Development of Augmented Reality-Based Learning Media on Solid Geometry Materials

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ABSTRACT*:* Augmented Reality is one of the technologies that has shown great potential in helping to improve the understanding of abstract concepts in education, especially in subjects that require complex visualizations such as solid geometry. The purpose of this research is to create augmented reality media for solid geometry materials at the Junior High School level that can be used in the learning process. This research falls into the Research and Development (R&D) category using the 4D development model which has the stages of Define, Design, Development, and Disseminate. The results of this study indicate that augmented reality media for solid geometry materials are very feasible to be used as learning media. These findings are based on the results of expert material testing with an average percentage of 94.00%, learning media experts with an average percentage of 84.67%, and student trials with an average percentage of 83.55%. Information provided by students states that the use of augmented reality media has a significant impact on improving students' understanding of solid geometry concepts. The use of augmented reality media in learning solid geometry also provides a more enjoyable and motivational learning experience.

Keywords: augmented reality, learning media, mathematics, solid geometry.

ABSTRAK*: Realitas Tertambah merupakan salah satu teknologi yang menunjukkan potensi besar dalam membantu meningkatkan pemahaman konsep-konsep abstrak dalam pendidikan, terutama dalam mata pelajaran yang memerlukan visualisasi kompleks seperti geometri ruang. Tujuan dari penelitian ini adalah untuk menciptakan media realitas tertambah untuk materi geometri ruang tingkat Sekolah Menengah Pertama yang dapat digunakan dalam proses pembelajaran. Penelitian ini termasuk dalam kategori Penelitian dan Pengembangan (R&D) menggunakan model pengembangan 4D yang memiliki tahapan-tahapan Definisi, Desain, Pengembangan, dan Penyebaran. Hasil dari studi ini menunjukkan bahwa media realitas tertambah untuk materi geometri ruang sangat layak digunakan sebagai media pembelajaran. Temuan ini didasarkan pada hasil pengujian material oleh ahli dengan persentase rata-rata 94.00%, ahli media pembelajaran dengan persentase rata-rata 84.67%, dan uji coba dengan siswa dengan persentase rata-rata 83.55%. Informasi yang diberikan oleh siswa menyatakan bahwa penggunaan media realitas tertambah memiliki dampak signifikan dalam meningkatkan pemahaman konsep-konsep geometri ruang pada siswa. Penggunaan media realitas tertambah dalam pembelajaran geometri ruang juga memberikan pengalaman belajar yang lebih menyenangkan dan motivasional.*

Kata Kunci*: realitas tertambah, media pembelajaran, matematika, geometri ruang.*

INTRODUCTION

In the current digital era, the integration of technology into education has become a key element in enhancing the quality of learning and providing a more

interactive and engaging learning experience for students. Augmented Reality (AR) is one of the technologies that has demonstrated significant potential in helping to improve the understanding of abstract concepts in education, particularly in subjects that require complex visualizations such as solid geometry (Gargrish et al., 2020; González, 2015).

Solid geometry is one of the topics in mathematics that is less favored by students (Afthori et al., 2022). The subject of solid geometry is often considered a difficult topic by many students as it involves understanding the shape, size, and proportion of objects in three-dimensional space (Untari et al., 2022). Research (Asri et al., 2024) has facilitated the introduction of solid geometry using printed books, images on the blackboard, and recycled materials such as cardboard, yet many students still have difficulty understanding the material. In addition to media issues, the use of conventional learning media such as two-dimensional images and physical models is often not sufficient to provide a deep understanding (Marasabessy et al., 2021).

The same issue is also found at SMP Negeri 7 Kendari. Based on observational results, it was found that teachers often face difficulties in teaching solid geometry due to the lack of teaching aids and learning media that can effectively represent three-dimensional concepts. Students frequently struggle with visualizing and understanding the relationships between various geometric elements in three-dimensional space. This often leads to a lack of deep understanding and ongoing conceptual errors, affecting the students' ability to solve problems related to solid geometry.

