

Learning Media Based on Augmented Reality on Cube Material Class IX Junior High School

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ABSTRAK

Penelitian ini bertujuan untuk menghasilkan media pembelajaran berbasis *augmented reality* pada materi kubus kelas IX SMP yang valid, praktis, dan memiliki efek potensial terhadap hasil belajar siswa kelas IX SMP Nurul Amal Palembang. Adapun jenis penelitian ini yaitu pengembangan dengan menggunakan model ADDIE yang terdiri dari tahap *Analyze, Design, Development, Implementation, dan Evaluation*. Teknik pengumpulan data yang digunakan adalah lembar validasi, angket, wawancara, dan tes. Berdasarkan hasil dari penelitian diperoleh bahwasanya media pembelajaran berbasis *augmented reality* pada materi kubus kelas IX SMP dinyatakan valid oleh validator, diperoleh kepraktisan dari siswa dalam tahap uji coba satu ke satu, uji coba kelompok kecil, dan uji coba lapangan, serta memiliki kepraktisan terhadap hasil belajar siswa setelah menggunakan media pembelajaran yang dikembangkan.

Kata kunci : Media Pembelajaran, *Augmented Reality*, Materi Kubus

ABSTRACT

This research aims to produce augmented reality-based learning media on class IX SMP cube material that is valid, practical, and has a potential effect on the learning outcomes of class IX students at Nurul Amal Middle School, Palembang. This type of research is development using the ADDIE model which consists of the *Analyze, Design, Development, Implementation and Evaluation* stages. The data collection techniques used were validation sheets, questionnaires, interviews and tests. Based on the results of the research, it was found that augmented reality-based learning media in class IX SMP cube material was declared valid by the validator, it was practical for students in the one-to-one trial stage, small group trials and field trials, and had practicality for learning outcomes of students after using the learning media developed.

Keywords : *Learning Media, Augmented Reality, Cube Material*

PENDAHULUAN

The acceleration of globalization and digital transformation requires educational institutions to adapt to learning that fosters digital literacy, creativity, collaboration, and 21st-century problem solving. The implementation of the Merdeka Curriculum provides teachers with space to design innovative, technology-based learning experiences, including interactive media that facilitate conceptual understanding and

higher-order thinking skills (Angga et al., 2022). Smart classroom infrastructure and collaborative ecosystems have been shown to support real-time student engagement and inquiry (Tissenbaum, 2019), while systematic instructional design models such as ADDIE help ensure iterative validity, practicality, and effectiveness in media development (Branch, 2010). On the other hand, immersive technologies such as Augmented Reality (AR) offer contextual 3D visualization and immediate feedback—capabilities highly relevant for spatial geometry topics in junior high school (Ibáñez & Delgado-Kloos, 2018; İslim et al., 2024; Palancı & Turan, 2021). Initial findings in the ninth grade at Nurul Amal Junior High School in Palembang indicate that students continue to make mistakes in applying formulas and understanding the concept of cubes; similar difficulties and procedural errors are frequently reported in mathematics topics that demand strong spatial and conceptual reasoning (Jedaus et al., 2019; Maryani & Setiawan, 2021). Therefore, a medium that combines 3D representation, interaction, and structured exercises is needed to improve their understanding.

Several studies demonstrate the potential of AR and immersive technology in STEM and geometry education. Comprehensive reviews report that AR can enhance motivation, spatial reasoning, and learning outcomes when aligned with clear pedagogical goals and assessment (Cevikbas et al., 2023; Erşen & Alp, 2024; Ibáñez & Delgado-Kloos, 2018). In mathematics specifically, AR has supported modelling, function visualization, and spatial skills through interactive 3D representations and markers/objects such as the Merge Cube (Del Cerro Velázquez & Méndez, 2021; Ozcakir & Cakiroglu, 2021; Salinas et al., 2013; Vostinar & Ferienc, 2023). Domestic developments further show the feasibility of Android-based AR media for geometry topics and worksheet integration to strengthen conceptual understanding and engagement (Fahmi & Noviani, 2021; Hakim, 2018; Insani & Firdaus, 2024; Sari & Kismiantini, 2023). Beyond mathematics, AR in science education also indicates positive effects on concept understanding and learner motivation, underscoring its cross-disciplinary potential (Karacan & Akoğlu, 2021; Wahyuni & Pratama, 2024; Yilmaz, 2021). At the ecosystem level, smart classroom infrastructure supports collaboration and data-driven inquiry (Tissenbaum, 2019), and creative/problem-based learning designs have been linked to improved self-regulation—an important complement to AR's interactive affordances (Hidajat, 2023). Related advances in VR/AR for geometric modelling in design and engineering contexts reinforce the value of immersive 3D environments for spatial cognition and transfer (Tretyakova et al., 2019).

