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DEVELOPMENT OF AUGMENTED REALITY-BASED LEARNING FOR FLAT-SIDED SPACE BUILDING MATERIALS

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ABSTRACT

Nowadays, technology is developing rapidly. Augmented reality is one of the technologies frequently used in the learning process. Augmented reality-based learning aims to improve mathematical reasoning skills by providing exciting and appropriate learning media. This study aims to develop mathematics learning media for flat-sided spatial geometry material based on augmented reality that can be tested on SMPN 16 Tangerang City grade VII students. This research uses the ADDIE development model, which includes analysis, design, development, implementation, and evaluation. The research data includes both qualitative and quantitative data. The instruments used are media validity expert assessments, media practitioner assessments, and respondent responses. The study results showed a significant increase in student's knowledge and skills during the learning process of mathematics on cube and cuboid materials based on augmented reality in grade VII students of SMPN 16 Tangerang City. This is indicated by the expert assessment results, which rated it as "valid," the media expert assessment results, which rated it as "very practical," and the respondents' answers, which were categorized as "moderate." Students' knowledge and skills increased significantly due to the application of augmented reality-based mathematics learning on cubes and cuboids.

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INTRODUCTION

Education is a basic need for every human being. As stated by Hamdan & Juwita (2020). Education can have a major impact on improving the quality of a country and building a reflection of a country's education. Education can be interpreted as a step for students to realize independent life in social contexts. (Nurasiah et al., 2022). The competencies that students can achieve at school include the ability to think logically, analytically, critically, carefully, responsibly, and responsively, and the ability to always try to solve problems (Kemendikbud, 2016).

Based on this, students encounter various problems, including difficulties in understanding learning material, including spatial geometry. According to Chotimah et al.,(2018), students generally show unsatisfactory results in solving problems related to flat-sided spatial geometry, with only 21% able to solve the problems, classifying the proficiency as low.

Internal or external factors can influence the level of student success in problem-solving. According to Slameto (2009) in Selvia et al., (2021) Internal factors include motivation, concentration, learning message processing, and storing learning outcomes. External factors include the learning environment, family members, and economic conditions. According to Parni et al., (2019), internal factors in student education include physiological, psychological, maturity, readiness, talent, and physical health. External factors encompass social environmental factors, such as teachers, administration, friends, family, and societal influences, and instrumental factors, such as infrastructure supporting education, arts, worship, sports, and technology spaces students use for learning.

Students also require appropriate teaching materials in the teaching and learning process. According to Sungkono et al., (2022). Effective learning media are educational tools that connect material with students, making learning activities more efficient and effective. Nur et al., (2023) Suggests that learning media can be enhanced using augmented reality technology by analyzing and capturing the appearance of virtual objects, providing students with a three-dimensional visualization of the material. Three-dimensional media use concrete objects in the learning process, making it easier for students to master abstract mathematical concepts. Teachers can effectively utilize various forms of concrete tools in spatial learning to share roles with these media (Israwati,2023).

Augmented reality (AR) is a virtual reality technology that can be integrated into the real world through a camera. AR has been widely developed to create learning materials specifically designed for use on smartphones (Suganda & Fahmi, 2020). Augmented reality technology can visualize material in three dimensions according to the learning material needed. Using augmented reality can help students understand learning materials more effectively. This is supported by research byNur et al., (2023) This found that learning media utilizing augmented reality based on the MLDC (Multimedia Development Life Cycle) software application can improve understanding and calculation of flat-sided spaces. This research involved designing and developing augmented reality-based mathematics learning media for flat-sided spatial geometry on a paper-shaped background.

Flat-sided spaces include three dimensions with height and width, formed with sides or facets known as surfaces (Alyusfitri et al., 2020). Each type of flat-sided space has a unique shape, volume, and area formula. Many students lose interest in learning about flat-sided spaces because they find it difficult and are unsure of the exact shape of each flat-sided space (Amatullah & AB, 2021).