An alternative solution that can address these issues is the use of Augmented Reality (AR) media. AR can play a crucial role with its ability to merge virtual objects into the real world (Saputra et al., 2020), allowing students to see and interact with three-dimensional representations of geometric shapes directly. Several studies have also shown that AR media can assist students in understanding the concepts of solid geometry (Adrian et al., 2020; Baalwi, 2023). Additionally, AR media can make it easier for teachers to display real-life examples of geometric shapes (Mursyidah & Saputra, 2022).

The novelty of this research lies in the development of content and AR applications specifically designed for the topic of solid geometry at the junior high school level, an area that has not been extensively explored using AR media, as previous studies focused on elementary school solid geometry material. This research does not only focus on using AR as a visualization tool but also integrates pedagogical approaches that support active and collaborative learning. The development of AR-based learning media for solid geometry not only supports visual and kinesthetic learning but also helps students build better spatial understanding, which is a critical component in learning mathematics. By leveraging AR, learning can become more engaging and motivate students to be active in the learning process, while enhancing their understanding of complex and abstract concepts.

Based on the description above, it seems necessary to conduct research on the development of augmented reality-based learning media for solid geometry materials. The aim of this research is to create augmented reality media for solid geometry materials at the Junior High School level that are highly suitable for use in the learning process.

RESEARCH METHOD

This research falls under the Research and Development (R&D) category using the 4D development model. This model comprises the stages of Define, Design, Development, and Disseminate. The first stage, Define, is conducted to establish and define the development requirements. The second stage, Design, involves the process of designing the learning media, illustrated using flowcharts and interface design. The third stage, Development, produces the development product through three validations: media expert validation, subject matter expert validation, and trials by learners. The fourth stage, Disseminate, is the final stage of application development used to distribute the developed product so that it is accepted by users (individuals or groups). Details of the 4D development model stages are presented in Figure 1.

