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Development of augmented reality learning media with ethnomathematics to improve critical thinking skills

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Abstrak

Penelitian ini bertujuan untuk menghasilkan media pembelajaran *augmented reality* dengan pendekatan etnomatematika materi bangun ruang sisi lengkung yang valid, praktis serta efektif dalam meningkatkan kemampuan berpikir kritis peserta didik. Penelitian ini merupakan penelitian pengembangan (R&D) dengan mengadaptasi model 4D. Sampel penelitian adalah 27 peserta didik kelas IX salah satu SMP di Lombok Barat. Media *augmented reality* dikembangkan menggunakan platform Assemblr Edu dalam bentuk dunia 3D dengan objek budaya Sasak yang interaktif. Pada tahap *development* dilakukan dua kali uji coba media untuk mendapatkan data kepraktisan dan keefektifan media. Instrumen penelitian meliputi angket validasi ahli media dan materi, angket kepraktisan untuk guru dan peserta didik, serta soal *pretest* dan *posttest* kemampuan berpikir kritis. Data dianalisis menggunakan indeks Aiken V untuk kevalidan, persentase untuk kepraktisan, serta standardized gain (g) untuk keefektifan. Hasil penelitian menunjukkan bahwa media pembelajaran yang dikembangkan dinyatakan (1) valid dengan skor rata-rata indeks Aiken sebesar 0,92 dalam kategori validitas tinggi; (2) praktis dengan persentase rata-rata kepraktisan sebesar 92% dalam kategori sangat praktis; (3) efektif meningkatkan kemampuan berpikir kritis peserta didik dengan nilai rata-rata standardized gain (g) sebesar 76% dengan kategori efektif sehingga penggunaan media pembelajaran *augmented reality* dengan pendekatan etnomatematika yang dikembangkan efektif dalam meningkatkan kemampuan berpikir kritis peserta didik.

Kata Kunci: media pembelajaran, *augmented reality*, etnomatematika, Assemblr Edu, berpikir kritis

Abstract

This study aims to develop an augmented reality learning media using an ethnomathematical approach on curved-sided geometric shapes that is valid, practical, and effective in improving students' critical thinking skills. This research and development (R&D) study adapted the 4D model. The sample consisted of 27 ninth-grade students from a junior high school in West Lombok. The augmented reality media was developed using Assemblr Edu in the form of interactive 3D worlds featuring Sasak cultural objects. During the development stage, two trials were conducted to obtain data on practicality and effectiveness. Research instruments included expert validation questionnaires (media and content), practicality questionnaires for teachers and students, and pretest and posttest questions on critical thinking skills. Data were analyzed using Aiken's V index for validity, percentages for practicality, and normalized gain (g) for effectiveness. The results showed that the developed augmented reality learning media was (1) valid, with an average Aiken's index score of 0.92; (2) practical, with an average practicality percentage of 92%; and (3) effective in improving students' critical thinking skills, with an average normalized gain (g) of 76%. Thus, the developed augmented reality learning media with an ethnomathematical approach is effective in enhancing students' critical thinking skills.

Keywords: *learning media, augmented reality, ethnomathematics, Assemblr Edu, critical thinking*

1. INTRODUCTION

Mathematics is a subject that is often considered intimidating and disliked because it is difficult for students to understand. One of the reasons for this is that students do not fully understand its practical benefits in everyday life (Putri, 2023). One branch of mathematics that students find difficult is geometry, as it requires a deep understanding of points, lines, planes, and spaces. To master geometry, students need a solid conceptual foundation in order to apply visualization skills, recognize shapes, and create sketches (Susanto & Mahmudi, 2021). However, in reality, students still struggle to visualize shapes, identify the structure of geometric objects, and even misunderstand mathematical symbols, resulting in students' thinking skills not being properly developed.

The above problem is supported by interviews with teachers and ninth-grade students at a junior high school in West Lombok, where many students still have difficulty understanding and visualizing the shapes of geometric objects, particularly in the topic of curved-sided three-dimensional figures. Furthermore, students' thinking skills especially critical thinking are underdeveloped or tend to be low because students are very passive during classroom learning. Based on the results of an initial critical thinking ability test administered to 27 ninth-grade students, the results showed that 23 students still answered incorrectly, while the other 4 answered correctly but incompletely. Therefore, it can be said that students' critical thinking skills are relatively low. This is caused by teaching methods at school that remain monotonous, relying on lectures without the use of teaching aids. In fact, teaching aids have high practical value in mathematics learning (Subarinah et al., 2019). One possible solution is to use appropriate learning media in the learning process to improve students' conceptual understanding and critical thinking skills.

