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Using Augmented Reality Based LKPD to Improve Mathematics Learning

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Abstract

This study develops a learning medium as a Student Worksheet (LKPD) based on Augmented Reality (AR) to support mathematics learning. The media is available only on Android devices and was developed using the ADDIE (*Analyze, Design, Development, Implementation, Evaluation*) model. Research instruments include interviews, evaluation tests, validation sheets, and student response surveys. Mathematical education lecturers conducted validation, while practicality testing consisted of individual, small-group, and field trials. Data were analyzed both quantitatively and subjectively. The validity results showed a score of 0.78 with the category "at the moment". The practical result indicated that the AR-based LKPD was in the "highly practical" category, with an average score of 4.24 and a completion rate of 83%. Moreover, AR-based LKPD enhanced student engagement, reduced learning fatigue, and improved mathematics learning outcomes. These findings imply that the AR-based LKPD can serve as an innovative alternative in mathematics learning and hold potential for broader implementation to improve the quality of teaching and learning processes.

Keywords: Augmented Reality; Mathematics Learning; Student Worksheets

1. Introduction

All sectors, including Education, are transforming as we enter the digital era. Education is one field that continues to develop along with technological advances. Augmented Reality (AR) is a technology. Artificial intelligence has transformed the way we learn. AR is increasingly important and engaging, and has numerous benefits for students, teachers, and the learning environment. According to Law Number 20 of 2003, Education is a learning process that enables students to actively develop their potential to gain strength, religious independence, intelligence, and noble character. According to Purwaningtyas et al. (2024), Education is activities that develop knowledge and skills through designed learning, both formal and non-formal Education.

Mathematics is an important lesson in school and essential for human activities. Understanding mathematical concepts needs to be taught from elementary school, because learning mathematics involves not only passively receiving information, but also actively involving students in a way (Safari & Rahmalia, 2024). Mathematics learning is also a teaching and learning activity that involves mathematics, making it valuable and relevant to everyday life (Setyo et al., 2020). In the context, ethnomatematics plays an important role as it connects mathematics with culture and community practices, thereby making learning more meaningful. This statement aligns with the opinion of (Rawani & Fitra, 2022) that learning mathematics requires an approach so that its implementation provides effectiveness. Ethnomathematics is a bridge between mathematics and culture. There are different ways of doing mathematics in community activities. Etnomathematics helps students understand that mathematics is not merely an abstract science, but also emerges from daily activities, traditions, and local culture that can be used as a context for learning. Thus, integrating ethnomatematics in mathematics education enriches students' understanding of concepts, fosters appreciation for local wisdom, and makes learning more contextual. Technological advances, especially the internet, greatly assist teachers in creating electronic teaching materials. Teacher skills are a key component in creating engaging teaching materials. The teacher is the most important contributor to the success of their students' learning process, remembering technology development at the right moment (Hariyati & Rahmadyanti, 2022) .

LKPD is a tool that helps learning, which helps students remember and understand what they have learned during the learning process (Ernawati & Nirfayanti, 2021) .According to Firmansyah (2021) ,Student Worksheet (LKPD) are tools to help support and facilitate teaching activities, allowing for effective student interaction. This allows educators to conduct learning more easily, and students will learn to learn independently and master how to complete written assignments. Technology makes learning easier. Because technology can make learning more engaging, it aims to facilitate learning. Therefore, advanced, reality-based learning materials are appropriate and suitable for fostering student interest in learning mathematics.

Prasetya (2024) said Augmented Reality is a technology that develops information rapidly and is used to facilitate the delivery of information virtually. According to Siregar et al. (2024) using AR in learning can increase students' motivation, involvement, and understanding of teaching materials. AR can also display 3D objects and animations as if they were in a real environment. Current teaching materials and learning processes have not changed and are not yet suited to student characteristics (Maskur & Rakhmawati, 2020) .Many educators have not yet adopted technology and still use conventional teaching materials. Therefore, the availability of teaching materials is a key factor in supporting the success of the learning process (Famulaqih & Lukman, 2024) .

AR-based worksheets are an excellent option for optimizing math learning. If images can move to explain the material being studied, as is commonly used in teaching materials, students will be more engaged in learning math. Research in education and AR development has produced positive findings. These results indicate that AR can be used as a learning tool. Most research about augmented reality in education shows that this technology can help education. This is supported by the study of Siregar et al. (2024) who found that the use of learning media augmented reality has a significant impact. A study by Pathorrahman et al. (2024) , found that using AR applications can enhance

learning by making it more engaging and enriching students' learning experiences. Explanation. This also agrees with Nurvitasari and Sulisworo (2023) AR-based LKPD can be interesting and motivate students to study mathematics. However, the learning media still used a laptop in that study.

