

DEVELOPMENT OF AUGMENTED REALITY-BASED LEARNING MEDIA ASSISTED BY ASSEMBLR EDU TO IMPROVE STUDENTS MATHEMATICAL UNDERSTANDING SKILLS

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ABSTRACT

This study was motivated by the low mathematical understanding ability of students due to the lack of use of interactive learning media. Augmented Reality through the Assemblr Edu platform was chosen as an innovation to improve these abilities. The purpose of this study is to determine the level of validity, practicality, and effectiveness of Augmented Reality-based learning media assisted by Assemblr Edu to improve students' mathematical understanding skills. The research followed a development approach, specifically Research and Development (R&D), using the ADDIE model (Analyze, Design, Development, Implementation, Evaluation). The study involved 37 students from class XI IPA 4 at MAN 1 Kota Serang, selected through purposive sampling. Data collection instruments included validation sheets, response questionnaires, and mathematical understanding skills test sheets. Data were analyzed using both qualitative and quantitative descriptive methods. The learning media was rated as highly valid by three material experts and three media experts, achieving validity percentages of 83.67% and 88.77%, respectively. The practicality of the media is categorized as practical through teacher and student assessments with a practicality score of 79.41% and 78.26% respectively. The media's effectiveness, as measured by an N-Gain score of 0.56 (56% effectiveness interpretation), was further supported by the paired t-test results ($t_{count} > t_{table}$), indicating a significant positive impact on students' mathematical understanding. These findings suggest that the developed learning media is valid, practical, and effective for enhancing students' mathematical understanding skills.

Keywords: augmented reality; mathematical understanding ability; learning media; research and development

ABSTRAK

Penelitian ini dilatarbelakangi oleh rendahnya kemampuan pemahaman matematis siswa akibat minimnya penggunaan media pembelajaran interaktif. Augmented Reality melalui platform Assemblr Edu dipilih sebagai inovasi untuk meningkatkan kemampuan tersebut. Tujuan dari penelitian ini adalah untuk mengetahui tingkat kevalidan, kepraktisan, dan keefektifan media pembelajaran berbasis Augmented Reality berbantuan Assemblr Edu untuk meningkatkan kemampuan pemahaman matematis siswa. Penelitian ini menggunakan pendekatan pengembangan, yaitu Research and Development (R&D), dengan menggunakan model ADDIE (Analyze, Design, Development, Implementation, Evaluation). Subjek dalam penelitian ini berjumlah 37 siswa kelas XI IPA 4 MAN 1 Kota Serang yang dipilih berdasarkan purposive sampling. Instrumen pengumpulan data meliputi lembar validasi, angket respon, dan lembar tes kemampuan pemahaman matematis. Data dianalisis menggunakan metode deskriptif kualitatif dan kuantitatif. Media pembelajaran dinyatakan sangat valid berdasarkan penilaian dari tiga ahli materi dan tiga ahli media, dengan persentase kevalidan secara berturut-turut sebesar 83,67% dan 88,77%. Kepraktisan media dikategorikan praktis melalui penilaian guru dan siswa dengan nilai kepraktisan masing-masing sebesar 79,41% dan 78,26%. Efektivitas media yang diukur dengan skor N-Gain

sebesar sebesar 0,56 (interpretasi efektivitas 56%) juga didukung oleh hasil uji *t*-paired ($t_{hitung} > t_{tabel}$), yang menunjukkan adanya pengaruh positif yang signifikan terhadap pemahaman matematika siswa. Temuan ini menunjukkan bahwa media pembelajaran yang dikembangkan valid, praktis, dan efektif untuk meningkatkan kemampuan pemahaman matematis siswa.

Kata kunci: *augmented reality*; kemampuan pemahaman matematis; media pembelajaran; penelitian dan pengembangan.



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Introduction

Mathematics is a fundamental subject in the education curriculum that plays a crucial role in the intellectual development of students. Proficiency in mathematics is essential for cultivating practical and critical thinking skills, which are necessary for solving complex problems and understanding other fields of study (Nurulaeni & Rahma, 2022). Furthermore, mathematics contributes importantly to the advancement of technology, science, and innovation that is indispensable in the current era (Daimah & Suparni, 2023). Therefore, strong mathematical skills are vital for academic and professional success.

