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Development of mathematics learning media based on Augmented Reality (AR) applications on cube material for junior high school students

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Abstract. *Mathematics is still considered a complex and tedious subject in school. The use of Augmented Reality (AR) technology in mathematics learning for junior high school students offers an innovative approach to improving understanding of abstract concepts. This study aims to develop learning media for cube material in junior high schools using Augmented Reality (AR) technology. The development method uses the Research and Development (R&D) model with a 4D model (Define, Design, Develop, and Disseminate). Data was collected through questionnaires and interviews and analyzed quantitatively and qualitatively. The validation process for the developed product was conducted by material and language experts, as well as media experts. Subsequently, small-scale and large-scale product trials were conducted with teachers and students at junior high schools in Jakarta. The test results showed an average overall rating of 92.46%. This means the AR product developed for cube material meets the criteria for being highly suitable as an alternative learning resource for junior high schools. The use of AR media can visualize three-dimensional geometric objects, making it easier for students to understand spatial and shape concepts.*

Keywords: *Augmented Reality, mathematics, learning media, cube, junior high schools*

1. Introduction

Mathematics learning, especially geometry, can be challenging for students due to its abstract nature (Wijayanti et al., 2025). Low understanding of mathematical concepts and problem-solving can be addressed by designing creative digital learning (Benavides-Varela et al., 2020). One of the technologies that offers an innovative approach to improving the understanding of abstract concepts is Augmented Reality (AR) technology (Hillmayr et al., 2020; Jessica et al., 2023). AR technology can effectively enhance students' understanding of complex mathematical concepts by displaying 3D virtual objects over real environments, describing abstract geometric concepts in concrete terms, and providing interactive experiences (Bulut & Borromeo Ferri, 2023; Cai et al., 2020; Cai et al., 2019; İslim et al., 2024; Liu et al., 2019; mohamed, 2025). In Indonesia, cubes are included in the mathematics curriculum for 8th-grade students in Junior High School (SMP). Previous studies have shown that the use of AR can help increase students' interest and understanding in learning abstract subjects such as mathematics (del Cerro Velázquez & Morales Méndez, 2021; Schutera et al., 2021). AR technology can also make learning more interactive and engaging, which helps in maintaining students' interest and motivation in mathematics (Cai et al., 2020; Cai et al., 2019; Liu et al., 2019; mohamed, 2025).

The use of Augmented Reality (AR) in mathematics learning has been applied to

various concepts and materials, such as modules with augmented reality (GeomAR3) (Nadzri et al., 2023), spatial construction materials using Android-based marker-tracking methods (Saputri & Sibarani, 2020), and many others. Previous research indicates that AR technology can help increase students' interest and understanding of abstract materials, such as mathematics. The use of AR technology in mathematics teaching can also be an effective tool for improving students' conceptual understanding and spatial skills (del Cerro Velázquez & Morales Méndez, 2021; Schutera et al., 2021). In addition, AR technology offers teachers opportunities to create engaging learning innovations that can foster student motivation, thereby improving student learning outcomes (Nabila et al., 2021), (Abdullah et al., 2022). However, not many have developed AR mathematics applications for 3D shape materials. On the other hand, a survey conducted among teachers and students at a Junior high school in Jakarta indicates a need to develop interactive digital media on spatial figures, such as 3D shapes, especially cubes. Therefore, it is necessary to use innovative and engaging learning media that facilitate students' understanding. This study was conducted to develop learning media for cube material in junior high schools using Augmented Reality (AR) technology (*Math AR cube material*).

2. Method

The development method uses the Research and Development (R&D) model with a 4D model (Define, Design, Develop, and Disseminate). Data was collected through questionnaires and interviews and analyzed quantitatively and qualitatively. The validation process for the developed product was conducted by material and language experts, as well as media experts. The research stages are shown in **Figure 1**.