Despite initial positive evidence, several gaps remain. First, many studies are still at early development stages or limited trials and do not specifically target misconceptions related to ninth-grade cubes or full integration with Merdeka Curriculum scenarios and assessment practices (Angga et al., 2022; Palancı & Turan, 2021). Second, some works generalize AR benefits in mathematics without employing formative assessment instruments directly linked to spatial geometry competency indicators and robust validation procedures (Akbar, 2013; Ibáñez & Delgado-Kloos, 2018). Third, pedagogical support for teachers and the integration of AR with collaborative activities and data-based feedback have not been sufficiently explored in junior high school contexts (Cevikbas et al., 2023; Tissenbaum, 2019). Fourth, adaptive/personalized designs to address procedural errors—such as incorrectly applying formulas for the area and volume of cubes—have not been a major focus in AR implementations (Del Cerro Velázquez & Méndez, 2021; Ozcakir & Cakiroglu,

2021). Finally, comprehensive validation across iterative research and development cycles (e.g., ADDIE) on the specific topic of cubes remains limited (Branch, 2010; Fahmi & Noviani, 2021; Sari & Kismiantini, 2023).

To address these gaps, this study developed AR learning media on cube geometry for ninth-grade students with the following features: (1) interactive 3D cube models (edges, faces, vertices, and nets) with transformation animations to link concrete and symbolic representations; (2) step-by-step exercises that include instant feedback and adaptive instructions targeting common errors; (3) a collaborative mode and performance panel for teachers to monitor misconceptions and prompt class discussions, aligning with intelligent learning infrastructure and generative activity principles (Cevikbas et al., 2023; Petersen, 2023; Tissenbaum, 2019); (4) integration of standardized formative assessments to support Merdeka Curriculum learning outcomes (Akbar, 2013; Angga et al., 2022); and (5) validation through expert review, practicality testing, and limited effectiveness testing, guided by best practices from AR studies in geometry and mathematics (Angraini, 2024; Kounlaxay, 2021; Lin, 2015; Rohendi, 2020) and iterative design frameworks (Branch, 2010; Ibáñez & Delgado-Kloos, 2018; İslim et al., 2024; Palancı & Turan, 2021).

Based on school observations and research, this study addresses the following research questions:

RQ1: How valid is the content and design of the AR media on the topic of cubes according to subject matter experts and media experts?

RQ2: How practical is the media for teachers and students (ease of use, acceptability, and suitability in the classroom)?

RQ3: How effective is the media in improving students' conceptual understanding and procedural skills in cube material?

RQ4: How do students perceive their motivation and learning engagement when using the media?

METHODS

This study employs a type of development research that aims to develop or produce a product and test it on students. The research was conducted in the odd semester of 2023/2024 through three stages of testing: one-to-one trials, small group trials, and field trials. The one-to-one trial stage involved three students with high, medium, and low ability levels. The small group trial involved nine students, also representing high, medium, and low ability levels, while the field trial involved 22 students.