Research by Khoirunnisa et al., (2020), found that students at SMP Taman Siswa Malang have difficulties with various applications related to the shape and solution of volume and surface area problems in flat-sided spaces. Similarly, research by Nursyamsiah et al., (2020) showed that students struggle to understand the net, elements, and properties and solve problems related to flat-sided spaces. Additionally, Syafi'ah et al., (2022). Students at SMP Negeri 11 Samarinda have difficulty determining the elements of flat-sided spaces, such as nets. Based on this research, traditional learning methods for flat-sided spaces are less likely to yield positive results. However, using augmented reality can enhance the learning process for flat-sided spaces. Researchers Umri et al., (2023) It was shown that utilizing augmented reality in the learning process improved student understanding, as evidenced by a significant difference between the average pretest score (49.68) and the average posttest score (74.84). Researchers Al Ikhsan et al., (2022), found that augmented reality as a learning medium for flat-sided space building piqued students' interest.

Therefore, developing augmented reality-based learning media for flat-sided space building materials is necessary. This research aims to design and develop augmented reality-based mathematics learning media for flat-sided space-building materials, which will be tested

on SMPN 16 Tangerang City grade VII students.

METHOD

This research follows the ADDIE development model. The stages in the ADDIE model are analysis, design, development, implementation, and evaluation. According to Hidayat & Nizar (2021) Using the ADDIE development model provides a systematic instructional design centered on individual learning. This research was conducted from November 2023 to January 2024 at SMPN 16 Tangerang City, with the subjects consisting of 8th-grade students: 9 students for a small-scale test and 40 students for a large-scale test.

The research focused on developing augmented reality-based teaching materials using the ADDIE model for flat-sided cubes and blocks. The stages in the ADDIE model are as follows: 1) Analysis Stage: The first stage involves analyzing needs, materials, technology, and the situation at SMPN 16 Tangerang City. Researchers identify problems to use as a reference in developing augmented reality learning media for flat-sided building materials. For example, many students do not understand the material using traditional media. This stage explains the problem analysis and the solution by developing augmented reality learning media; 2) The Design stage involves designing learning media based on augmented reality; 3. Development stage: This stage shows the process of implementing the design created in the previous stage. Development is carried out using Unity 3D 2022 software and is adapted to the school curriculum; 4) Implementation stage: This involves testing the augmented reality-based learning media with 8th-grade students, with ten students in a small-scale test and 40 students in a large-scale test at SMPN 16 Tangerang City; 5) Evaluation stage: This involves assessing the learning media based on reviews by media experts, practitioners, and student responses to determine the feasibility of the developed augmented reality learning media.

Research data include findings from media experts, material experts, and students. Qualitative data are obtained from suggestions for improvements to the augmented reality-based learning media provided by several experts and practitioners. Quantitative data are obtained from questionnaires and tests assessing students' practical use of the media and their test results before and after using augmented reality. The research instrument includes a questionnaire with the following components:

Media Validity Expert Assessment Questionnaire

The Media Validity Expert Assessment Questionnaire includes the following aspects: 1)

Learning Aspects (Interactivity, Motivation to learn, Expected functions, Ease of understanding); 2) Media Aspects (Efficiency of media use in terms of time, Program reliability, Usability, and Compatibility; 3) Design Aspects: Detail of the AR media attractiveness of the AR media display, balance (size of the AR display presented), and user interface (UI) that is easy for users to understand; 4) Conclusion**:** whether it is worth using or not.

The score is determined using a 5-point Likert scale: 5 (Very Good), 4 (Good), 3 (Quite Good), 2 (Less Good), and 1 (Very Less Good).

Media Practitioner Expert Assessment Questionnaire

The Media Practitioner Expert Assessment Questionnaire includes the following questions: The media is an innovation as a learning medium, the learning media used is relevant to the material presented, The title of the learning media is under the material presented, Illustrations on the learning media are easy to understand, Learning media makes learning more engaging, The learning media used can clarify the material, Learning media can be used anytime Learning media can be used anywhere, Students can learn independently with this media, Learning media makes it easier for teachers to deliver material, Learning media makes it easier for students to learn, Students can use learning media independently, Learning media arouses students' curiosity.