Based on the aforementioned explanation, this study focuses on developing a learning medium in the form of an Augmented Reality (AR)-based worksheet designed to be implemented through Android devices. The selection of Android as a platform is grounded in its wide availability and accessibility for students, making this medium more practical to use in the learning process. The integration of AR within the worksheet provides a more interactive and contextual learning experience, as students are not only engaged with static texts and images but can also directly interact with virtual objects displayed through the application. Accordingly, AR-based worksheets are expected to enhance students' learning interest, strengthen conceptual understanding, and support the achievement of more optimal learning outcomes, particularly in mathematics, which is often perceived as abstract and difficult to comprehend. SMP LTI Igm in Palembang, South Sumatra.

2. Method

The research location was SMP LTI Igm in Palembang, South Sumatra. The study was conducted by ninth-grade students, as many as 18 at SMP LTI Igm. This type of research uses research and development methods. *Research and development* methods are used to produce specific products and test the effectiveness of these products (Sudaryono, 2016).

The procedure used in this study is the ADDIE development model. The ADDIE model concept is applied to build basic performance in learning, namely, developing a learning product design (Hidayat & Nizar, 2021). The ADDIE model consists of several stages: analysis*, design, development, implementation, and evaluation* (Pribadi, 2014).

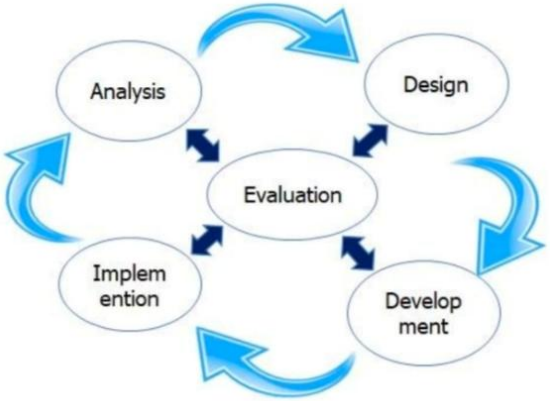


Figure 1. Explaining the ADDIE development model (Dwitiyanti et al., 2020).

In the analysis phase of this research, the researchers analyzed the materials, curriculum, and student needs. They then began developing research instruments and product designs during the design phase. The product was created, validated, and formatively modified in the development phase. Next, implementation and evaluation took place.

Validation sheets collect data on a medium's feasibility and the teaching materials' design. In this case, LKPD is using *augmented reality.* The following is a grid of validation sheets tested in this study. Table 1 shows the LKPD validation sheet, which is designed based on four aspects, namely content and presentation, language, appearance, and usefulness. The content and presentation aspects include indicators of suitability and completeness of the material. Aspects of the accuracy of the text with the material. Aspects of the display include attractiveness, design accuracy, color, font, and image suitability. Practical aspects include ease of use, support of teaching materials for student learning independence, ability to increase learning motivation, and ability to increase knowledge and broaden students' horizons.

Table 1. LKPD Validation Sheet Grid

Aspects	Indicators
Contents & Presentation	Conformity of the material with SK, KD, and indicators The material presented is in line with the learning objectives Material completeness Ease of understanding sample questions Collapse of material presentation Presentation support
Language	Appropriateness of writing and use of letters Straightforward (accuracy of sentence structure and effectiveness sentence) Communicative and motivating sentence structure for students Language suitability with the thinking level of students Ability to encourage participants' curiosity Educate Accuracy of text with material
Display	Early view appeal Display design precision Color and font selection Compatibility between stories, images, and materials.
Benefits	Easy to use Teaching material support for participants' learning independence Educate The ability of teaching materials to increase motivation Learn The ability of teaching materials to increase knowledge and broadening learners' horizons

Source: adopted and modified (Batubara, 2023)

In addition to finding out whether the augmented reality application media is valid, a validation sheet has been prepared. The following is the grid for the Augmented Reality application media validation sheet.