The ability to understand mathematics is a critical component of the learning process, as it encompasses students' skills in interpreting, analyzing, and applying mathematical concepts effectively in various contexts. This goes beyond the mere memorization of formulas, involving the comprehension of the underlying principles of mathematical concepts, which allows students to construct deeper and more applicable knowledge. However, various studies indicate that students' mathematical understanding skills in Indonesia remain low. This can be attributed to the use of conventional teaching methods that are less interactive and fail to engage students actively in the learning process (Ammar, Khairina, & Hafriani, 2024; Kandaga, 2024).

The results of the 2022 PISA survey revealed a decline in the mathematical abilities of Indonesian students, as evidenced by a drop of 13 points in the average math score, from 366 in 2018 to the current level. The survey also indicated that almost no Indonesian students reached Level 5 or higher, with only 0.1% of male students and 0.0% of female students achieving this level, significantly lower than the OECD average of 10.5% for male students and 6.8% for female students (OECD, 2023). Level 5 or above tasks involve modeling complex problems mathematically and selecting, comparing, and evaluating problem-solving strategies appropriately, areas in which Indonesian students are relatively weak. According to Suraji, Maimunah, & Saragih (2018), mathematical problem-solving ability is positively correlated with concept-understanding ability, suggesting that the low problem-solving ability observed among Indonesian students may stem from insufficient understanding of mathematical concepts.

The role of learning media cannot be separated from learning. According to AECT in (Asnawir & Usman, 2002), any form used to disseminate information is called media. Kristanto (2016) emphasized that every learning media functions as a means to achieve learning objectives. Gagne, Briggs, & Wager, (1992) explain that various physical tools used to convey the content of the subject matter include

books, audio tapes, videos, videotapes, films, slides, pictures, charts, televisions, and computers.

In the digital era, technological advancements have driven innovations in education, particularly in developing interactive and engaging learning media. One of the most recent innovations is the use of Augmented Reality (AR) technology, which enables users to interact with three-dimensional visual content directly in real-world environments (Belda-Medina & Calvo-Ferrer, 2022). AR can bridge the gap between abstract mathematical concepts and visual understanding, offering students a more immersive learning experience (Salinas et al., 2013). The implementation of this technology is expected to address existing learning challenges, such as low student engagement and limited conceptual comprehension.

Preliminary interviews with mathematics teachers at MAN 1 Kota Serang reveal that students' understanding of basic mathematical concepts is low, resulting in subpar academic performance. The current learning media used in the school primarily rely on conventional methods, such as textbooks and simple presentations, which fail to engage students effectively and do not promote interactive, experience-based learning. In learning, not only mathematical material but also problem-based learning is very important to implement (Agustina & Vahlia, 2017). Prior to the introduction of Augmented Reality (AR) technology, pretest results indicated that students' understanding of mathematical material was at a low level, particularly for abstract concepts that require deep visualization.

In this context, Assemblr Edu was chosen as a learning tool due to its key features, including interactive three-dimensional object visualization, the ability to integrate multimedia content (such as text, images, and videos), and convenient access through smartphone devices (Oktaviana & Jasril, 2023). These features provide significant potential to create more engaging learning experiences and make it easier for students to grasp mathematical concepts in depth.

Previous research has demonstrated that the implementation of augmented reality (AR)-based technology in education can enhance learning outcomes and increase student motivation. Larasati & Widyasari (2021) found that AR-based media significantly improved students' understanding of science and mathematics concepts. Similarly, Anggraini, Suastika, & Triwahyuningtyas (2024) reported that the use of AR in learning activities increases students' interest in the material being taught, thereby positively influencing their critical and conceptual thinking abilities. However, most existing studies are limited to the application of AR technology without integrating platforms specifically designed for educational purposes, which hinders its accessibility and effectiveness in formal learning environments. Consequently, this study utilizes Assembler Edu, an AR-based learning platform that facilitates the creation of interactive content and provides access across various devices.

Based on the identified problems, this study aims to develop Augmented Reality-based learning media assisted by Assembler Edu that is valid, practical, and effective in significantly enhancing students' mathematical understanding skills. Mathematics learning is not only oriented to improving student learning outcomes, but must also be oriented to improving problem-solving abilities (Komariya,

Farida & Vahlia, 2018). The anticipated outcomes of this media development include the validation of its effectiveness in increasing student engagement and comprehension of mathematical material. Ultimately, this media is expected to contribute meaningfully to efforts aimed at improving the quality of mathematics education.