The questions are scored using a Likert scale: Score 1 = Not Good, Score 2 = Less Good, Score 3 = Quite Good, Score 4 = Good, Score 5 = Very Good.

Student Response Questionnaire

The questionnaire for students gathers their opinions after using the media, using a Likert scale with the following scores: Score 1 (Strongly Disagree), Score 2 (Disagree), Score 3 (Neutral), Score 4 (Agree), Score 5 (Strongly Agree).

The analysis method for calculating the assessment questionnaires is as follows:

Development Analysis of Media Validity Test

According to Sukma et al., (2022) the data on the results of media validation consist of assessments by material experts and media experts obtained from a questionnaire to determine the quality or level of media validity. A Likert scale is used in the form of 5 scales: 5 (Very Good), 4 (Good), 3 (Quite Good), 2 (Less Good), and 1 (Very Less Good). The data obtained is then used to calculate the percentage of the

assessment results using the formula provided by Arifin et al., 2020

$$\overline{X} = \frac{fr}{n} \times 100\%$$

Description:

$\overline{X}$ = Average Score

fr = Frequency of Answers

N = Number of Respondents

The results obtained will be converted into qualitative data with the Likert scale presented in table 1.

Table 1. Qualitative Criteria With Likert Scale (Arifin et al.,2020)

Scale	Interval Persentase	Category
5	91% - 100%	Very Valid
4	81% - 90%	Valid
3	71% - 80%	Moderately Valid
2	61% - 70%	Less Valid
1	0% -60%	Not Valid

Media Practicality Test Development Analysis

Data obtained from student questionnaire results which are then compiled. The results of the preparation are then found using a percentage of the formula, among others: (Indahwati & Abdullah :2019)

$$Percentage\ of\ Practicality\ Level = \frac{Obtained\ Score}{Maximum\ score} \times 100\ \%$$

After obtaining the results of the practicality of the media, the value is categorized in Table 2.

Table 2. Criteria for Media Practicality Test Results, Budiyono (2020:141)

Interval Persentase	Category
$80 \leq V < 100$	Very Practical
$60 \leq V < 80$	Practical
$40 \leq V < 60$	Practical Enough
$20 \leq V < 40$	Less Practical
$0 \leq V < 20$	Not Practical

Learner Response Development Analysis

The results of students' responses are obtained after students use the media. The value is obtained from the student questionnaire results, which are then compiled. The results of the preparation are then found in a percentage using the formula, among others (Indahwati & Abdullah, 2019)

$$Percentage\ Value\ (N) = \frac{Obtained\ Score}{Maximum\ score} \times 100\ \%$$

After obtaining the learning test results using the media, the values are categorized in Table 3.

Table 3. Qualification Criteria for Learning Test Results Using Media (Sukmawati & Purbaningrum: 2021)

Interval Persentase	Category
80 < N < 100	High
60 < N ≤ 79	Medium
0 ≤ N ≤ 60	Low

RESULT AND DISCUSSION

The research aims to design and develop learning media for mathematics using augmented reality to teach the concepts of cubes and blocks. Participants in this research include media and material experts, specifically media experts from the Department of Mathematics Education at Muhammadiyah Tangerang University and teachers from the Department of Mathematics Education at SMPN 16 Tangerang City. Additionally, grade VII students were involved as research subjects.

Media Expert Questionnaire Assessment

Media experts play a crucial role in evaluating the media components using a Google Form, aiming to assess the validity of these components. The assessment data from this Google Form will be represented on a 5-point scale. The questionnaire prepared for media experts includes 12 questions focusing on various aspects: Learning Aspects (Interactivity, Motivation to learn, Expected functions, Ease of understanding); Media Aspects (Efficiency of media use in terms of time, Program reliability, Usability, Compatibility; Design Aspects (The AR media display is quite detailed, The AR media display is attractive, Balance (size of the AR display presented), User Interface (UI) that is easy for users to understand; Conclusion

whether it is worth using or not.