The use of media in mathematics learning is very important. Learning media makes learning mathematics more interesting and ignites students' enthusiasm and passion for learning (Isnaeni & Hildayah, 2020). Furthermore, mathematics learning media are essential to help students who experience difficulties in understanding the material (Sripatmi et al., 2023). Teachers play a crucial role in selecting appropriate learning media that align with the abilities and characteristics of students.

Along with the advancement of time and technology, learning media have also increasingly developed into various types, both in physical and digital forms. Schools have technological facilities such as computer laboratories and smartboards that can support digital learning media. Currently, most students already own and are accustomed to using various types of technology, such as smartphones (Lu'Luilmaknun et al., 2021). This allows students to utilize the technology they have to better understand the material. In line with this, Novitasari et al. (2021) state that technology-based learning media can help students understand the material through visualization and problem investigation.

One implementation of cutting-edge technology that can be applied as a learning medium is Augmented Reality (AR).

AR technology is capable of combining two-dimensional (2D) and three-dimensional (3D) objects and projecting them directly into the real world (Aditama et al., 2019). This allows AR media to help students understand concepts effectively by creating 3D objects of geometric shapes. As a result, students can optimally develop and enhance their critical thinking skills. This is in line with the opinion of Hidayat et al. (2024) that AR has the ability to stimulate students' critical thinking about everyday situations and events.

AR media can help students understand the material. This is in line with the research by Khotimah & Satiti (2019), who developed AR media on the topic of geometric shapes to enhance students' understanding. However, to further improve conceptual understanding, a material approach relevant to students' lives and environment such as local culture or ethnomathematics learning is needed. Ethnomathematics refers to mathematics that grows and develops within a particular community's culture (Aminah et al., 2023). An example of implementing ethnomathematics in AR media is creating 3D objects of Sasak culture that contain elements or shapes of geometric figures, in order to help students understand concepts and thereby improve their critical thinking skills. This is supported by Turmuzi (2022), who stated that learning using an ethnomathematical approach influences students' learning outcomes and thinking abilities. Critical thinking is an important competency for students.

Critical thinking is the ability to consider various pieces of information originating from many different sources, to process that information creatively and logically, to challenge it, to analyze it, and to reach a well-developed conclusion that can be defended and justified (Moon, 2008). In the context of geometry, critical thinking is reflected when students are able to analyze the properties of geometric shapes, connect concepts to real-life situations, and construct logical arguments in solving contextual problems. The indicators of critical thinking ability used in this study are a modification of Facione's (2023) critical thinking indicators, namely interpretation, analysis, evaluation, and inference.

One platform that can be used to create AR media is Assemblr Edu, along with Blender for creating 3D objects. Assemblr Edu is an application developed to create interactive and engaging three-dimensional (3D) and AR content by combining several available objects (Chairudin et al., 2023). Assemblr Edu is easy to access and use, and supports multimedia integration such as videos, audio, and 3D models that can be created independently, for example using Blender. This is in line with the opinion of Nugrohadi & Anwar (2022) that Assemblr Edu, which is easily accessible, user-friendly, and utilizes animations to present material interactively from various perspectives along with flexible editing features, is able to attract students' attention during the learning process.

Based on the explanation above, it is necessary to develop a learning medium that can overcome the difficulties of visualization and conceptual understanding in the geometry topic of curved-sided three-dimensional figures at school using augmented reality technology. Several studies that have developed AR media, such as Khotimah & Satiti (2019); Verdiatmoko & Pinandita (2025), state that this AR media is valid, practical, and effective for use in mathematics learning. The materials in the AR media from the research by Khotimah & Satiti (2019); Verdiatmoko & Pinandita (2025) are generally plane figures and flat-sided three-dimensional figures. In this development research, the material used in the AR media is the more complex topic of curved-sided three-dimensional figures. However, a more relevant material approach is needed—not only referring to textbooks but also relevant to students' lives and environment, such as using local cultural objects or ethnomathematics, in order to improve students' critical thinking skills. Based on this, an augmented reality learning medium with an ethnomathematical approach on the topic of curved-sided three-dimensional figures was developed to improve students' critical thinking skills.