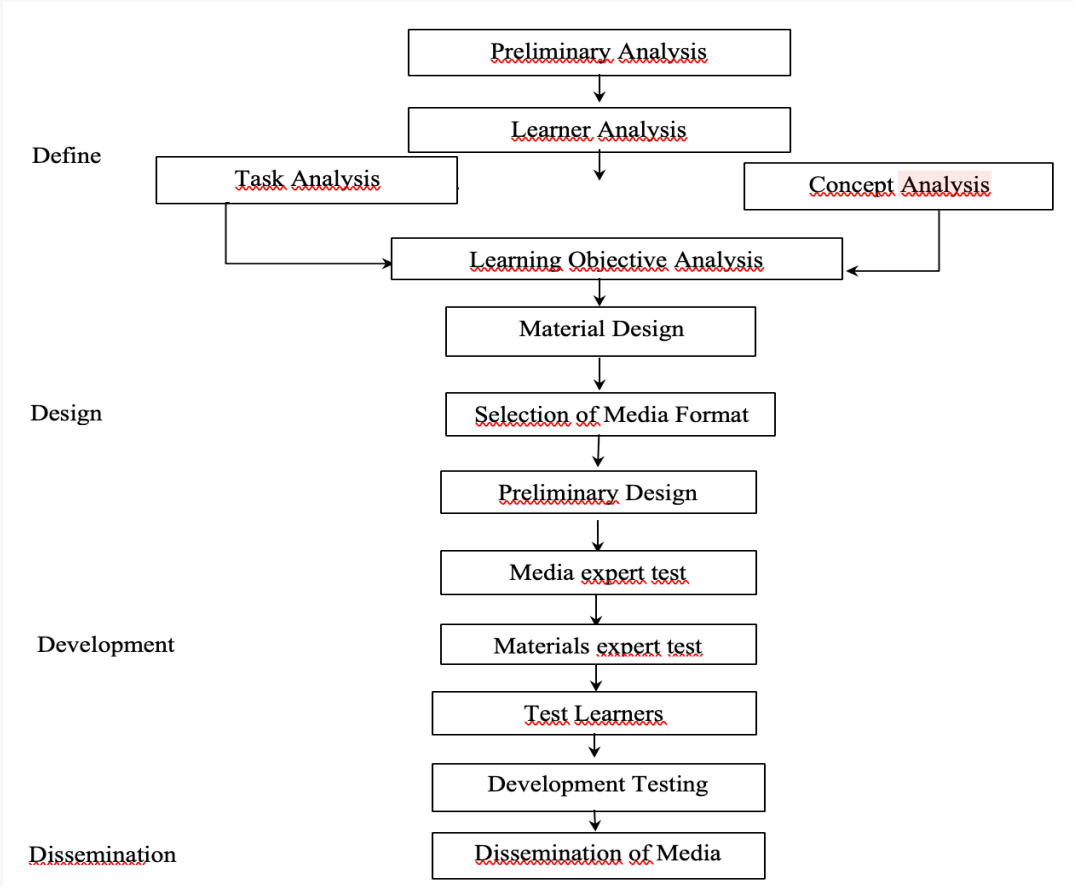


Figure 1. 4D Development Model (Mulyatiningsih, 2019)

This study employs data collection techniques such as interviews, observations, questionnaire distribution, and documentation. The data is analyzed using a Likert scale. The calculation of the feasibility percentage for the augmented reality media uses the following formula:

$$Feasibility\ Percentage(\%) = \frac{Total\ Score\ Obtained}{Maximum\ Possible\ Score} X\ 100\%$$

The processed data is interpreted using a feasibility percentage scale, which is presented in Table 1.

Table 1. Feasibility Percentage Scale

Presentase	Kriteria
76% - 100%	Highly feasible/excellent
51% - 75%	Feasible/good
26% - 50%	Moderately feasible/moderately good
0% - 25%	Not feasible/poor

Source: Modified (Fatasya et al., 2023)

RESULT AND DISCUSSION

The results of this research are detailed according to the following stages of the 4D model:

Define

This stage began with initial analysis activities to identify problems in mathematics lessons. From interviews conducted with mathematics teachers, it was found that the introduction to solid geometric shapes still relied on traditional methods using blackboards, books, and recycled materials like cardboard. The use of Android-based learning media had not yet been implemented in classroom activities.

The analysis phase continued with a student analysis, which was conducted using a questionnaire. The results of this analysis showed that augmented reality media had not been used in the learning process at the school. Until now, students had primarily used smartphones for social media, online chatting, and playing games.

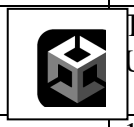
The researchers also conducted a task analysis, where it was found that students need to master basic competencies in solid geometry. A concept analysis was performed to determine the materials to be organized within the augmented reality media. Based on this analysis, the materials developed included the introduction of solid shapes such as cubes, rectangular prisms, prisms, pyramids, cylinders, cones, and spheres. The final analysis in this stage was the analysis of learning objectives. The learning objectives according to this material are for students to understand and enhance the method of drawing solid shapes.

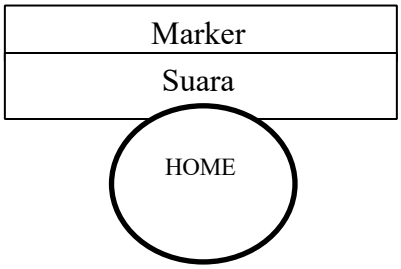
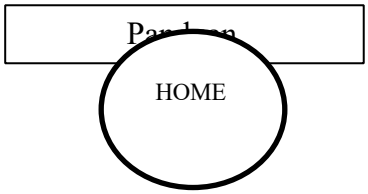
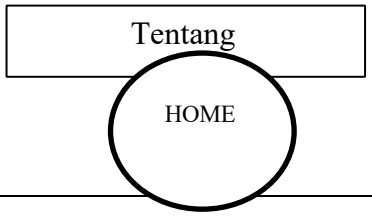
Design

During the design stage, the researcher will begin by drafting the application in the form of a storyboard and designing the menu structure. This stage involves

analyzing the 3D images that will be developed and displayed in the form of solid geometry. The initial design of the application is presented in Table 2.