Table 2. Augmented Reality Application Media Validation Sheet Grid

Aspects	Indicators
System Quality	Functionality
	Efficiency
Display Design	Consistency
	Color Usage
	Use of Icons
Augmented Reality	3D Objects
	User Interaction with AR

Table 2 shows the AR media validation sheet compiled based on three aspects, namely system quality, display design, and *augmented reality*. The quality aspects of the system include indicators of functionality and efficiency. The design aspect of the display includes the consistency of color and icon use. Aspects of Augmented Reality include 3D objects and user interaction with AR.

Next, the evaluation test question will be validated to determine whether the questions are valid. The following is a grid for the evaluation test question sheet.

Table 3. Evaluation Test Question Validation Grid

Aspects	Indicators
Content (Content)	Suitability of evaluation techniques with learning objectives
	Instrument equipment
Construction Questions	Presence of instructions
	Clear questions and demand answers
	Variety of questions
	Clarity of images and writing
Augmented Reality	Accuracy of sentence writing
	Appropriateness of language use

Source: Suhardi (2022)

Table 3 shows the validation sheet of the evaluation test questions, which are arranged based on three aspects, namely content, question construction, and language. The content aspect (content) includes the suitability of assessment techniques and the completeness of the instrument. The construction aspect of the question includes the presence of instructions, clear question words, variation of the question, and the image's clarity. The linguistic aspect includes the accuracy of sentence writing and the appropriateness of language use.

The questionnaire given to students allows us to evaluate students' responses to the teaching materials that have been developed. The grid of questionnaire instruments can be seen in Table 4 below:

Table 4. Questionnaire Sheet Grids

Aspects	Indicators
Uses	The use of these teaching materials makes learning more attractive and more effective
	The use of these teaching materials can increase knowledge
Ease	Teaching materials present the material clearly and easily understood
Satisfaction	The teaching materials presented are interesting and fun
	Teaching materials are used according to expectations
Attraction	The design of teaching materials is interesting and adaptive (has high adaptability to the development of knowledge and technology)
	Contains illustrations, pictures, explanations that are in harmony with material

Source: Adopted and modified (Batubara, 2023)

Learning materials support the learning process, making learning more engaging and compelling, and enhancing students' knowledge. The content is presented clearly and efficiently, enabling learners to grasp concepts more effectively. Furthermore, the materials provide satisfaction by offering an enjoyable learning experience that aligns with users' expectations. With an attractive design adaptive to the development of science and technology, as well as illustrations and images consistent with the subject matter, the learning materials possess strong appeal and contribute to improving students' motivation and comprehension.

Interviews with students are conducted after the trial stage of teaching materials to support the data on the practicality and potential effects of the developed teaching materials, as well as a final evaluation for improving the teaching materials developed based on comments and suggestions provided by students.

The test instrument is used to determine the level of students' mastery of the learning materials that have been provided with the teaching materials that have been developed, as well as to find out the potential problem-solving effects of the products that have been developed. The test instruments provided were in the form of 5 written test questions.

Data analysis techniques for validation sheets are given to experts using data obtained in the form of qualitative and quantitative data. Qualitative data is in the form of suggestions and comments given by experts, while quantitative data is in the form of data from the Likert scale assessment. Quantitative data uses *the Likert* scale with an assessment score that can be seen in Table 5.

Table 5. likert Scale Assessment Score

Answer	Score
Strongly agree	5
Agree	4
Enough	3
Disagree	2
Strongly Disagree	1

Source: Sugiyono (2016)

Based on the table above, if the validator gives a very agreeable answer, the result of the score is 5. Agreeing will be given a score of 4, it is enough to be given a score of 3, disagreeing will be given a score of 2, and strongly disagreeing will be given a score of 1. After scoring using the Likert scale, the next step is to categorize the level of validity. Here is a table of validity categories.

Table 6. Validity Categories

Validity Value	Validity Categories
$0 \leq V < 0.4$	Low Validity
$0.4 \leq V < 0.8$	Medium Validity
$0.8 \leq V \leq 1$	High Validity

Source: Istiqomah et al. (2021)

Based Based on Table 6 above, the researcher set the teaching materials' validity target to have a medium validity category in this study. If the teaching materials developed have a low validity category, then the teaching materials will be revised again to reach the medium validity category.

The analysis in the practicality questionnaire is qualitative and quantitative. Qualitative data is in the form of suggestions and comments provided by experts; on the other hand, quantitative data is in the form of data from the results of the Likert scale assessment. It can be seen from a practicality criterion, which can be seen in Table 7.