The responses are measured using a Likert scale with the following ratings 5 (Very Good), 4 (Good), 3 (Quite Good), 2 (Less Good), 1 (Very Less Good). The results of the media expert questionnaire assessment are presented in Table 4.

Table 4. Media Validity Test Results (Maulana et al :2020)

Category	Media Expert Assessment		Total score	Maximum Score
	I	II		
Learning Aspect	18	20	38	40
Media Aspect	15	17	32	40
Design Aspect	17	16	33	40
Total			103	120
Category			Valid	

Based on Table 4, the media expert assessment for learning mathematics of cubes and flat-sided blocks using augmented reality obtained the following results: in the learning aspect, according to the first Media Expert Assessment, has a total score of 18, while according to the second Media Expert Assessment, it gets a score of 20, so the total score in the Learning Aspect is 38. Next is the media aspect; according to the first Media Expert Assessment, it has a total score of 15, while according to the second Media Expert Assessment, it gets a score of 17, so the total score in the media Aspect is 32. The third aspect is the design aspect; according to the first Media Expert Assessment, it has a total score of 17, while according to the second Media Expert Assessment, it gets a score of 16, so the total score in the Design Aspect is 33.

The overall results of the media expert assessment for the augmented reality-based learning of mathematics of cubes and flat-sided blocks amounted to a total score of 120 from the 12 questionnaire questions. The Media Expert Assessment Questionnaire evaluates the following aspects: Learning Aspects (Interactivity, Learning motivation, Expected functions, Ease of understanding). Next is the Media Aspect (Efficiency of media use in terms of time, Program reliability, Usability, and Compatibility. The Design Aspect (AR media display is quite detailed, the AR media display is attractive, the Balance (size of AR display presented), the User Interface (UI) is easy for users to understand, and the Conclusion whether it is worth using or not. The scores are determined using a Likert scale with the following ratings 5 (Very Good), 4 (Good), 3 (Quite Good), 2 (Less Good), 1 (Very Less Good).

These results indicate that the media is categorized as very valid. When calculated

as a percentage, the media validation score is 103, placing it in the "Valid" category for augmented reality-based learning assessments by media experts.

Assessment of Media Practicality Expert Questionnaire

Material experts are crucial in assessing the material components using a Google Form to determine their validity. The assessment data from this Google Form are represented on a 5-point scale. The questionnaire for the practitioner expert consists of 12 questions. The results of the assessment based on expert practitioners can be found in Table 5:

Table 5. Media Practicality Test Results

Category	Category
Score obtained	53
Total Percentage	83%
Category	Very Practical

The Table 5 shows that in the validation of the material, it can be seen that the Technical, Content, Design aspects of learning flat-sided spatial structures based on augmented reality have a score of 53, this is obtained through a questionnaire in the form of a form given as many as 12 questions using a Likert scale Score 1 = Not Good, Score 2 = Less Good, Score 3 = Quite Good, Score 4 = Good, Score 5 = Very Good, with the following questions The media is a new innovation as a learning media, (Learning media used is relevant to the material presented, The title of the learning media is in accordance with the material presented, Illustrations on the learning media are easy to understand, Learning media makes learning more interesting, The learning media used can clarify the material, Learning media can be used anytime Learning media can be used anywhere, Students can learn independently with this media, Learning media makes it easier for teachers to deliver material, Learning media makes it easier for students to learn, Students can use learning media independently, Learning media arouses students' curiosity). Based on the question, a score of 53 was obtained, then looking for a percentage by :

$$Percentage\ of\ Practicality\ Level = \frac{Obtained\ Score}{Maximum\ score} \times 100\ \%$$

Then getting an average result of 83% which shows that the material is complete and in accordance with the learning indicators. So that means that learning mathematics of flat-sided spatial structures based on augmented reality is categorized as "Very Practical" for the learning process.

Learner Response Questionnaire

The analysis of student validity data was conducted by distributing questionnaires to 8th-grade students. This questionnaire contained 28 questions with moderate categories. The questionnaire aimed to gather students' opinions after using the media, using a Likert scale with the following ratings: Score 1 (Strongly Disagree), Score 2 (Disagree), Score 3 (Enough), Score 4 (Agree), Score 5 (Strongly Agree). The learning test results are presented in Table 6.