Table 2. Augmented Reality Media Storyboard

No.	Design	Description
1		The initial display shows the Unity logo
2	AUGMENTED REALITY BOOK BANGUN RUANG AR Bangun Ruang Panduan Tentang Keluar	1. The splash screen storyboard. The initial view of this augmented reality application features the default display of the Unity 3D logo accompanied by the main design created by the researcher. 2. Main menu: The main page includes options for, "AR Bangun Ruang", "Panduan", "Tentang", "Keluar".
3	Kubus Balok Limas Prisma Tabung Bola Kerucut HOME	The AR solid geometry display features various types of solid shapes.

4		The marker displays the solid geometry object that can be scanned by the AR camera's marker and can also produce sound.
5		"Panduan" in the Unity application interface provides information on how to use the application.
6		In the "Tentang" section, information regarding the background and purpose of the application's creation can be provided.

Development

This stage involves the implementation of the design into the form of an augmented reality media application. When the application is clicked, it will display the Unity logo on the augmented reality application, and thereafter, the user will be directed to the main menu page as shown in Figure 2.

Figure 2. Main Menu Display

The main menu display features an orange color that can provide joy and impression, accompanied by a yellow color that can attract students' attention (Rengganis, 2017). This color combination/mixture can spark students' interest in learning and can enhance their learning outcomes (Fauzi, 2021). In Figure 2, there is a view of the running application, which contains menu buttons that function to facilitate user access to the next menu. The main menu includes buttons for AR Solid Geometry, Guide, About, and Exit. The AR Solid Geometry button will direct the user directly to the materials menu page. The Guide button will direct the user directly to the application usage procedure page. The About button leads directly to the about page. The Exit button allows the user to exit the application. If the user wishes to access the material, they must press the AR Solid Geometry button, and the results to be displayed are presented in Figure 3.

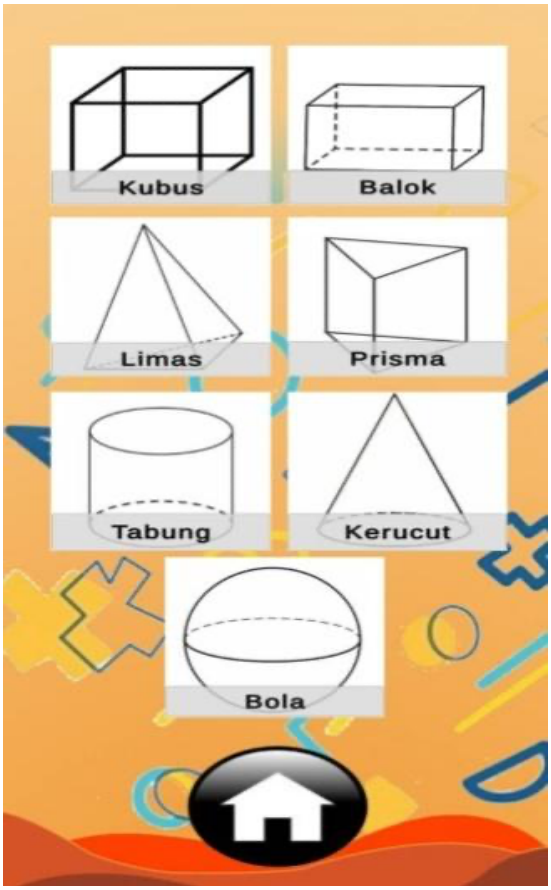


Figure 3. AR Solid Geometry Button Menu (Materials)

In Figure 3, there are buttons for cube, block, prism, pyramid, cylinder, cone, and sphere that contain an AR camera scan on the target image to display the 3D shape. For example, if you want to access the cube material, you would press the cube button and point it at the developed cube marker. The result displayed will show a 3D object

and sound explaining the cube material. The display of the marker scan result is presented in Figure 4.