The product developed in this study is an Augmented Reality-Based Learning Media that focuses on Cube material. The method used in the development is the ADDIE model. There are five stages in development according (Branch, 2010) as follows:

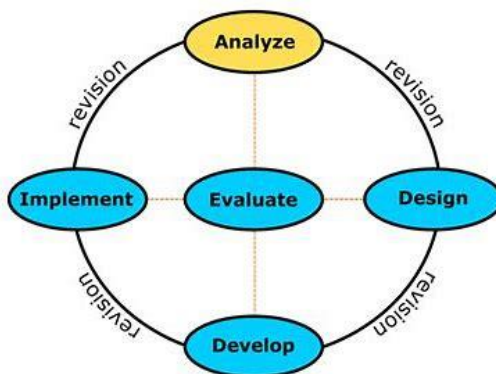


Figure 1. ADDIE model development flow

This research was conducted operationally using the ADDIE model as follows: in the **Analyze** stage, researchers identified students' learning needs on the topic of cubes through classroom and learning environment observations, device (gadgets/connections) audits, questionnaires on digital learning habits and difficulties in understanding spatial concepts, and structured interviews with mathematics teachers. Then the “Cube” material was mapped (sides-edges-vertices, nets, surface area, volume, units) along with common misconceptions (e.g., incorrect substitution of formulas, incorrect calculation of side area), then the CP and TP of the Merdeka Curriculum were derived into operational indicators and mastery criteria, as well as a formative assessment item design.

In the **Design** stage, researchers designed the learning flow (pre-core-post), interaction flowcharts, and storyboards for each screen/scene displaying 3D cube models, nets, open-close animations, and gradual exercises with instant feedback. text, visual, and audio narrative content was compiled along with navigation/gestures; at the same time, evaluation instruments were prepared, including subject matter/media expert validation sheets, implementation observation sheets, teacher/student practicality questionnaires, and learning outcome tests (pre-test–post-test) along with rubrics and decision criteria (valid, practical, effective).

In the **Development** stage, the design was developed into a functional AR prototype (3D objects, interactions, tiered question bank, adaptive feedback), then validated in two rounds by subject matter experts (concept suitability with CP/TP) and media experts (display, navigation, accessibility), with revisions based on input; one-to-one testing on three students was conducted to assess the comprehensibility of instructions and ease of use, followed by small group testing (± 8 –10 students) to check stability, flow, and duration, while refining the instruments (item readability, simple reliability) and preparing learning activity logs.

In the **Implementation** stage, after being declared valid and practical, the media was submitted to teachers and tested in real learning in one class through a series of pretests, core activities with AR exploration (models/networks/step-by-step exercises/discussions based on activity logs), and posttests; observers noted the implementation and obstacles, and teachers and students filled out practicality questionnaires.

Finally, in the **Evaluation** stage, formative evaluation is conducted at each sub-stage for iterative improvement, while summative evaluation assesses (a) validity (expert validation scores according to criteria), (b) practicality (questionnaire scores of at least “good”), (c) effectiveness (improvements in learning outcomes analyzed

descriptively and N -Gain or simple statistical tests where possible), and (d) potential effects on motivation/engagement (questionnaires and observation findings); the final decision (ready for dissemination/minor revision/further revision) is made while maintaining research ethics through school permission, parental consent where necessary, and student data anonymization.

The data collection techniques employed in this study include validation sheets, questionnaires, interviews, and tests. The validation sheet, designed for validators, aims to gather suggestions and comments that will be used to improve the validity of the learning media developed. Questionnaire sheets aimed at students who participate in one-to-one trials, small group trials, and field trials, which aim to assess the practicality of a learning medium developed. Interviews with teachers aimed at exploring related information. Tests conducted by students aim to see the potential effect on learning outcomes.

Table 1. Validation Categorisation Criteria

Score	Category
81,00-100,00	Very Valid
61,00-80,00	Valid
41,00-60,00	Less Valid
21,00-40,00	Invalid
00,00-20,00	Very Invalid

(Akbar, 2019)

Calculate validation scores from experts using the formula:

$$V = \frac{\sum x}{n} \times 100$$

Description:

V = Validity

$\sum x$ = Total validation score from validators

n = Total maximum score

The practicality data analysis involves using questionnaire data from both students and educators. The responses are calculated using a Likert scale, following specific rules for scoring student and educator questionnaires.