Research Methods

This study employs development research, commonly referred to as Research and Development (R&D), utilizing the ADDIE development model, which encompasses five stages: Analyze, Design, Develop, Implement, and Evaluate. The ADDIE model, specifically applied in the context of learning media development, aims to produce products and procedures that undergo systematic field testing, evaluation, and refinement. This ensures that the outcomes align with the desired criteria of validity, practicality, effectiveness, and established standards (Suryani, Setiawan, & Putria, 2018). The cyclical stages of the ADDIE model are illustrated in Figure 1.

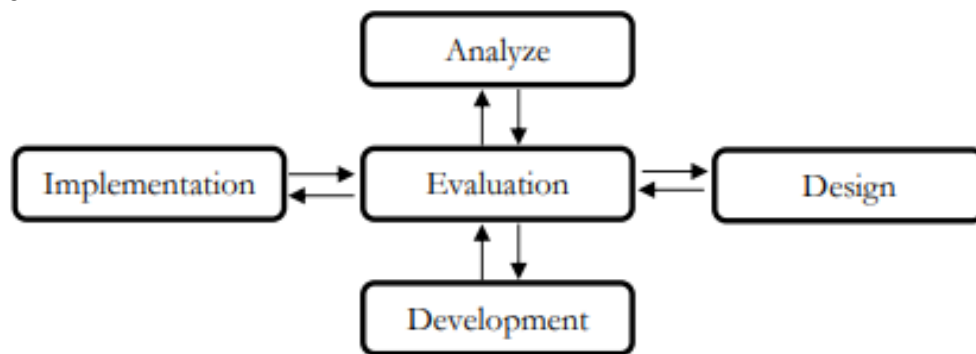


Figure 1. Development stages of ADDIE model

The research subjects were 37 students from class XI at MAN 1 Kota Serang, selected through purposive sampling. The research object was AR-based learning media developed using Assembler Edu. Data collection used are interviews, questionnaires, tests, and documentation. The instruments used are non-test and test instruments. The non-test instrument consists of a validation questionnaire sheet by material and media experts and a practicality questionnaire sheet by teacher and student responses, while the test instrument is in the form of a mathematical understanding ability test. Validation by material experts aims to evaluate the feasibility of content, presentation, benefits, and language, while validation by media experts assesses the feasibility of media design, system quality, and Augmented Reality. Assessment of the practicality of learning media is done through teacher responses, which include aspects of appearance design, material, language, and benefits, as well as student responses that include appearance, use, presentation of material, language, and benefits.

The mathematical understanding ability test was conducted to evaluate the effectiveness of the Augmented Reality-based learning media. This test was administered both before learning (pretest) and after learning (posttest) using the media. The test comprised questions aligned with indicators of mathematical understanding, which include: (1) restating a mathematical concept, (2) providing examples and non-examples of a mathematical concept, (3) classifying objects

based on whether they meet the requirements of the concept, (4) applying concepts algorithmically, (5) presenting mathematical representations of a concept, and (6) applying a concept to solve problems.

The data analysis techniques used in this research include qualitative data analysis techniques and quantitative descriptive analysis techniques. A qualitative analysis technique was conducted to process data from pre-research interviews to analyze the curriculum, student characteristics, and needs, as well as comments and suggestions for improvement given by material and media experts. Meanwhile, quantitative descriptive analysis was used to assess media quality criteria based on aspects of validity, practicality, and effectiveness. The level of validity and practicality was analyzed using the following formula and the percentage results were interpreted based on the validity and practicality categories listed in Table 1.

$$P = \frac{\sum \text{score per item}}{\text{maximum score}} \times 100\% \dots\dots (1)$$

Table 1. Categories of validity and practicality of learning media

| Percentage Interval | Category |
|-------------------------|-------------------------------|
| $80\% < V \leq 100\%$ | Very Valid/Very Practical |
| $60\% < V \leq 80\%$ | Valid/Practical |
| $40\% \leq V \leq 60\%$ | Quite Valid / Quite Practical |
| $20\% < V \leq 40\%$ | Less Valid / Less Practical |
| $0\% \leq V \leq 20\%$ | Not Valid / Not Practical |

(Arikunto & Jabar, 2007)

The level of effectiveness of learning media is determined based on pretest and posttest data obtained from student learning outcomes. N-Gain calculation is used to measure the increase in value between pretest and posttest, with the following formula:

$$(g) = \frac{S_{post} - S_{pre}}{S_{maks} - S_{pre}} \dots\dots (2)$$

Description:

(g) : N-gain index

S_{post} : Posttest score

S_{pre} : Pretest score

S_{maks} : Maximum score idea

The results of the N-Gain value are then determined based on the criteria shown in Table 2 below:

Table 2. Criteria for n-gain

| N-Gain Score | Criteria for N-Gain |
|----------------------------|---------------------|
| $N-Gain < 0,3$ | Low |
| $0,3 \leq N-Gain \leq 0,7$ | Medium |
| $0,7 < N-Gain$ | High |

(Sukarelawan, Indratno, & Ayu, 2024)

The N-Gain Score results obtained were then converted to a percentage to assess the effectiveness of the product. The classification of effectiveness refers to Table 3 below:

Table 3. Classification of learning media effectiveness

| Percentage Achievement Level | Classification |
|------------------------------|----------------------|
| $P < 40\%$ | Not effective |
| $40\% \leq P \leq 55\%$ | Less effective |
| $56\% \leq P \leq 75\%$ | Moderately effective |
| $P > 75\%$ | Effective |

(Sukarelawan, Indratno, & Ayu, 2024)

To test the significance of differences in pretest and posttest results, the t-paired test was used. The formula of the t-paired test according to Sugiyono (2013) with the formula:

$$t_{count} = \frac{\bar{X}_2 - \bar{X}_1}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2} - 2r\left(\frac{S_1}{\sqrt{n_1}}\right)\left(\frac{S_2}{\sqrt{n_2}}\right)}} \dots (3)$$

Description:

\bar{X}_1 = the average value of the sample before the media is applied (pretest)

\bar{X}_2 = the mean value of the sample after the media is applied (posttest)

S_1 = standard deviation before the media is applied

S_2 = standard deviation after the media is applied

n_1 = number of students before the media is applied

n_2 = number of students after the media is applied

Calculating the t_{table} is done by determining the significance value $\alpha = 0,05$ and the degree of freedom ($df = n - 1$). This study uses the hypothesis:

- H_0 : There is no significant improvement in students' mathematical understanding ability after the application of AR-based learning media assisted by Assemblr Edu.
- H_a : There is a significant improvement in students' mathematical understanding ability after the application of AR-based learning media assisted by Assemblr Edu.

The calculation results are compared with the rule:

- If $t_{count} \leq t_{table}$, then H_0 is accepted and H_a is rejected
- If $t_{hitung} > t_{tabel}$, then H_0 is rejected and H_a is accepted

Results and Discussion

The product developed in this study is Augmented Reality-based learning media assisted by Assemblr Edu to improve students' mathematical understanding skills. The following is a description of the product development process based on the ADDIE model.

Analyze Stage

The analysis stage involved curriculum analysis, needs analysis, and an analysis of student characteristics. This process was based on preliminary

observations conducted through interviews with teachers and students at MAN 1 Kota Serang. Curriculum analysis focused on the curriculum implemented at the school, namely the 2013 curriculum, and identified the third-dimensional material as the subject matter, which revealed challenges in students' mathematical understanding skills. Needs analysis, conducted with input from teachers, highlighted the necessity of learning media that leverage technology to enhance interactivity and improve students' comprehension of abstract mathematical concepts through more concrete visualizations. The analysis of student characteristics revealed a positive attitude toward the use of technology, including smartphone applications, in both daily life and learning contexts. However, it was noted that applications utilizing Augmented Reality technology had not yet been integrated into the learning process.

Based on the analysis stage, it was concluded that Augmented Reality-based learning media is required for teaching three-dimensional material to enhance students' mathematical understanding skills.

Design Stage

The second stage of the ADDIE development model is the design stage, which involves creating the initial design of the product and its development process. This stage begins with the preparation of the main tools, namely the Assemblr Edu account integrated with Assemblr Studio, as well as supporting tools such as Blender, Canva, and Sketchfab. The selection of Assemblr Edu as the operational application for the product is based on its user-friendly interface and its ability to create Augmented Reality-based media without requiring any coding. In this stage, a flowchart is designed to visualize the flow of the learning media. The flowchart of Assemblr Edu usage is depicted in Figure 2.