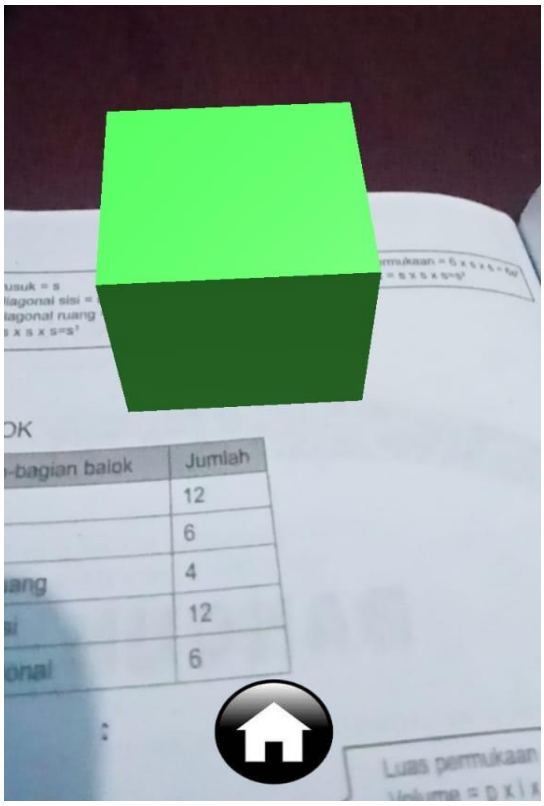


Figure 4. AR Media Camera Scan Results

After the development process of the augmented reality media is completed, the next step is to conduct a material expert validation test. This test is carried out by three mathematics teachers. Based on the results of the validation, an average score of 94.00% was obtained, which is categorized as highly feasible. In detail, the results of the material expert test are presented in Figure 5.

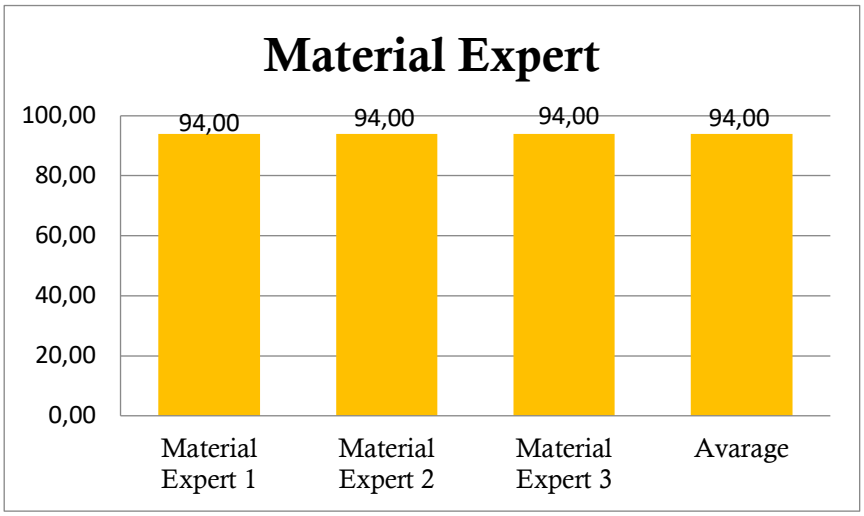


Figure 5. Material Expert Validation Results

Since the material expert validation results are highly feasible, the validation process can continue with media experts. This media expert validation test is conducted by three lecturers from Muhammadiyah University of Kendari. Based on the validation data obtained from the media experts, the average score was 84.67%, which is categorized as highly feasible. The detailed results of the media expert validation are presented in Figure 6.