Table 2. Criteria for categorisation of prettiness

Score	Category
81,00-100,00	Very Practical
61,00-80,00	Practical
41,00-60,00	Less Practical
21,00-40,00	Not Practical
00,00-20,00	Not Very Practical

((Akbar, 2019)

Next, convert the score into a percentage and then categorize it according to the product's practicality criteria. The formula used to determine the score of practicality is as follows:

$$P = \frac{\sum x}{n} \times 100$$

Description:

P = Score of practicality

$\sum x$ = Total score of students' answers

n = Total maximum expected score

Effectiveness data are analyzed based on evaluation exercises from the e-module, which consist of essay exercises. The effectiveness of the product is determined after a learning outcome test, which measures students' problem-solving ability through specific test indicators. Students' answers are assessed using problem-solving scoring guidelines. The obtained scores are then converted and categorized into levels of problem-solving ability, with the following formula used to determine the value:

$$Nilai = \frac{\sum x}{n} \times 100$$

Description:

$\sum x$ = Total score of students' answers

n = Total maximum expected score

Furthermore, it provides criteria for measuring the category of problem-solving ability. The following table outlines the criteria for problem-solving ability.

Table 3. Measurement of Problem Solving Ability

VALUE CRITERIA	CRITERIA
High	$80 \leq \text{Score} < 100$
Medium	$65 \leq \text{Score} < 80$
Low	$0 \leq \text{Score} < 65$

(Jedaus et al., 2019)

RESULTS AND DISCUSSION

Analyze stage (analysis): Needs Analysis

A needs analysis was conducted to determine the learning needs of students in the mathematics class IX SMP Nurul Amal Palembang. Based on the information obtained by the teacher, students tend to be passive during the learning process due to the limited tools available, such as learning media, which can encourage them to be more active in the learning process.

Material Analysis

At the material analysis stage, it was conducted with the aim of determining the extent of mathematics learning in class IX at SMP Nurul Amal Palembang. At this stage, the researcher analysed the cube material. Based on the information obtained from the teacher, students are considered good enough at learning with cube material. However, during the learning process, students still have difficulty solving problems because they forget the concept of cubes and are not familiar with determining the formula for cube materials. In answering the problem formulation and research questions, the research results must be explicitly concluded. The interpretation of the findings is done using logic and existing theories. Findings in the field are integrated with the results of previous research or existing theories. For this purpose, a reference is necessary. In generating new theories, old theories can be confirmed or rejected; some may need to be modified to incorporate elements from the old theory.

Curriculum Analysis

Based on information from teachers at SMP Nurul Amal Palembang, this school applies an independent curriculum. The results of the curriculum analysis on the material of Flat Side Cube Building can be seen in the table below:

Table 4. Phase D Learning Outcomes (CPs)

Elements	Learning Outcomes	Elements
Measurement	By the end of phase D, students can create the flat side of the cube with the net and students can determine surface area and volume flat-sided cube to solve related problems.	Measurement

Table 5: Learning Objectives (TP)

Material	Learning Objectives
Build Space	P.1 Understand the nets of flat-sided cuboid shapes
Build Space	P.2 Find a way to determine the surface area of a side space flat cube

Table 6: Indicators of achievement of learning objectives

Indicators of Achievement of Learning Objectives
P.1 Students are able to draw the nets of flat-sided cuboid shapes
P.2 Students are able to solve problems related to the surface area of side spaces flat cube
P.3 Students can solve problems related to the volume of flat-sided spaces cube

Design stage

The design of the product begins with designing activities that are inserted outside of the product, namely in the student activity sheet and of course, still integrated with the product, aiming to analyse the results of student answers so that students can be seen who already understand and who do not understand the concept of cubes. Then, proceed with designing a flowchart that provides an overview of the process of making the product, from one stage to another. Next, make a storyboard as a step in the development of learning media. Then compile the instrument as a tool to see the validity and practicality of the learning media developed.