2. METHOD

This type of research is research and development (R&D), which aims to produce a product and test its effectiveness. The research and development model used is the 4D model by Thiagarajan et al. (1974) which consists of define, design, development, and disseminate. The stages of this model can be seen in Figure 1.

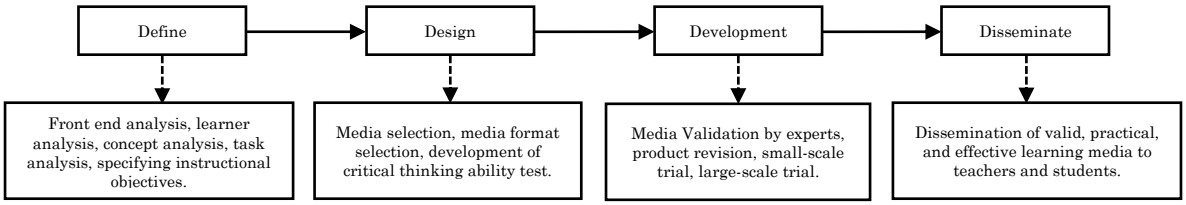


Figure 1. Research Procedure of the 4D Model

This study used a one-group pretest-posttest design without a control class and was conducted at one of the junior high schools in West Lombok, with a research sample of 33 ninth-grade students. The data collection instruments used in this study were questionnaires and a critical thinking ability test. The data analysis techniques employed aimed to obtain a learning medium that is valid, practical, and effective in improving students' critical thinking skills.

The validity of the media was obtained from the validation results of five media and material experts, which were analyzed using the Aiken V formula. The criteria for media validity can be seen in Table 1.

Table 1. Media Validity Criteria

Value	Criteria
$V \leq 0{,}4$	High Validity
$0{,}4 < V \leq 0{,}8$	Moderate Validity
$V > 0{,}8$	Low Validity

Sources: Retnawati (2016)

The practicality of the media was obtained from the results of practicality questionnaires completed by 3 teachers and 6 students. The criteria for media practicality can be seen in Table 2.

Table 2. Media Practicality Criteria

Value	Criteria
81% – 100%	Very Practical
61% – 80%	Practical
41% – 60%	Moderate Practical
21% – 40%	Not Practical
0% – 20%	Highly Impractical

Sources: Tampubolon & Manurung (2022)

The effectiveness of the media in improving students' critical thinking skills was obtained from the pretest and posttest results of 27 students in the large-scale trial, which were then analyzed using the standardized gain (g) expressed as a percentage. The criteria for media effectiveness can be seen in Table 3.

Table 3. Media Effectiveness Criteria

Percentage (g)	Criteria
$< 40\%$	Not Effective
$40\% - 55\%$	Less Effective
$56\% - 75\%$	Moderate Effective
$\geq 76\%$	Effective

Sources: Hasan, Susilawati, & Andayani (2025)

3. RESULTS AND DISCUSSION

3.1 Research Results

The final result of this study is an augmented reality learning medium using an ethnomathematics approach on the topic of curved-sided geometric shapes, which is valid, practical, and effective in improving critical thinking skills through several research instruments. The validity results of the research instruments are presented in Table 4.

Table 4. Research Instrument Validity Results

Instrument	Validity Score	Criteria
Media Expert Questionnaire	0,89	High Validity
Material Expert Questionnaire	0,89	High Validity
Teacher Practicality Questionnaire	0,88	High Validity
Learner Practicality Questionnaire	0,87	High Validity
Critical Thinking Ability Pretest	0,87	High Validity
Critical Thinking Ability Posttest	0,86	High Validity

Based on Table 4, the data show that all research instruments achieved high validity, so they can be used as good research instruments. The development of the augmented reality learning medium in this study used the 4D development model by Thiagarajan et al. (1974) through the following phases:

3.1.1 Define

In the Define phase, several analyses were conducted to establish and formulate aspects related to learning needs as prerequisites for developing the learning medium. This phase began with an initial analysis to identify problems in mathematics learning at the school. Based on the results of observations and interviews with teachers and students, information was obtained that the learning method used still relies on lectures without the use of media or additional teaching aids. In fact, the school has adequate facilities such as computer laboratories and smartboards, but these have not been utilized optimally.

Learner analysis was conducted to understand the characteristics and learning needs of students through observations and direct interviews with ninth-grade students. The results showed that their participation in mathematics learning, particularly on the topic of curved-sided three-dimensional figures, remains low. Students expressed the need for a medium that can help visualize curved-sided three-dimensional figures in a tangible way and connect them to local cultural contexts.