Table 7. Practicality assessment criteria

Achievement Rate	Categories Practicality
$3.25 < \bar{X} \leq 4.00$	Very Practical
$2.50 < \bar{X} \leq 3.25$	Practical
$1.75 < \bar{X} \leq 2.50$	Impractical
$0 < \bar{X} \leq 1.75$	Very Impractical

Source: Kolo & Muh. (2021)

From Table 7 above shows that teaching materials with *augmented reality technology* are considered practical if they meet the minimum practical criteria and the average score is below 2.50. Furthermore, the analysis of the interview data was carried out by converting the interview results into the form of interview transcripts. Then, after the data is analyzed, it is presented as a discussion.

The students' ability test results will be assessed to determine the potential effects of the developed product. The product developed is considered to have potential if students can achieve a minimum completeness score of 70, and the total percentage of students who pass the required completeness is 70% (Ulfah et al., 2022). Here is a table of completeness categories.

Table 8. Completeness Categories

Interval	Category
$85 \leq H \leq 100$	Very High
$70 \leq H < 85$	High
$55 \leq H < 70$	Keep
$40 \leq H < 55$	Low
$0 \leq H < 40$	Very Low

Based on table 8, if the score falls within the range of 85-100, it is categorized as "Very High", if it is within 70-84, it is considered "High", if it is within 55-69, it belongs to the "Keep" category, if it is within 40-55, it is classified as "Low", and if it is within 0-39, it is categorized as "Very Low".

3. Results and Discussion

3.1 Results

3.1.1 Analysis stage

This analysis stage aims to identify information about mathematics learning, student needs, and any difficult-to-understand material. This analysis is necessary to develop media based on student needs. According to an interview with a math teacher, students still rely on math textbooks and LCD projectors to support their learning. However, these learning media reduce student interest due to the lack of engaging learning.

Initial survey results conducted by the researchers indicated that students expected enjoyable learning. Furthermore, when questioned about the material, students reported a lack of understanding of similarity-related issues. Similarity is a mathematical concept, specifically geometry, which studies the relationships between different shapes and sizes.

Based on the needs analysis and discussions with mathematics teachers, the development of teaching materials focused on creating media to enhance student interest and learning outcomes. Therefore, it was decided that Augmented Reality-Based Student Worksheets (LKPD) were the appropriate teaching materials.

3.1.2 Design Stage

The design stage is the planning stage. Researchers undertake two steps at this stage: developing research instruments and designing the product. Before the teaching materials are implemented with students, they are first evaluated by a validator to determine the validity of the Student Worksheets (LKPD). This instrument uses four aspects: content and presentation, language, appearance, and usability.

After the teaching materials were declared valid, the student worksheets (LKPD) were piloted with students to determine their practicality. They used a questionnaire of four aspects: usefulness, ease of use, satisfaction, and attractiveness. Interviews were also conducted to support the practicality data. To determine their potential impact, researchers administered an evaluation test to students.

The first step in product design is creating a paper-based initial design for the activities included in the LKPD. The second step is AR design, starting with determining the application to create 3D objects and the application to display the AR. The following are the materials needed to complete the application development.

a. Unity Engine 2021 for app creation
b. Vuforia for creating markers, databases, and licenses
c. SketchUp for 3D object creation

The final stage in the design process is designing the Sheet Work Participant Educate use application using Canva. In the first section, the researcher explains the learning objectives,

instructions for using the Student Worksheet (LKPD), core competencies, basic competencies, and competency achievement indicators.

3.1.3 Development Stage

The development phase consists of several stages: product creation, validation, and formative revision.

a. Product Creation

The product creation phase involves several steps. First, the researcher creates AR media. The researcher creates a 3D object using the SketchUp application. The following image shows a 3D object in SketchUp.