Development Stages Augmented Reality Object Creation

Before making the product, namely the researcher's learning media, create a 3D object first in the Blender application, starting from making the Cheng Ho Grand Mosque Support, cube nets, decreasing the surface area formula and cube volume, which of course has been coloured as shown below:

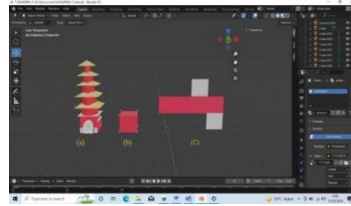


Figure 2. Augmented Reality Object Creation

Making Learning Media

At this stage, researchers realise the design from the previous design stage. The following is a display of the learning media product design that has been developed.



Figure 3. Front Cover of Learning Media

Making Instructions for Media Use

After the learning media have been developed, the researcher provides instructions for using the media, which aim to guide students through the steps of using the media. Additionally, the researcher inserts questions and markers to facilitate student responses and make it easier for researchers to analyse student answers. So that researchers can determine whether the student truly understands the concept of cubes. The following instructions are for using learning media.



Figure 4. Instructions for using the media

Expert Validation Process


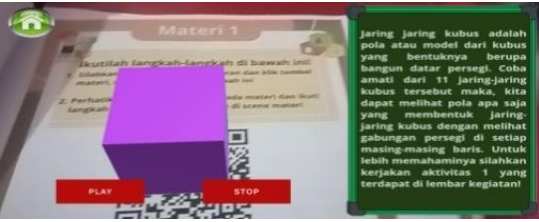
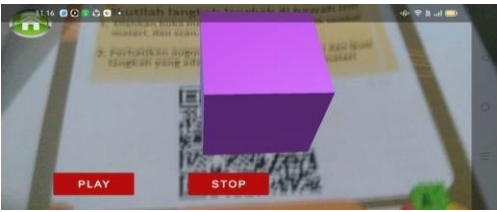

At the expert validation stage, which aims to validate the learning media by identifying and addressing areas that still require improvement, the learning media is evaluated against several aspects outlined in the validation sheet. The following are results of validation based on the three validators.

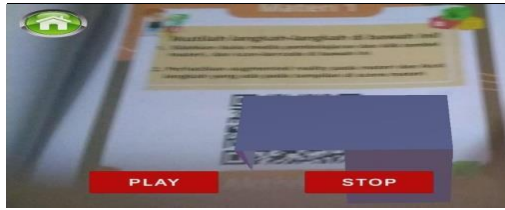
Table 7. Categories of Learning Media Validity

Validator	Aspect				Total
	Design AR	Material	Language	Media	
I	13	25	15	18	71
II	13	30	15	20	58
III	12	26	14	17	52
Avarage	0,79	0,84	0,73	0,76	0,60
Description Valid	Medium	High	Medium	Medium	Low

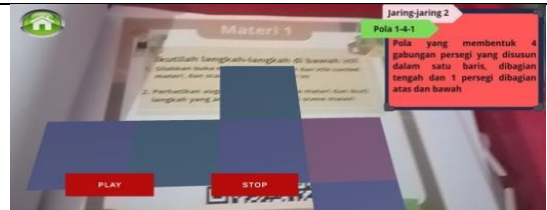
After that, researchers will make improvements in accordance with the validator's direction until this *Augmented Reality-based* learning media is deemed valid. The following can be seen as an improvement of the learning media developed. Related to the validity of the learning media developed. In this case, the learning media aligns with the characteristics of *Augmented Reality*, which combines the real world with virtual elements, is interactive in real-time, and can be displayed in three dimensions (Azuma et al., in Peddie, 2017). It can be concluded that the learning media developed are ready for testing. This is in line with previous research, such as that by Listiawan & Antoni (2021), which suggests that the learning media developed are categorised as valid based on suggestions and recommendations.