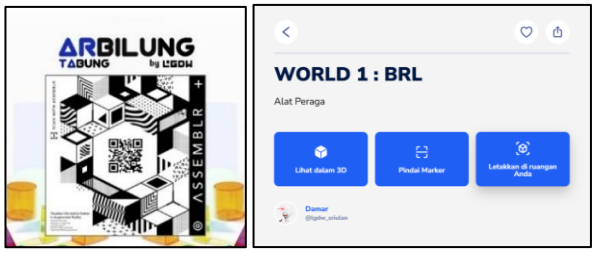
Task and concept analysis aims to determine the main competencies and map the core material to be developed in the learning medium based on the learning outcomes established in the Merdeka Curriculum. The focus of the analysis is on curved-sided three-dimensional figures (cylinders, cones, spheres), including their elements, surface area and volume formulas, and their applications. These concepts are linked to an ethnomathematical approach based on Sasak culture, such as in the form of ketak crafts or tigapo cakes.

Based on the task and concept analysis, learning objectives can be formulated. For example, for the topic of cylinders, the learning objectives are that students will be able to: (1) identify the elements of a cylinder, (2) discover the surface area and volume of a cylinder, and (3) determine the surface area and volume of a cylinder through contextual

problems related to Sasak culture. Thus, these learning objectives focus not only on mastering mathematical concepts but also on developing critical thinking skills and appreciation for local culture through interactive and meaningful media.

3.1.2 Design

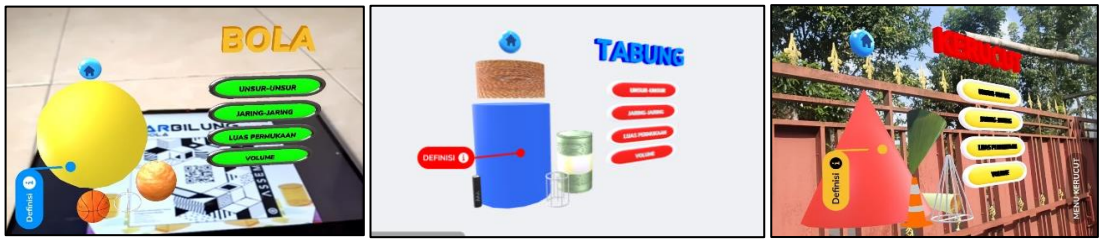
The media design phase was carried out based on the results of the analysis from the previous define phase. As a result, augmented reality technology was chosen as the basis for the media being developed, with the material using a Sasak cultural ethnomathematical approach. The AR media can be accessed via a link or by scanning an AR marker, which can be seen in Figure 2(a), and then selecting the AR display format shown in Figure 2(b).



(a) (b)

Figure 2. AR Marker and AR Format Options

The AR format in the media consists of three types: marker-based AR in the "Scan Marker" menu shown in Figure 3(a), markerless AR in the "View in 3D" menu shown in Figure 3(b), and projection-based AR in the "Place in Your Room" menu shown in Figure 3(c).



(a) (b) (c)

Figure 3. AR Format Display

This AR media also integrates other interesting learning media, such as instructional videos shown in Figure 4(a) and interactive example questions shown in Figure 4(b), to practice and improve students' critical thinking skills.

(a) (b)

Figure 4. Learning Videos and Interactive Example Questions in AR

3.1.3 Development

After the design was completed, the media went through the development phase to obtain AR media that is valid, practical, and effective in improving students' critical thinking skills.

Validation by experts aimed to obtain a learning medium that is valid in terms of both media and material aspects, conducted by 5 media experts and 5 material experts respectively. The results of the media validation assessment can be seen in Table 5.

Table 5. Validation by Media Experts

Assesment Aspect	Validity Score	Category
Display	0,92	High Validity
Construction	0,88	High Validity
Language	0,95	High Validity
Average	0,92	High Validity

Based on Table 5, the AR media on average was declared valid with a high validity category. The aspects of display, construction, and language also received a high validity category.

Then, the results of the material expert validation can be seen in Table 6.