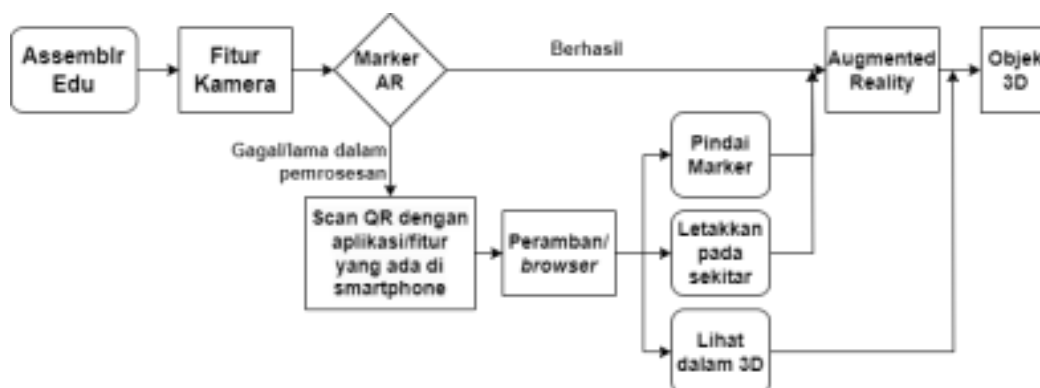


Figure 2. Flowchart of using assemblr edu

In its implementation, users have two options for marker scanning. The first option is to use the camera feature in the Assemblr Edu application, which is directed at the AR target marker. The second option involves utilizing the smartphone's QR scanner, which is directed at the center of the marker if the initial scanning process fails or is slow. This scanning process will open a browser that provides three options: viewing objects in 3D, scanning markers, and placing objects in the surrounding environment (markerless).

Development Stage

The third stage is the development stage, during which researchers create Augmented Reality-based learning media according to the previously established design. The resulting AR markers are divided into eight parts, namely: understanding three-dimensional elements, projection of distances between points, projection of the distance from a point to a line, projection of the distance from a point to a plane, application of distance concepts, practice questions, and discussions. This division of markers is implemented to optimize the efficiency of the learning media's data size and performance. The display of the developed AR-based media is presented in Figures 3–4.

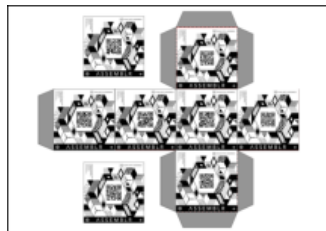


Figure 3. ARealm marker



Figure 4. ARealm class view

The developed learning media is named "ARealm," derived from the terms "AR" (Augmented Reality) and "Realm" (field), reflecting its aim to present complex and realistic visuals, allowing users to interact directly with objects in space. As shown in Figure 3, the AR markers are arranged in a cube shape, consisting of eight markers designed to display 3D objects in AR, aligned with the workflow illustrated in Figure 2. Additionally, the Assemblr Edu application features an online class function to enhance the flexibility of the student learning process, as shown in Figure 4, with the ARealm class code "yxaqw."

Of the eight AR markers, the following development outcomes were produced using Assemblr Studio. The resulting learning media, as developed by the researchers, is displayed in Figures 5–9.