Table 8. Revisions to the Media

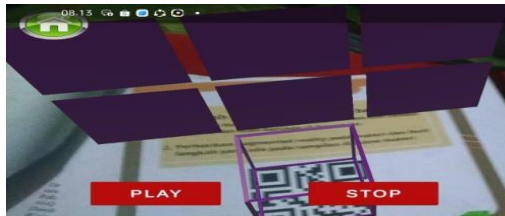
Before Revision	After Revision
 <p>The material is expanded by adding a discussion of the material in addition</p>	 <p>Discussion on the material has been added</p>
 <p>Give an explanation of each pattern in the net.</p>	 <p>Explanation of each pattern in the mesh has been added</p>



Fix some patterns that aren't quite right



Pattern improvement on cube nets



Add colour to each side of the cube with a different colour



Colour correction on each side of the cube



Differentiate the buttons on the information so they are easy to read



Improvements to Differentiate the buttons in the information so that it is easy to read

After making improvements and being deemed valid, the learning media will be tested through one-to-one, small-group, and field tests. When conducting trials, there are learning steps with a contextual approach model as follows:

Invitation

Prior to inviting students, the researcher prepares the classroom for the learning session. Students are then invited to observe the cube-shaped part of the Cheng Ho Grand Mosque, which connects the material to real life. The researcher states the learning objectives and encourages students to share their knowledge about cubes. In this step, students receive the Augmented Reality learning media and usage instructions.

Researchers step in by giving students *Augmented Reality-based* learning media and instructions for using them.

Exploration

During the exploration step, students collect information through observations and inquiry, forming the basis for problem-solving. The researcher directs students to study the cube material in AR by scanning the provided marker in the instructions.

Explanation and Solution

This step focuses on students providing explanations and solutions based on findings from exploration. Students solve problems on worksheets to determine cube patterns and formulas, using their explanations as a foundation for problem-solving.

Taking Action on Cube Material

In this step, students synthesize information to make decisions and form conclusions about cube nets. Their conclusions about net shapes and patterns are presented below.

After product testing, students complete a questionnaire covering material, attractiveness, and usability to evaluate the practicality of the learning media. The results are shown below.

Table 9. Category of Practicality of One to One Trial Learning Media

Student Name Initials	Total f	Max Score N	Score	Average
M	57	72	79,1	86,5
A	64	72	88,8	
F	66	72	91,6	

According to the one-to-one trial questionnaire, all three students very practical that the AR-based media stimulated their curiosity about cubes. This shows increased practicality for the learning media.

The one-to-one stage allows it to proceed to the next stage, which is the small group trial.

Table 10. Category of Practicality of Learning Media for Small Group Tests

Student Name Initials	Total f	Max Score N	%	Average (%)
ASR	53	72	73,6	83,2
US	67	72	93	
MSA	55	72	76,3	
GA	65	72	90,2	
FK	66	72	91,6	
WNP	54	72	75	
LS	57	72	79,1	
TR	57	72	79,1	
AA	66	72	91,6	

Based on the questionnaire collected, which strengthens the practicality of the small group trial, the aspect of attractiveness is evident, as seen in the responses of 9 students who selected "very practical" for the 4th statement item, "With *Augmented Reality-based* learning media encourages my curiosity in cube material." Evaluation at this stage demonstrated the practicality of the learning media tested during the small group stage, indicating that it can be continued to the next stage, namely the field test.

Table 11. Field Trial Learning Resources Category

No.	Student Name Initials	Total f	Score Max N	Score	Average
1.	MF	55	72	76,4	87,5
2.	MJA	59	72	81,9	
3.	MKN	63	72	87,5	

4.	MRK	52	72	72,2	
5.	MRR	62	72	86,1	
6.	MRS	57	72	79,2	
7.	MWDS	60	72	83,3	
8.	NAAR	59	72	81,9	
9.	NIY	63	72	87,5	
10.	NRP	67	72	93,1	
11.	NS	62	72	86,1	
12.	NSA	62	72	86,1	83,9
13.	RID	66	72	91,7	
14.	RN	63	72	87,5	
15.	RK	56	72	77,8	
16.	RR	64	72	88,9	
17.	RS	64	72	88,9	
18.	SF	59	72	81,9	
19.	SW	58	72	80,6	
20.	PB	57	72	79,2	
21.	PTP	59	72	81,9	
22.	TDA	62	72	86,1	