Table 6. Validation by Material Experts

Assesment Aspect	Validity Score	Category
Material Presentation	0,95	High Validity
Critical Thinking	0,87	High Validity
Construction	0,93	High Validity
Language	0,97	High Validity
Average	0,93	High Validity

Based on Table 6, the material in the AR media on average was declared valid with a high validity category, as were the aspects of material presentation, critical thinking,

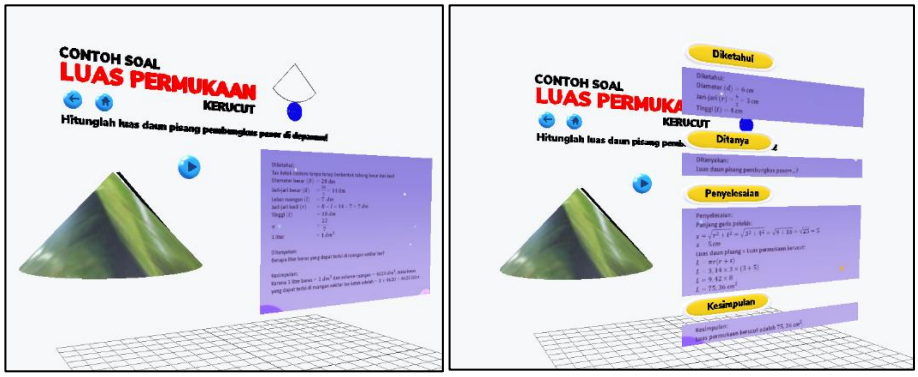
construction, and language. Based on the results of the media and material expert validation, the average media validation results from the experts can be seen in Table 7.

Table 7. Average Results of Media Validation by Experts

Assesment	Validity Score	Category
Media	0,92	High Validity
Material	0,93	High Validity
Average	0,92	High Validity

Based on Table 7, it can be concluded that the developed AR media is valid with a high validity category, both in terms of media and the material within it.

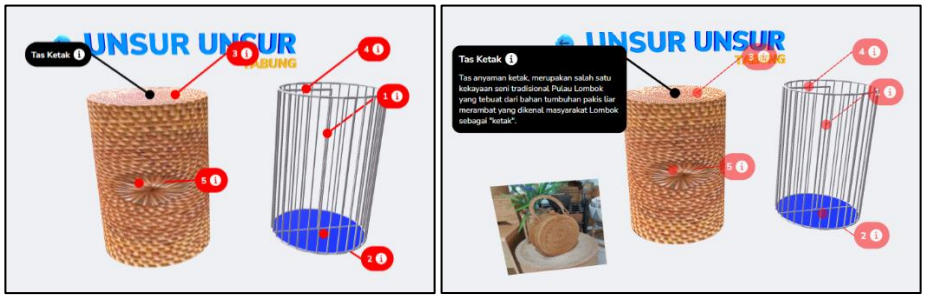
In the results of the media and material validation, there were several revision suggestions from the experts. The revision suggestion from the media expert was to make the display of example questions more interactive, as shown in Figure 5(a) before the revision and Figure 5(b) after the revision.



(a) (b)

Figure 5. Media Revision from the First Suggestion

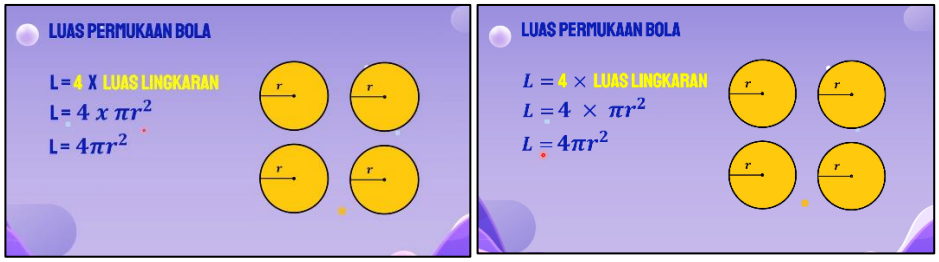
The second suggestion was to add original images of Sasak cultural objects, as shown in Figure 6(a) before the revision and Figure 6(b) after the revision.