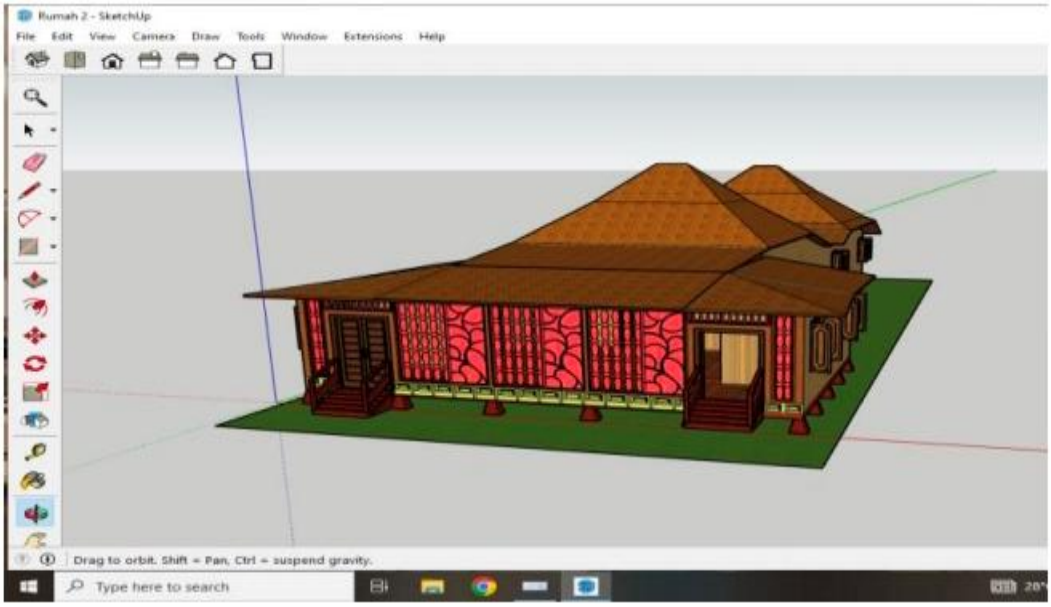
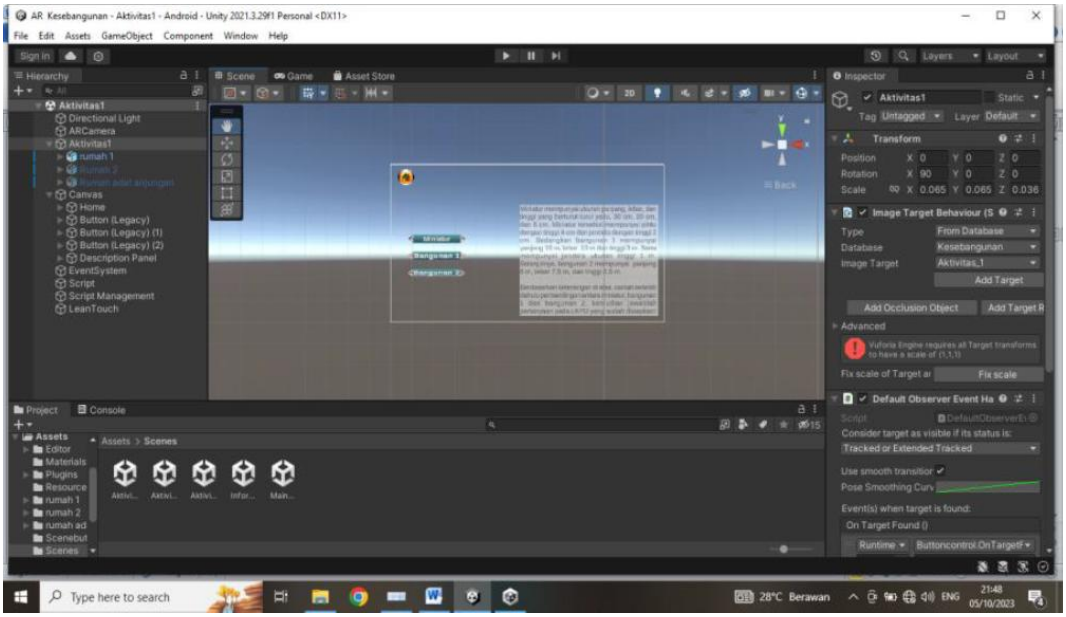


Figure 2. 3D Object View in Sketchup

Next, the 3D objects are imported into the Unity application. Before creating an application in Unity, researchers must obtain a Vuforia license, which will be integrated into Unity. To create an application in Unity, researchers must create a main menu scene and a game scene to display the 3D objects. Then, they program or code the application to get it up and running. Below are screenshots of the scenes and code in Unity.