Based on the questionnaire collected, which reinforces the practicality of the field trial in the aspect of material, it is seen that there are no students who respond "very practical" to the 4th statement item, "I find it easier to understand the cube material by using *Augmented Reality-based* learning media." In the aspect of attractiveness as well, no students responded "very practical" on the 2nd statement item "The appearance of *Augmented Reality-based* learning media makes learning mathematics more interesting". And the media developed is still minimal in the aspect of ease of use, namely in the 1st statement item "*Augmented Reality-based* learning media can be installed easily". Due to the mobile phone used by the student having a small storage space, while the media developed requires a large storage space. In this case, regarding the practicality of *Augmented Reality-based* learning media, both from one-to-one trials, small group trials, and field trials, aspects such as material, attractiveness, and ease of use are considered. The learning media developed is also in line with Hakim's (2018) opinion regarding the advantages of *Augmented Reality*, one of which is its interactivity. The learning media developed by researchers can enable students to interact directly with AR objects through hand movements or screen touches on AR objects. Based on the questionnaire collected, which reinforces the practicality of the field trial in the aspect of material, it is seen that there are no students who respond "Disagree" or "Strongly Disagree" to the 4th statement item, "I find it easier to understand the cube material by using *Augmented Reality-based* learning media." In the aspect of attractiveness as well, no students responded "Disagree" and "Strongly Disagree" on the 2nd statement item "The appearance of *Augmented Reality-based* learning media makes learning mathematics more interesting". And the media developed is still minimal in the aspect of ease of use, namely in the 1st statement item "*Augmented Reality-based* learning media can be installed easily". Due to the mobile phone used by the student having a small storage space, while the media developed requires a large storage space. In this case, regarding the practicality of *Augmented*

Reality-based learning media, both from one-to-one trials, small group trials, and field trials, aspects such as material, attractiveness, and ease of use are considered. The learning media developed is also in line with Hakim's (2018) opinion regarding the advantages of *Augmented Reality*, one of which is its interactivity. The learning media developed by researchers can enable students to interact directly with AR objects through hand movements or screen touches on AR objects. When compared to related studies, the findings of this study demonstrate a high to very high level of practicality in small-group testing and field testing. These results surpass the practicality achieved in previous studies, both in small-group testing and field testing (Suganda et al., 2020). In line with this, other studies (Fahmi & Noviani, 2021; Irfansyah & Anifah, 2022; Karacan & Akoglu, 2021) also report high practicality in small group tests and field tests. However, the results of the analysis in this study indicate a better practicality category, accompanied by positive feedback from users (teachers and students), which suggests that the media is ready for wider implementation in the classroom.

According to the research, the practicality obtained in this study is lower than that in previous research. This may be due to the lack of student experience with the use of *Augmented Reality-based* learning media. If you have done the above activities, based on formative evaluation. Then, proceed with conducting a summative evaluation to determine the effectiveness of the product, namely, the learning media developed. This aims to measure the potential effect of learning media on student learning outcomes.

The value of student learning outcomes on cube material can be seen in the following table:

Table 12. Student learning outcomes

No.	Student Name	Question					Total Value
		1	2	3	4	5	
1	M	4	4	2	4	4	90
2	M	4	4	2	4	4	90
3	M	4	3	4	4	4	95
4	M	2	4	4	1	3	70
5	M	2	1	4	4	1	60
6	M	4	4	4	0	4	85
7	M	4	4	2	4	4	90
8	N	2	4	2	4	1	65
9	N	4	4	4	4	4	100
10.	N	4	4	4	1	4	85
11.	N	4	3	3	3	3	80
12.	N	4	1	4	4	4	85
13.	R	4	1	4	4	4	85
14.	R	4	1	4	1	4	70
15.	R	2	1	4	4	4	75
16.	R	4	1	4	4	3	85
17.	R	4	4	4	4	1	85
18.	S	2	2	4	4	3	75
19.	S	4	4	0	0	0	40
20.	P	4	4	2	4	1	75
21.	P	2	3	2	3	3	65
22.	T	2	4	4	2	4	80