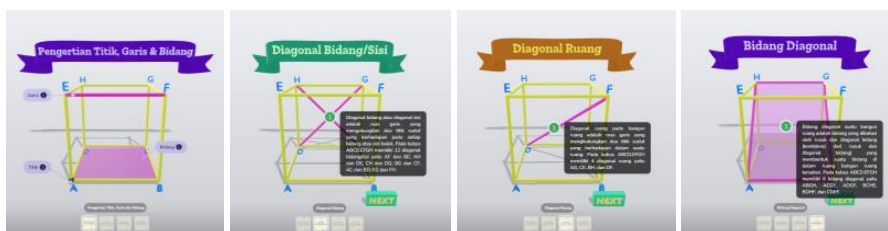


Figure 5. Contents marker understanding of the elements in building space

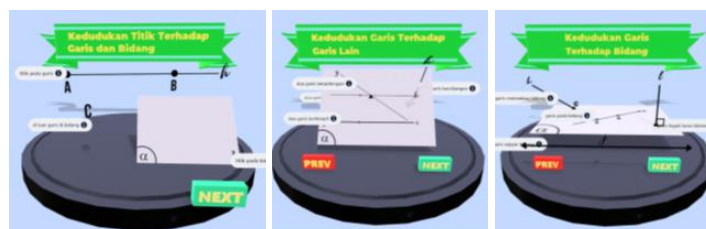


Figure 6. Contents marker position of the point, line, and plane

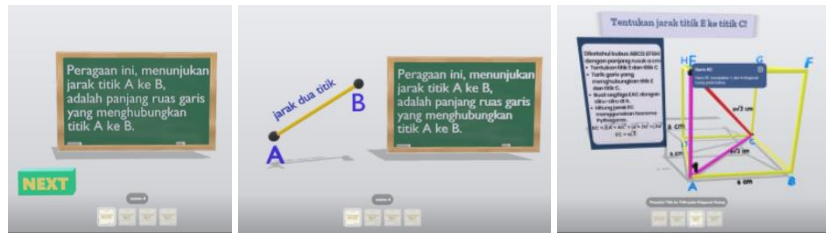


Figure 7. Contents marker projection distance point to point

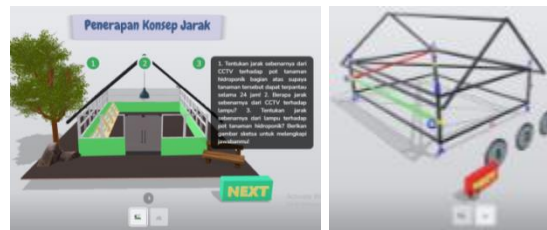
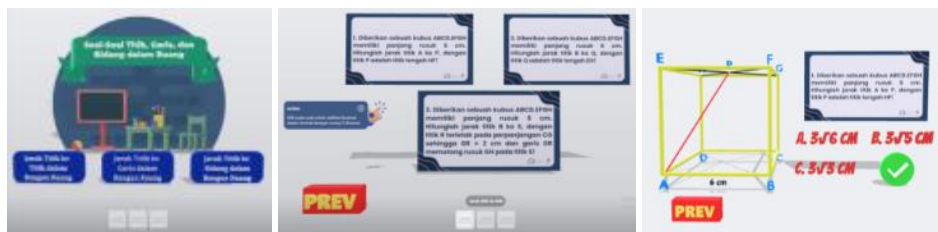


Figure 8. Contents marker application of the concept of distance



Gambar 9. Contents marker distance problems point, line, and plane

After the learning media was developed, validation tests were conducted with material and media experts to determine the validity of the Augmented Reality-based learning media. Validation by three material experts assessed four aspects: content/material feasibility, presentation feasibility, benefits, and language. The results of the material expert validation assessment are presented in Table 4.



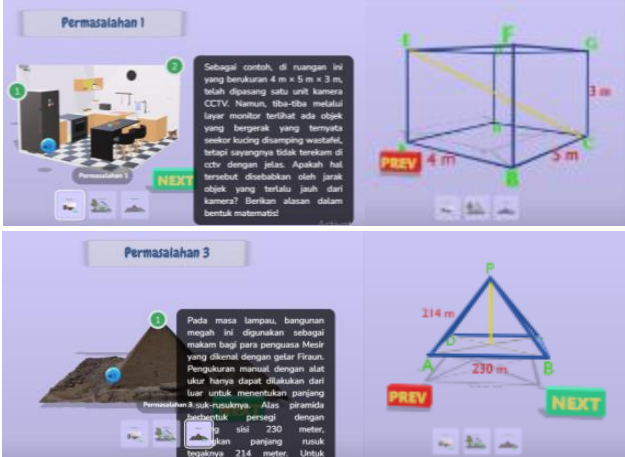
Table 4. Material expert validation results

| Aspect | Validator | | | Raw Score | Ideal Score | Percentage | Category |
|---|-----------|----|----|-----------|-------------|------------|------------|
| | 1 | 2 | 3 | | | | |
| Content/Material Feasibility | 46 | 54 | 56 | 156 | 192 | 81,25% | Very Valid |
| Presentation Feasibility | 16 | 17 | 19 | 52 | 60 | 86,67% | Very Valid |
| Benefits | 7 | 8 | 8 | 23 | 24 | 95,83% | Very Valid |
| Language | 7 | 6 | 7 | 20 | 24 | 83,33% | Very Valid |
| Final Percentage of Material Expert Validation | | | | 251 | 300 | 83,67% | Very Valid |

Based on Table 4, the final percentage of the material expert validation results was 83.67%, which falls into the "very valid" category, indicating that the learning media is suitable for testing with revisions. Suggestions for improvement from the material experts included enhancing the quality of the material and exercises to align with Higher Order Thinking Skills (HOTS) by adding a variety of practice questions focused on the application of distance concepts, emphasizing

literacy to promote a deeper understanding. The revisions made based on the material experts' suggestions are presented in Table 5.