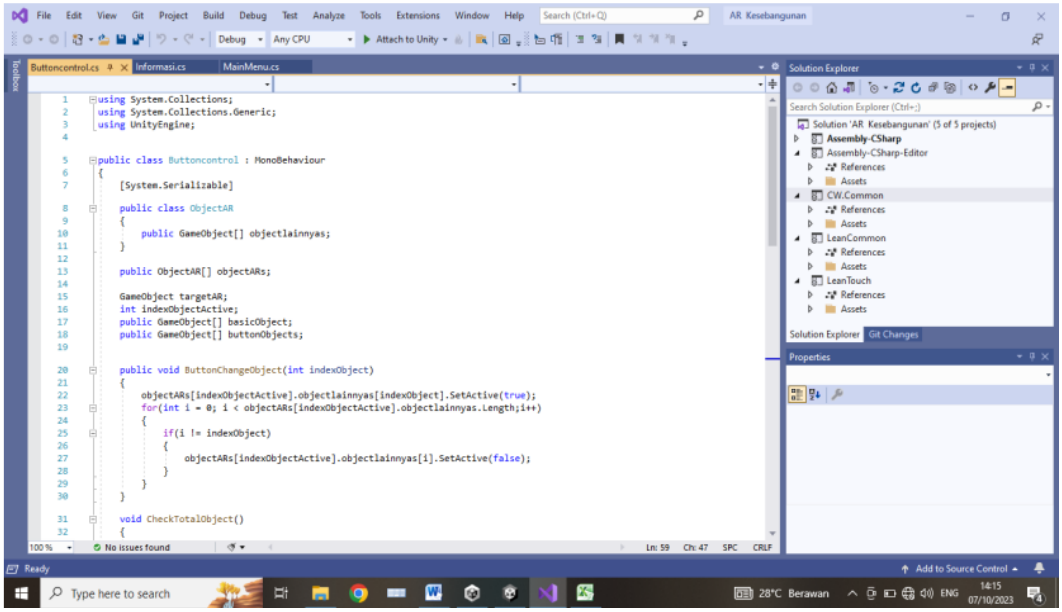


Figure 3. Screenshots of the scenes and code in Unity

b. Product Validation

After creating the teaching materials, the researchers validated them with three expert validators. The validators were selected based on their expertise in their respective fields. Two material experts from the Mathematics Education Study Program served as LKPD validators, and one media expert from the Information Systems Study Program served as the AR application validator. The table below displays the validation results from these experts.

Table 9. Analysis of Expert Validation Results

Validator	Score	Category
Subject Matter Expert 1	0.78	Medium Validity
Subject Matter Expert 2	0.76	Medium Validity
Media Expert	0.8	High Validity
Average score	0.78	Medium Validity

Based on Table 6, the validation results indicate that the evaluation by Subject Matter Expert 1 obtained a score of 0.78, while Subject Matter Expert 2 obtained a score of 0.76. Both sroes fall into the “Medium Validity” Category, suggesting that the material aspect is feasible, although further refinement is still possible. Furthermore, the evaluation by the Media Expert resulted in a score of 0.80, categorized as “High Validity”, indicating that the media aspect is considered highly feasible and supportive of successful learning. Overall, the average validation score was 0.78, classified in the “Moderate Validity” category, which implies that the developed product is suitable for use in the learning process while still allowing opportunities for quality improvement.

One-on-One Test

This face-to-face trial assessed the practicality of the developed LKPD product. The trial was conducted at this stage on six ninth-grade students with high, medium, and low abilities. These students were selected based on their final exam scores.

After the LKPD was piloted, a questionnaire was completed to assess the practicality of the teaching materials. During the individual pilot test, one student commented that using AR-based teaching materials made learning more engaging, but some information in Activity 3 was unclear, making it difficult to understand. The researcher will then make improvements based on the comments and suggestions received during the individual pilot test.

Figure 5. One-on-One Trial

Small Group Test

The small-group trial refined the previous stage, the one-on-one trial. The small-group trial was conducted with nine ninth-grade students based on applicability, appeal, and effectiveness. At this stage, the researcher explained that the developed worksheets were relevant to real-world contexts. The researcher interacted directly with the students and identified difficulties using the teaching materials, which would inform subsequent revisions.

Figure 6. Small Group Trial

During small-group testing, a student commented that their 3D object drawings tended to shift independently and not stay in place. Therefore, the student suggested that the 3D objects should stay in place and not move independently. The researchers will use these suggestions and comments to make improvements.

Field Test

At this stage, researchers will test the practicality and potential impact of using Sheet Work Participant Educate for the subject Research. The LKPD will be piloted on 18 ninth-grade students. However, this field trial will be conducted online due to the implementation of online learning for students in the Palembang area.

