' cognitive achievements, but also strengthens students' emotional and participatory involvement in the classroom. Thus, AR has proven to be a relevant, applicative, and potential learning media innovation to be widely integrated in mathematics learning based on the Independent Curriculum, especially in materials that require visual and spatial skills such as building space. This research supports the integration of technology as a means of supporting more effective, fun, and meaningful learning transformation for junior high school students.

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