Table 5. Revision results based on material expert comments

| Comments and Suggestions for Improvement | |
|--|---|
| Before Revision | After Revision |
| Addition of markers on the material of the application of the concept of distance (There isn't any) |  |
| Addition of two questions/exercises in the form of stories or real life | |
|  |  |

Validation was also conducted by three media experts, covering three aspects: display design, system quality, and Augmented Reality features. The results of the media expert validation assessment are presented in Table 6.

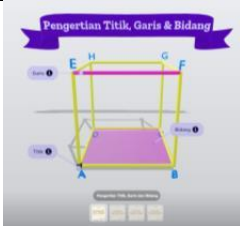
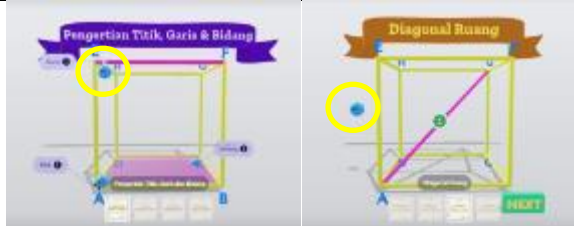

Table 6. Media expert validation results

| Aspect | Validator | | | Raw Score | Ideal Score | Percentage | Category |
|--|-----------|----|----|------------|-------------|---------------|-------------------|
| | 1 | 2 | 3 | | | | |
| Display Design | 49 | 48 | 56 | 153 | 168 | 88,69% | Very Valid |
| Sistem Quality | 13 | 14 | 16 | 43 | 48 | 87,50% | Very Valid |
| Augmented Reality | 18 | 16 | 20 | 54 | 60 | 90,00% | Very Valid |
| Final Percentage of Media Expert Validation | | | | 250 | 276 | 88,77% | Very Valid |

Based on Table 6, the final percentage of the media expert validation results was 88.77%, which falls into the "very valid" category, indicating that the learning media is suitable for testing with revisions. The media experts suggested improvements, including diversifying the 3D objects to enhance relevance, modifying the access to the discussion of questions, and adding explanatory

sounds to facilitate students' understanding of the material. The revisions made based on the media experts' suggestions are presented in Table 7.

Table 7. Revision results based on media expert comments

| Comments and Suggestions for Improvement | |
|--|---|
| Before Revision | After Revision |
| Addition of sound feature | |
|  |  |
| Changes in access to the discussion section of the question that will appear at the end of the question | |
| (A separate marker has been created for the discussion of questions, which is now integrated with the discussion on the application of distance concepts.) |  |

Implementation Stage

The implementation stage aimed to assess the practicality and effectiveness of the developed learning media. The implementation involved one math teacher and 37 students from MAN 1 Kota Serang. Both teachers and students completed a response questionnaire to evaluate the practicality of the product. Additionally, students took pretest and posttest questions to measure the effectiveness of the product. The results of the teacher's response assessment are presented in Table 8.

Table 8. Teacher response results

| Aspect | Score obtained | Maximum score | Percentage |
|--------------------|-----------------------|----------------------|-------------------|
| Display Design | 20 | 24 | 83,33% |
| Material | 12 | 16 | 75,00% |
| Language | 12 | 16 | 75,00% |
| Benefits | 10 | 12 | 83,33% |
| Final Score | 54 | 68 | 79,41% |

Based on Table 8, the assessment results from the math teacher at MAN 1 Kota Serang indicate that the product is practical, with a percentage of 79.41%. This suggests that the learning media is suitable for teaching mathematical material in the third dimension. Meanwhile, the results of the student responses are shown in Table 9 below:

Table 9. Student response results

| Aspect | Score obtained | Maximum score | Percentage |
|--------------------------|----------------|---------------|---------------|
| Display | 252 | 296 | 85,14% |
| Usage | 332 | 444 | 74,77% |
| Presentation of Material | 339 | 444 | 76,35% |
| Language | 123 | 148 | 83,11% |
| Benefits | 228 | 296 | 77,03% |
| Final Score | 1274 | 1628 | 78,26% |