After the LKPD was tried out, several students thought that using AR-based LKPD makes Sheet Work Participant Educate more interesting because it can visualize 3D objects. Some students also stated that they could use the worksheet independently, but sometimes they also needed guidance to complete the tasks listed in the worksheet. The following table shows the results of the questionnaire data analysis regarding the AR-based worksheet's feasibility.

Table 10. Analysis of Practicality Questionnaire Results

Level	Score	Category
One on one	4.03	Very Practical
small group	4.36	Very Practical
Field test	4.34	Very Practical
Average score	4.24	Very Practical

The individual trial scored 4.03, while the small group trial scored 4.36. The field trial scored 4.34, resulting in an average practice questionnaire score of 4.24, categorized as very practical based on these three stages. In other words, this augmented reality worksheet is suitable for mathematics learning.

Next, we examined the evaluation test data from this study to determine whether the sheet Work in this AR-based study can influence student learning outcomes. Data on student learning completion is shown in the bar chart below.

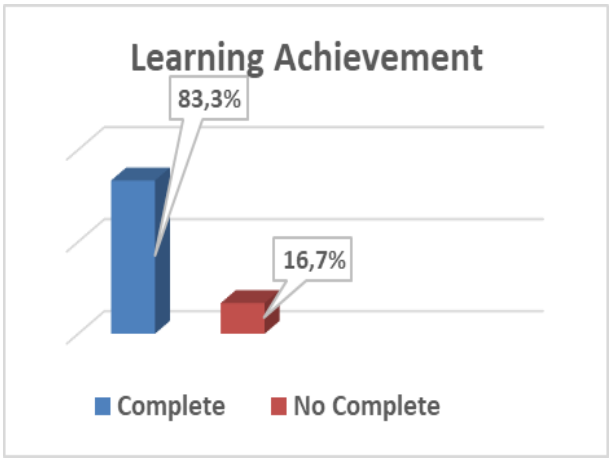


Figure 7. Learning Outcomes.

The The graph above shows that 83.3 % of students completed the evaluation test. However, 16.7% of students were declared ineligible to take the test. This was because 16.7% of students achieved the Minimum Passing Score (KKM). The developed product is considered to have potential effectiveness if students achieve a minimum passing score of seventy, and the total percentage of students who pass the required passing score is seventy percent. (Ulfah et al., 2022) . This matter show that augmented reality-based LKPD can improve student learning outcomes.

3.1.4 Implementation Stage

After the LKPD product has been tested in the previous stage and deemed practical and potentially impactful, the LKPD is suitable for implementation in a real-life learning environment. The teaching materials are then handed over to teachers for application in the learning process.

In this stage, students use their smartphones to work on AR-based worksheets, while in the previous stage, students only used the group representative's smartphone. Learning using Augmented Reality technology makes students more enthusiastic and involved because AR media can display 3D objects and make it easier to understand the material.

3.1.5 Evaluation Stage

This evaluation stage is carried out to review things related to AR-based LKPD development. Stage: This is done to analyze the strengths and weaknesses of the teaching materials that have been tested. Through the results of the trials, questionnaires, and interviews related to AR-based LKPD with grade 9 students, it can be concluded that AR-based student worksheets (LKPD) have practical value and the potential to impact student learning outcomes. This is because AR can display 3D objects in real time, making it easier for students to understand the concept of similarity and making the learning process more engaging and less boring.

Based on observations during the implementation of the AR-based worksheet, they found that it could not be implemented on devices other than Android. Students using iOS devices could not access the AR contained in the worksheet. This was a weakness of the AR-based worksheet they had developed.

3.2 Discussion

Augmented reality-based teaching materials are said to be engaging because they can directly display 3D objects. This is done using the context of the limas house, a traditional house and culture from South Sumatra. The cohesion between mathematics and culture is known as ethnomathematics. (Wulanda & Widiyasari, 2024). Thus, through AR-based LKPD sheets in the context of the Limas House, students can learn mathematics while learning about South Sumatra's culture and traditional houses. This aligns with research conducted by Sulfayanti et al. (2022) which states that by integrating the Limas House as a South Sumatran culture in learning, it is hoped that students will understand mathematical concepts and appreciate their ancestral culture and heritage. Gustina et al. (2025) also said combining AR and ethnomathematics deepens students' reasoning and encourages meaningful and culturally relevant learning experiences.