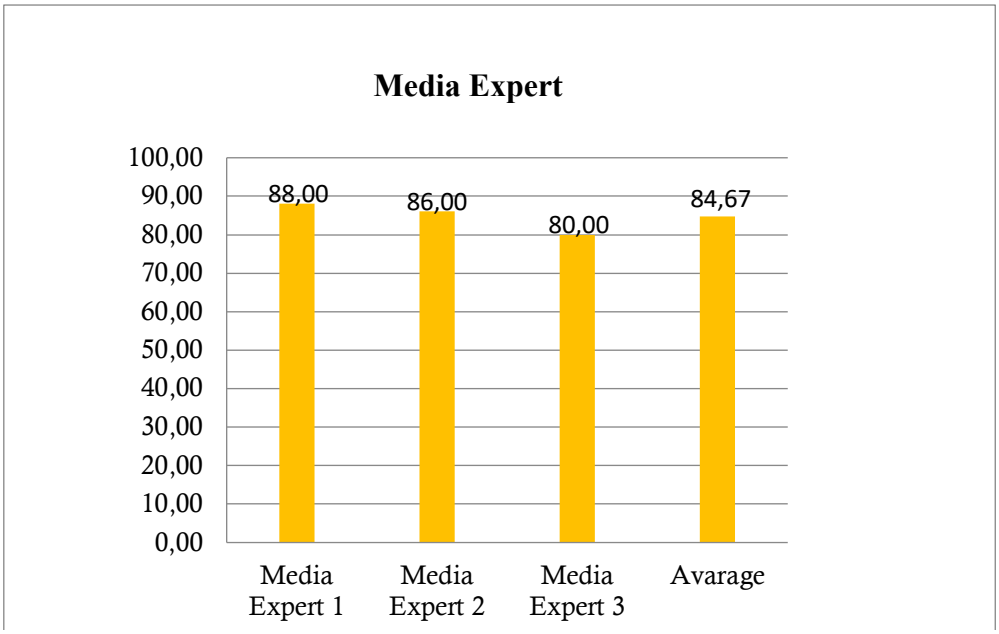


Figure 6. Media Expert Validation Results

After the material and media expert validation results are found to be highly feasible, the validation process is continued with a trial involving students. The

validation was conducted with 20 students, resulting in an average percentage of 83.55%, which is categorized as highly feasible. The results of the student trial validation are presented in Figure 7.