Total	1.730
Average	78,6
Category	Medium

From the table above, it can be seen that the evaluation test results after using Augmented Reality (AR)-based learning media show a potential effect on learning outcomes: 78.6% of students were in the “moderate” category, which indicates that the majority of students were finally able to determine the formula for the surface area and volume of a cube. Thus, AR-based learning media on cube material for ninth-grade junior high school students has a potential effect on learning outcomes. The students stated that the use of AR helped them understand and remember the material because they could interact directly with the objects in the media. These findings align with studies demonstrating that AR enhances understanding of geometric concepts and learning performance through 3D visualization and real-time interaction (Lin, 2015; Nurhayati, 2022; Pangestu, 2020; Rohendi, 2020). In comparison, research by Wahyuni & Pratama, (2024) reported an average learning outcome of 83.6; while other studies also showed an increase in learning achievement/thinking skills in the use of AR in mathematics and science, for example, an increase in geometric thinking skills/learning outcomes at the junior high school/high school level (Suprpto, 2021). Based on this comparison, the potential effect in this study is still below that of several previous studies. One factor we identified is that students have limited time to complete the questions during the class test, which means that the practice space and feedback have not been optimally utilized.

Implementation stage

After conducting product revision activities at the *development* stage, and declaring them valid, practical, and with potential effect. Then, the developed product, namely *Augmented Reality-based* learning media, will be implemented in the real classroom environment in class IX SMP Nurul Amal. During the learning process, the teacher uses learning media developed by researchers. The teacher first conveys the achievements and objectives that students will learn. Furthermore, the teacher guides the students through the steps of using learning media. With that, students can learn well in a conducive environment.

Evaluation stage

At this stage, identifying problems or difficulties that students face when using learning media. During the implementation of learning, issues arise with the installation of learning media; often, students encounter difficulties installing them. Because not all students have access to the devices needed to access *Augmented Reality-based* learning media. In this case, the evaluation helps researchers in the necessary improvements and adjustments to *Augmented Reality-based* learning media.

This study (Vostinar & Ferienc, 2023) demonstrates the potential of AR in enhancing students' conceptual understanding and spatial abilities through the use of innovative learning tools, such as the Merge Cube. This tool enables students to interact with and manipulate 3D models, significantly supporting interactive and multisensory learning. Other research (Ozcakir & Cakiroglu, 2021) developed and evaluated the 'SPATIAL-AR Toolkit', designed to improve students' understanding of three-dimensional concepts in mathematics. This toolkit includes various spatial tasks and a mobile AR interface, which have been proven effective in improving students' spatial abilities and learning motivation. AR has proven to enhance not only geometry

understanding but also students' motivation to learn. This technology offers new ways to present learning materials, making them more engaging and facilitating a deeper understanding of complex concepts. Therefore, the use of AR in mathematics education offers various innovative ways to improve student understanding and engagement. This ranges from the use of interactive, handheld models to app-based learning that supports deeper visualization and interaction with the subject matter. This technology promises to revolutionize how we teach and learn geometry in education.

CONCLUSIONS

This study established that the mosque-based geometry e-module, developed through the ADDIE procedure, is both feasible for use and shows potential to improve learning outcomes. Validation demonstrated a “very valid” rating, and practicality tests found the module “very practical.” However, effectiveness on learning outcomes reached only a “moderate” category, indicating that further optimization is necessary to fully enhance its impact. Brief implications and suggestions: To achieve high effectiveness, broader implementation across multiple classes or schools is recommended. Additionally, refining features such as adaptive feedback and tiered exercises is recommended. Future research should utilize larger samples and apply inferential analysis to strengthen conclusions about effectiveness.

ACKNOWLEDGEMENTS

If necessary, thanks can be added to those who have helped the research, especially to those who have helped fund the research.

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