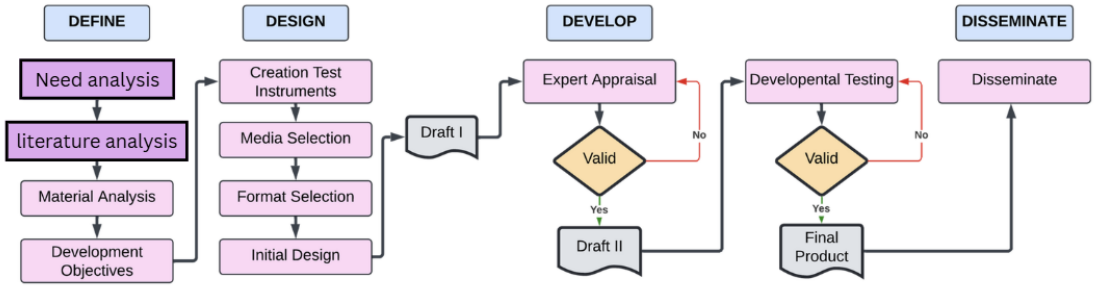

Figure 1. Research flow diagram

The research initially followed a define (1) stage, which included need analysis of the teacher and the student, literature analysis, material analysis, and the development of Objectives. The next stage is design (2), which includes preparing feasibility test instruments, determining the media format, and drafting the initial product. The development of Math AR cube material applications using Unity3D, Blender, and Canva. After the initial product is created, it proceeds to the development (3) stage, which includes expert validation testing and trials with students, as well as the development of the final Product. The last stage is disseminated (4), which includes product distribution.

This study used mixed-methods, concurrent embedded design to collect and analyze data. In this study, quantitative methods were the primary method, and qualitative methods were the secondary method. To obtain primary data, a questionnaire was used.

The questionnaire used in the expert test and trial test with teachers and students in small and large groups was analyzed using a Likert scale (Sugiyono, 2015), as shown in **Table 1**. Responses to each item on the Likert scale instrument had a maximum score of 5 and a minimum score of 1.

Table 1. Likert Scale

Answer Assessment Score	Information
5	Strongly agree
4	Agree
3	Doubtful
2	Don't agree
1	Strongly Disagree

Data obtained by transforming quantitative data into qualitative data is used to assess the feasibility of the Math AR cube material product. The criteria for the feasibility of the Math AR cube material product are presented in **Table 2**.

Table 2. The AR cube material product Eligibility Interval

Interval	Kategori
$0\% \leq P \leq 20\%$	Very Inadequate
$20\% < P \leq 40\%$	Not Worth It
$40\% < P \leq 60\%$	Decent Enough
$60\% < P \leq 80\%$	Feasible
$80\% < P \leq 100\%$	Very Feasible

The criteria in the table above can be used to determine the suitability of the Math AR cube material product for learning activities. The percentage (P) is calculated based on data obtained from questionnaires distributed using the following formula:

$$P = \frac{The\ score\ obtained}{Maximum\ \ score} \times 100\%$$

3. Results and Discussions

The Math AR cube material applications were developed using Unity3D, Blender, and Canva. The design stage produces prototype I of the product, which then enters the development stage. During the development stage, validation tests are conducted by experts, and product trials are conducted with students and teachers. Prototype I is first validated by experts to ensure it produces a suitable product before being trialed with students and teachers.

The expert validation process is carried out by subject-matter and language experts, as well as media experts, who submit assessment instruments and questionnaires. Validation is conducted by two experts, both lecturers in the Mathematics Education Study Program at Universitas Negeri Jakarta. The results of validation by subject matter and language experts are presented in **Table 3**.

Table 3. Results of Material and Language Validation

Aspect	Validation percentage	Feasibility Assessment
Content suitability	85%	Very Feasible
Completeness	85%	Very Feasible
Presentation	92.86%	Very Feasible
Language suitability	86.67%	Very Feasible

Table 4. Media Validation Results

Aspect	Validation percentage	Feasibility Assessment
Application design	93.75%	Very Feasible
Content	92.8%	Very Feasible
Media	96.7%	Very Feasible

The validation results from subject-matter and language experts averaged 87.38%, which is very acceptable. The results of media expert validation obtained an overall average of 94.4% with very feasible criteria.

The results of the final Math AR cube material product are presented in **Figure 2**. The Math AR application for cube spatial material can be installed on Android-based mobile phones. When you open the AR for the cube spatial material application, the first page will appear as shown in **Figure 2**. In the first menu, there is an AR Camera option to start using this application for learning cube spatial material.