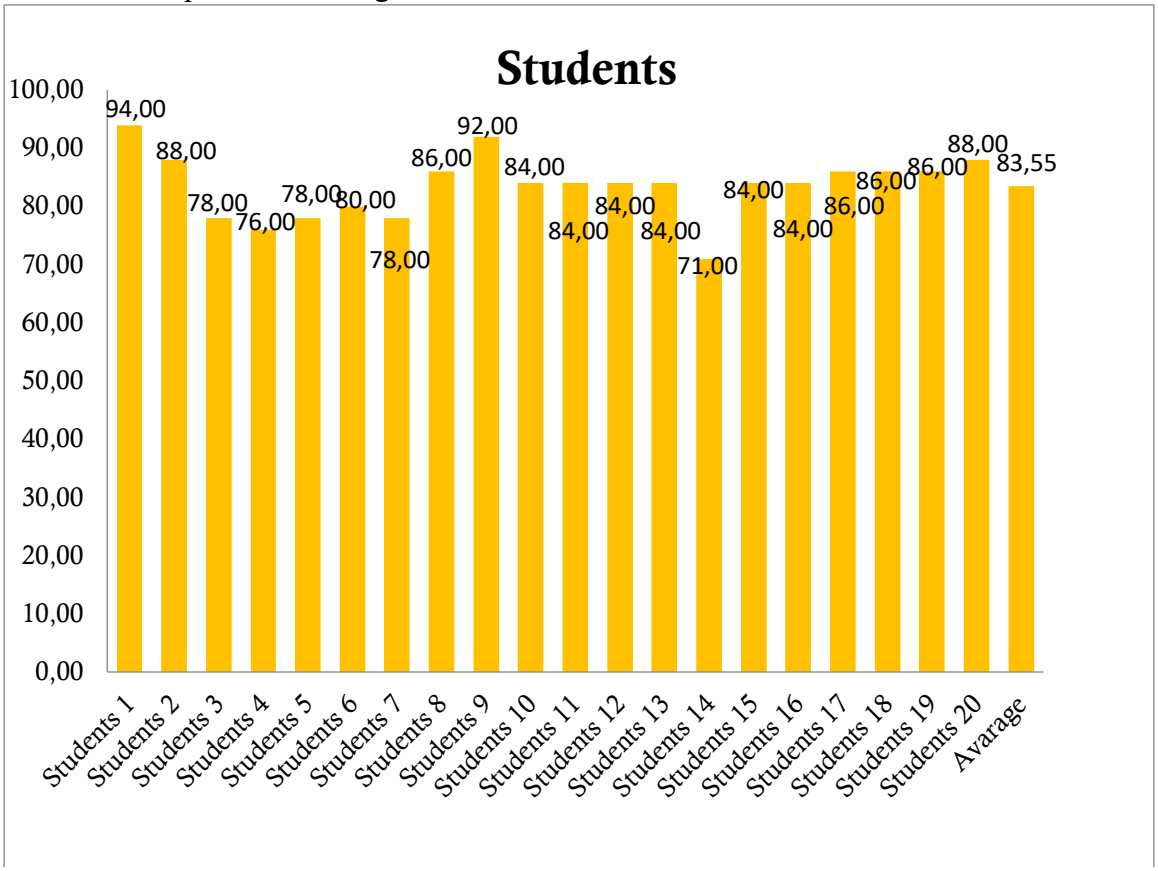


Figure 7. Student Validation Results

Disseminate

During the Disseminate, the product can be widely disseminated and introduced to the public. In this final stage, the distribution of the developed learning media is completed and disseminated to the target audience or students. This stage ensures that the educational tool reaches its intended users, facilitating access to innovative learning methods and potentially enhancing the educational experience. The augmented reality learning media can be accessed through Google Drive at the following link: https://drive.google.com/file/d/1kHNv1QEfTRO2lSG2yizzzCgx5AIv-h1s/view?usp=drive_link

Discussion

This research has successfully developed an Augmented Reality (AR)-based learning media designed for solid geometry materials. The results of the testing conducted show that this learning media is highly feasible for use in teaching mathematics, particularly solid geometry in junior high schools. Students have also

expressed that the use of augmented reality media significantly enhances their understanding of solid geometry concepts. This aligns with previous research findings that demonstrate how AR technology can increase interactivity and understanding of complex materials through deeper visualization (Alves et al., 2019; Krüger et al., 2022).

One important aspect revealed in this study is the improvement in students' ability to visualize solid shapes in three dimensions. Students reported that interacting with virtual objects displayed through AR made it easier for them to understand the concepts and relationships within the studied solid shapes. Research by (Abdinejad et al., 2020; Ramadhanti et al., 2021) also supports this finding, showing that 3D visualization through AR helps students develop better spatial understanding.

Visualization through AR provides manipulable representations of mathematical objects, offering students ways to rotate, zoom in on, and explore solid shapes in ways that are impossible with two-dimensional images (Arifin et al., 2020). This advantage creates a space for more intuitive and detailed understanding of geometry and spatial structures, which are key components in solid geometry materials.

Moreover, the use of AR in teaching solid geometry also provides a more enjoyable and motivational learning experience. This aligns with research findings (Hidayat & Asmalah, 2022; Kaur et al., 2020; Schultz & Kumar, 2024) that augmented reality in educational activities shows higher learning motivation, reduced math anxiety, enhanced learning motivation, and provides good visualization. Through AR media, students are not just passive recipients of information but also active participants in the process of constructing their own knowledge (Nurhidayanti et al., 2022).

CONCLUSION

The results of this study indicate that augmented reality media for solid geometry is highly suitable to be used as a learning medium. These findings are based on the results of material expert tests with an average percentage of 94.00%, learning media experts with an average percentage of 84.67%, and student trials with an average percentage of 83.55%. Information provided by students states that the use of augmented reality media has a significant impact on improving their understanding of solid geometry concepts. The use of augmented reality media in teaching solid geometry also provides a more enjoyable and motivational learning experience.

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