(a) (b)

Figure 6. Media Revision from the Second Suggestion

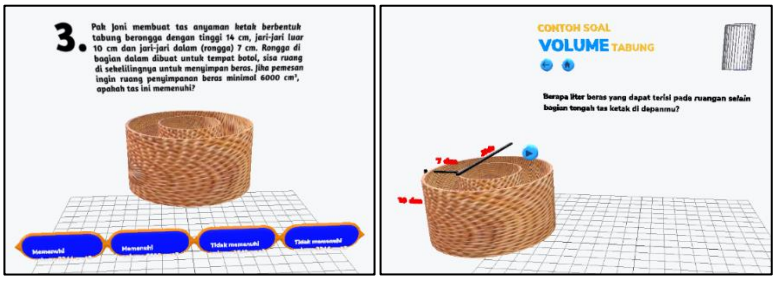
The suggestion from the material expert was to correct the mathematical symbols in the AR learning video, as can be seen in Figure 7(a) before the revision and Figure 7(b) after the revision.



(a) (b)

Figure 7. Material Revision from the First Suggestion

Then, the second suggestion was to revise the example questions so that students could better practice their critical thinking skills, as shown in Figure 8(a) before the revision and Figure 8(b) after the revision.



(a) (b)

Figure 8. Material Revision from the Second Suggestion

After the AR media was revised and declared valid, a small-scale trial of the media was conducted involving 3 mathematics teachers and 6 ninth-grade students to obtain data on the practicality of using the AR media in learning. The results of the media practicality assessments by teachers and students can be seen in Table 8.

Table 8. Results of Media Practicality by Teachers and Students

Assesment Aspect	Practicality Percentage		Category
	Teachers	Students	
Ease and convenience of using the media	100%	90%	Very Practical
Feasibility of media display	92%	92%	Very Practical
Level of interest in the media	88%	90%	Very Practical
Ease of understanding the material	93%	93%	Very Practical
Average	93%	91%	
Media Practicality Average	92%		Very Practical

Based on Table 8, according to both teachers and students, the AR media is very practical to use as a learning medium in the classroom. Subsequently, an analysis was conducted based on the students' odd semester mathematics final exam (UAS) scores, which can be seen in Table 9.

Table 9. Results of Practicality by Students Based on UAS Scores

UAS Score	Passing Grade	Percetage	Category
< 75	Below the passing grade	93%	Very Practical
≥ 75	Above the passing grade	89%	Very Practical

In Table 9, it can be seen that the percentage of media practicality according to students with UAS scores below the passing grade is greater than that of those above the passing grade, although both groups have a very practical percentage.

Finally, a large-scale trial of the media was conducted with 27 ninth-grade junior high school students to determine the effectiveness of the media in improving their critical thinking skills. The media was implemented twice over two sessions on April 1 and 2, 2026.. The effectiveness analysis used the standardized gain (g) on the pretest and posttest results. The results of the gain analysis for the critical thinking ability test are presented in Table 10.

Table 10. Result of g Analysis of Critical Thinking Ability Test

Test Type	Total Score	g	g %	Category
Pretest	93	0,76	76%	Effective
Posttest	761			

Based on Table 10, overall the AR media is effective in improving students' critical thinking skills, as it achieved a gain score of 76% in the effective category. Furthermore, a gain analysis was also conducted for each indicator of critical thinking ability, which can be seen in Table 11.

Table 11. Result of g Analysis for Each Critical Thinking Ability Indicator

Indicator	Score		g	g (%)	Category
	Pretest	Posttest			
Interpretation	22	194	0,78	78%	Effective
Analysis	12	157	0,63	63%	Moderate Effective
Evaluation	14	212	0,86	86%	Effective
Inference	45	198	0,77	77%	Effective
Average			0,76	76%	Effective

In Table 11, it was found that the use of AR media can help students analyze the material and problems quite effectively. However, overall, the AR media is effective in improving students' critical thinking skills, with an average gain score of 76% in the effective category.

3.1.4 Disseminate

In this disseminate phase, the AR learning media that has gone through the development stage and has been declared suitable for use as a learning medium is disseminated to teachers and ninth-grade students at the junior high school. This AR learning media can be accessed freely by opening the link bit.ly/MARKERARBILUNG or by scanning the QR code in Figure 9.

Figure 9. QR Code of the Media

3.2 Discussion

The product resulting from the development in this study is an augmented reality learning medium with an ethnomathematical approach on the topic of curved-sided three-dimensional figures. In the define phase, it was found that students have difficulty understanding the material and visualizing the shapes of three-dimensional figures due to monotonous learning methods without the use of learning media. According to Lu'luilmaknun & Novitasari, (2024), culture-based or ethnomathematical mathematics learning can be implemented using technology-based learning media. Therefore, AR technology using the Assemblr Edu platform was chosen as the media format due to its advantages in helping visualize three-dimensional objects interactively in 3D.