Based on Table 9, the results of the student response questionnaire indicate a final percentage of 78.26%, which falls within the practical category. These results suggest that the Augmented Reality-based learning media is considered engaging and beneficial for students in learning mathematics, particularly in three-dimensional topics. This finding aligns with the research by Suliyono, Pranyata, & Yuwono (2022), which shows that AR-based learning media is highly practical for facilitating the learning of three-dimensional materials. The practicality of the display and language aspects received percentages of 85.14% and 83.11% respectively, which are higher than those of other aspects. Students reported that the display of the learning media is visually appealing and aids in understanding complex mathematical concepts through the three-dimensional illustration feature. The three-dimensional visualization in AR media allows students to interact directly with abstract objects, which is consistent with constructivism theory. According to this theory, meaningful learning occurs when students actively construct their understanding through direct experience (Sugrah, 2019). This finding is supported by the research of Fauziyah, Sugiman, & Munahefi (2024), which indicates that the use of AR can enhance student engagement and stimulate interest in learning mathematics. Furthermore, the use of clear and precise language enables students to follow instructions and grasp mathematical concepts without confusion. This aligns with the research of Auwaliyah, Sahrina, Soekamto, & Masruroh (2023), which highlighted that appropriate writing improves students' ability to identify the key language in reading materials.

The practicality of the aspects of use, material presentation, and benefits received percentages of 74.77%, 76.35%, and 77.03%, respectively. These results indicate that AR media is considered practical and effectively meets students' needs in the mathematics learning process. In terms of usability, this media is easily accessible via common devices such as smartphones or computers, which supports accessibility, although it is influenced by each student's network speed. Regarding material presentation, AR helps reduce students' cognitive load, allowing them to focus on understanding core concepts without being overwhelmed by excessive information (Afidah, 2015 ; Kairu, 2021). The question and discussion features are designed to reinforce students' understanding. In the benefits aspect, AR media aids students in solving mathematical problems relevant to real-life situations, ultimately enhancing their critical and analytical thinking skills. This aligns with the findings of Maulana & Rafianti (2023), who state that the use of AR significantly contributes to developing students' problem-solving abilities.

The mathematical understanding ability test was conducted before the application of learning media (pretest) and after its application (post-test). This step aimed to assess the effectiveness of the Augmented Reality-based learning media using Assembler Edu. The results of the students' pretest and post-test scores are presented in Table 10.

Table 10. Recapitulation of mathematical understanding ability test results

| Test | Lowest Score | Highest Score | Average | Variance |
|----------|--------------|---------------|---------|----------|
| Pretest | 14,29 | 42,86 | 28,83 | 103,23 |
| Posttest | 38,10 | 90,48 | 68,47 | 205,76 |

Based on Table 10, the average pretest score of 28.83 increased to 68.47 in the post-test, indicating an improvement in student understanding following the treatment. Additionally, the variance in scores increased from 103.23 in the pretest to 205.76 in the post-test, suggesting that some students experienced a more significant improvement in their understanding than others, leading to a wider variation in results. Therefore, while overall understanding increased, there was greater variability in the level of understanding across students.

After obtaining the pretest and post-test results, the next step is to analyze the N-Gain to measure the improvement in students' mathematical understanding after using the learning media. The N-Gain Score recapitulation is presented in Table 11 as follows:

Table 11. N-gain score results

| N-Gain Score Limit | Criteria | Frequency | Average N-Gain Score | Percentage | Classification |
|-----------------------------------|----------|-----------|----------------------|------------|-------------------------|
| $N\text{-Gain} < 0,3$ | Low | 3 | 0,56 (Medium) | 56% | Moderately Effective |
| $0,3 \leq N\text{-Gain} \leq 0,7$ | Medium | 24 | | | |
| $0,7 < N\text{-Gain}$ | High | 10 | | | |

Based on Table 11, the N-Gain results show that 3 students into the low criteria, 24 students into the medium criteria, and 10 students into the high criteria. The average N-Gain Score indicates a 0.56 increase in students' mathematical understanding ability, placing it in the medium category, with a percentage classification of the effectiveness of learning media at 56%. This suggests that the Augmented Reality-based learning media using Assembler Edu is moderately effective. The t-paired test supports this effectiveness with the results of $t_{count} = 16,88$ and $t_{table} = 2,028$, where $t_{count} > t_{table}$, so it can be concluded that students' mathematical understanding increased significantly after the use of Augmented Reality-based learning media assisted by Assembler Edu.

Previous research, such as that by Larasati & Widyasari (2021), demonstrates that AR-based learning media can generally enhance students' mathematical comprehension skills. Furthermore, according to Tuta et al. (2022), Assembler Edu offers excellent features, including three-dimensional interactive visualization and multimedia integration, which help students understand abstract concepts more effectively. In this study, Assembler Edu-assisted media proved to be

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