AR-based worksheets will help students understand the concept of similarity because they display a Limas House in 3D and directly. The use of teaching materials has a significant impact on the learning process. Students often struggle to grasp the concepts and problems presented because they lack a concrete context, leading them to simply imagine the context without directly seeing it. This aligns with the findings of Fauzi and Arisetyawan (2020). that the difficulties of learning mathematics are conveyed in an informative manner, meaning that students only get information from the teacher's explanation.

AR-based student worksheets (LKPD) support students' understanding of concepts and problems. This is because the application of AR technology in learning can display virtual objects projected into the real world. This statement aligns with Safari and Sabila's (2024) statement that learning using visual aids such as 3D objects allows students to connect abstract concepts with real-world situations. Omurtak and Zeybek (2022) also concluded that students enjoy using AR applications because AR applications make abstract concepts tangible and make learning more enjoyable.

This augmented reality-based teaching material can be accessed using a smartphone. 3D objects will appear on the smartphone screen after scanning the barcode on the worksheet. This allows students to access AR using their smartphones without working in groups. However, in this study, Nurvitasari and Sulisworo (2023) found that AR operations in learning still use laptops.

AR media is crucial in mathematics for presenting complex concepts. Students enjoy completing activities in worksheets and following instructions throughout the learning process. AR methods can enhance students' specific abilities while producing better learning outcomes than conventional methods (Velazquea & Mendez, 2021) . Some students, who see 3D objects appear through AR technology, immediately understand the instructions and complete the worksheets, but others remain confused. Maximizing the benefits of AR for students in learning mathematics requires a more wide-ranging approach in its implementation (Gusteti et al., 2023) .

Students' progress in learning to solve problems independently has been enhanced through the use of Sheet Work participant, an Augmented Reality-based participant. AR allows mathematics to be taught contextually and interactively, increasing student engagement and understanding (Estapa & Nadolny, 2022) . Furthermore, research results show that students prefer to participate in augmented reality-based worksheets during the learning process. AR makes learning more engaging and effective. Students are enthusiastic about learning because AR technology can display 3D objects in the real world.

The results of the student evaluation test showed an increase in the percentage of student learning achievement scores after using LKPD, which indicates the potential impact of LKPD based

on Augmented Reality. This is also in line with the study by Darmansyah et al. (2024) which states that the use of AR media has a positive and significant influence on improvement results in student studies on eye science lessons for class VIII. Ikmawati et al. (2024) also studied the use of Augmented Reality in mathematics subjects, including nets of cubes and cuboids, which has been demonstrated. AR media supports learning outcomes, with students' average grades increasing from 70 to 85. Therefore, several studies have shown that using Augmented Reality media in the learning process can improve student interest and learning outcomes. This is because AR makes learning more engaging and easier to understand.

4. Conclusion

This study successfully developed a Student Worksheet (LKPD) based on *Augmented Reality* (AR) using the enthnomathematic context of the limas house for teaching the concept of similarity. The findings indicate that the developed product meets the criteria of validity, demonstrates a very high level of practicality, and shows effectiveness through its potential effect on students' mastery of learning outcomes. These results highlight that integrating AR with ethnomathematics as an LKPD can provide students with a more contextual, interactive, and meaningful learning experience.

The novelty of this research lies in the combination of three aspects: the use of AR technology, the integration of the Limas House as a representation of local cultural ethnomathematics, and its implementation on the Android platform. This combination enriches mathematics learning resources and demonstrates that culturally grounded and technologically supported learning media can be innovative alternatives to improve students' interest and understanding of mathematics.

Nevertheless, this research has several limitations. The product is only accessible on Android-based devices, limiting its use across other platforms such as iOS. In addition, the AR features occasionally face technical instability, which may disrupt the learning process. The scope of the material is also restricted to the concept of similarity, and the study was conducted only at the Grade IX Junior High School level, making it less generalizable to other educational contexts.

Future research is recommended to expand the coverage to other mathematics topics, such as solid geometry or algebra, and to develop compatibility with multiple platforms, including iOS. Further trials should also be conducted at different educational levels, such as elementary and senior high schools, to test its effectiveness across various stages of student development. Improving the technical stability and responsiveness of the AR system is also essential to enhance accessibility and usability for teachers and students. This study provides a foundation for developing innovative learning materials that combine modern technology with local cultural wisdom in mathematics education.

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