The AR media was designed in the design phase by selecting an AR format in the form of an interactive 3D world. The AR can be accessed in three modes: marker-based, markerless, and projection-based AR. Based on the results of the define phase, the material in the AR media covers curved-sided three-dimensional figures with a Sasak cultural ethnomathematical approach, including ketak bags, tigapo, cerorot, and pesor. Ethnomathematics-based learning was chosen because it can influence students' learning outcomes and thinking abilities, such as critical thinking (Turmuzi, 2022). Then, in the development phase, trials and analyses were conducted to obtain AR media that is valid, practical, and effective for improving students' critical thinking skills.

The results of media validation conducted by experts showed that the AR media achieved high validity in several aspects, such as an attractive appearance with a structured layout. The construction aspect was good because the interactive features of the AR media functioned smoothly, and the language used in the media was clear and easy to

understand, thus helping students learn better. Furthermore, the results of material validation by experts showed that the material in the media also achieved high validity. This is because the material is presented systematically in accordance with the learning outcomes and objectives, incorporating engaging and relevant 3D objects of Sasak AR culture. In addition, there are interactive example questions using language that is easy to understand, allowing students to practice and even improve their critical thinking skills. Based on the validation results from media and material experts, the developed AR media was declared valid with high validity. This is in line with the opinion of Khotimah & Satiti (2019), who stated that AR learning media is valid for use as a learning medium.

In the small-scale trial of the media involving 3 teachers and 6 students, the practicality results showed that students with UAS scores below the passing grade rated the practicality higher than students with scores above the passing grade. The reason for this lies in the opinions of students with UAS scores below the passing grade, who felt that the AR media helped them more in terms of visualization and problem-solving compared to students with UAS scores above the passing grade. Overall, based on the results of the practicality analysis by teachers and students, the data showed that the AR media is very practical to use as a learning medium in the classroom due to its advantages in helping students understand conceptual material and visualize three-dimensional objects. This is in line with the opinion of Nurhasanah et al. (2023) that AR learning media is very practical for use by both teachers and students.

In the large-scale trial involving 27 ninth-grade students, a pretest was administered before using the media and a posttest afterward. The results of the test score analysis using the standardized gain (g) showed that the AR media proved effective in significantly improving scores from the pretest to the posttest. During the pretest, most students were confused and had difficulty answering; however, after using the media, their ability to solve problems and think critically on the posttest questions improved significantly, as evidenced by the increase in scores. This is supported by the gain (g) analysis results for each critical thinking indicator, which on average were classified as effective. The analysis indicator was classified as moderately effective due to the brief implementation period of the media and the absence of more detailed material explanations within the media. Based on these results, the AR media has generally proven effective in improving students' critical thinking skills. This is in line with the opinion of Khotimah & Satiti (2019) that AR media is effective for use as a learning medium in the classroom.

After the AR media was declared valid, practical, and effective in improving students' critical thinking skills, the next phase was the disseminate phase, in which the AR media was distributed to students and teachers via a link and QR code so that it can be utilized as a learning medium at school.

4. CONCLUSION

Based on the discussion and the results of the research conducted, several conclusions can be drawn as follows:

1. The augmented reality learning medium using an ethnomathematics approach on curved-sided geometric shapes was successfully developed, achieving a validity score of 0.92 and categorized as high validity.
2. The augmented reality learning medium using an ethnomathematics approach on curved-sided geometric shapes achieved a practicality percentage of 92%, placing it in the very practical category.
3. The effectiveness of the augmented reality learning medium with an ethnomathematical approach on the topic of curved-sided three-dimensional figures proved to be effective in improving students' critical thinking skills, achieving a gain score (g) of 76% in the effective category. Specifically, there was an increase in the average scores from the pretest to the posttest, as calculated by the gain score for each critical thinking indicator.

5. RECOMENDATION

Some of the AR 3D objects used are still rigid and utilize traditional Sasak food. For future researchers, it is recommended to create AR 3D objects with different, more innovative, and relevant cultural contexts. Additionally, the material within the media should be developed to include more in-depth explanations of sample questions in order to help students analyze both the objects and the material effectively. Furthermore, before using the AR media, ensure that the devices used, such as smartphones or laptops, meet the minimum technical standards for AR technology, have a good internet connection, and prepare other devices for students who do not have their own smartphones or laptops.

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