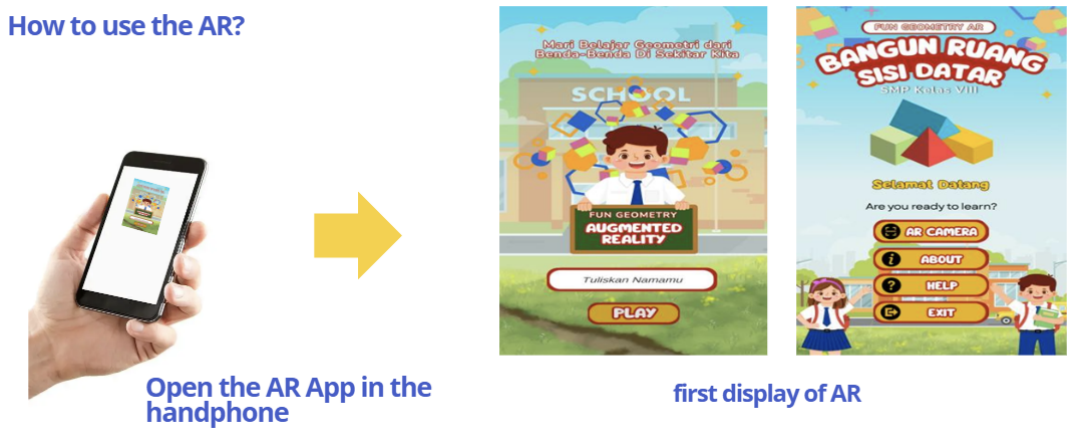

Figure 2. Final product display of the Math AR cube material application and how to use it

After selecting the AR camera menu and pointing the camera at the marker, the spatial material will be displayed in the Android application, including explanations of cubes and quizzes to deepen understanding, as shown in **Figure 3**.

Figure 3. The content of the Math AR cube material application

After validation testing, the product was tested with students and teachers at both small and large scales. The field trial involved teachers and students in grade VIII at Junior High School (SMP) in Jakarta.

The overall results of the testing by experts, students, and teachers are shown in **Table 5.**

Table 5. Overview of Expert Validation and Trial Result for Math AR Cube Material

No	Stage of Research	Evaluation Result (Percentage)	Interpretation
1.	Material and Language Expert Validation	87.38 %	Very Feasible
2.	Media Expert Validation	94.4 %	Very Feasible
3.	Teacher Small Group Trial	87.38 %	Very Feasible
4.	Student Small Group Trial	86.87 %	Very Feasible
5.	Teacher Large Group Trial	99.83 %	Very Feasible
6.	Student Large Group Trial	86.59 %	Very Feasible
Average of Evaluation Result		**92.46 %**	

Table 5 shows the overall average score for the Math AR cube material development stage, which is 92.46%. This means the Math AR cube material is well-suited for use as a digital medium in the learning process for eighth-grade junior high school students. Results from trials conducted in schools using AR cube material show that the AR display is highly engaging and increases student interest. In testing the material coverage, the results show that the cube material coverage in the AR application is complete and adequate. The language used is easy for teachers and students to understand and has been verified by experts. In terms of suitability for students, the Math AR cube material application is designed for 8th-grade students, ensuring student engagement, relevance, and increased motivation.

4. Conclusions

The research and development carried out has resulted in a learning media product that uses Math Augmented Reality (AR) on cube material. The product has gone through several stages of development, namely define, design, develop, and disseminate. The Math AR cube material application received an overall average score of 92.46%. This

means the AR product developed for cube material meets the criteria for being highly suitable as an alternative learning resource for junior high schools. The Math AR cube material application meets the standards for design, scope of content, and language. The use of AR media can visualize three-dimensional geometric objects, making it easier for students to understand spatial and shape concepts. Therefore, the digital module produced is suitable as an alternative learning resource for flat-sided solid figures, especially for cube material. There are several suggestions, namely that further research is needed to test the application's effectiveness. Then, additional interactive features are required, namely interactive exercises that provide immediate feedback and can be used repeatedly.

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