Table 6. Learning Test Results Using Media

Category	Category
Score obtained	129
Total Percentage	65%
Category	Medium

The table above shows that the score obtained is 129 from 28 questions with moderate categories. The questionnaire for students gathered their opinions after using the media, using a Likert scale with the following ratings: Score 1 (Strongly Disagree), Score 2 (Disagree), Score 3 (Enough), Score 4 (Agree), Score 5 (Strongly Agree) The percentage was obtained by dividing the total score of 129 by the total weight of the values and then multiplying by 100%. This resulted in a percentage of 65%, which falls into the moderate category. Based on the study's data, gathered through questionnaires distributed to media experts, practitioners, and students, the results meet the validity standards with a $60 \leq V < 80$ scale.

According to Figure 1 (Building a Space Cube using Unity) and Figure 2 (Building a Space Cube using Unity), these tools encourage students to easily understand the shapes of flat-sided spaces and cubes. The data shows a score of 65%, placing it in the moderate category. The results from the distributed questionnaires meet the validity standards with a scale of $60 \leq V < 80$, supporting the idea that using Unity for building space cubes helps students grasp the concepts of flat-sided space blocks and cubes more effectively.

Figure 1. Build a cube using unity

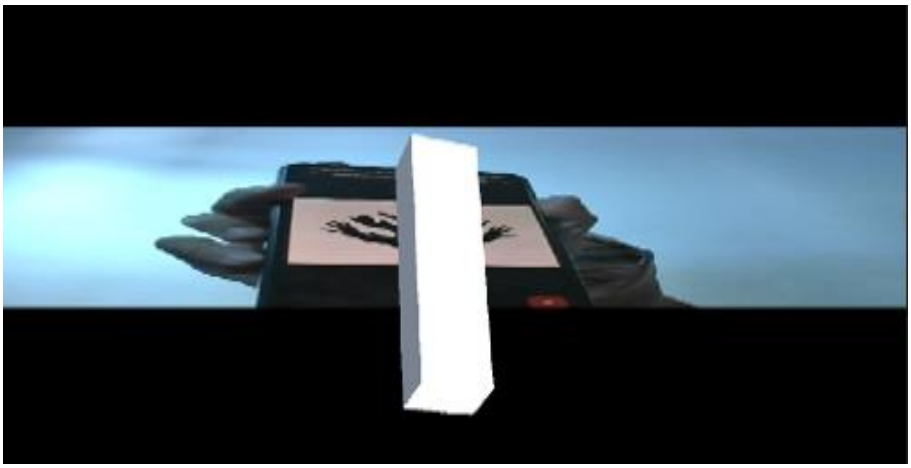

Figure 2. Building block space using unity

CONCLUSION

This research was conducted by designing and developing flat-sided spatial mathematics learning media based on augmented reality on a paper-shaped background. The media was then tested, and it was concluded that the augmented reality-based learning media for cubes and blocks met the validity standards. Thus, it can be stated that the augmented reality-based mathematics learning media created was valid, as assessed by expert practitioners and media experts. This learning media can be implemented effectively. This is evidenced by a significant increase in the knowledge and skills of grade VII students at SMPN 16 Kota Tangerang after using the augmented reality-based learning media. This indicates that the application of augmented reality in teaching cubes and flat-sided blocks can effectively improve students' knowledge and skills and can achieve learning objectives.

Based on observations during the augmented reality-based learning process using the Unity application, there were noticeable differences in student knowledge and skills. This suggests that developing augmented reality-based media using the Unity application positively impacts student knowledge and skills. This aligns with the learning objectives, showing that teaching cubes and flat-sided blocks with augmented reality using the Unity application greatly improves student knowledge and mathematics skills for grade VII students at SMPN 16 Kota Tangerang. This finding supports the conclusion that augmented reality-based learning media for cubes and flat-sided blocks is valid and feasible for application in the learning process, as it enhances student learning outcomes.

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