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Augmented Reality Learning Media Using on Geometry Materials to Enhance Student Learning Outcomes

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Abstract
The fundamental problem addressing this research is the persistent difficulty elementary students face in visualizing three-dimensional geometric concepts, leading to low motivation and suboptimal learning outcomes. This study aims to: (1) develop a valid Augmented Reality (AR) learning media using the Assemblr application; (2) assess its practicality among teachers and students; and (3) evaluate its effectiveness in improving student learning outcomes. Employing a Research and Development (R&D) approach with the ADDIE model, this study was conducted in Pangkajene District involving 47 students across two trial cycles. Data were collected via expert validation, questionnaires, and pretest-posttest designs. The results indicate that the AR media is "Very Valid" (4.12/5.00) and "Practical" for classroom use. Crucially, the media proved effective, raising classical mastery from 80% in Trial I to 96.3% in Trial II. The findings suggest that AR bridges the gap between abstract mathematical objects and concrete operational cognitive stages. Future research should integrate the Technological Pedagogical Content Knowledge (TPCK) framework to further empower teachers in developing similar adaptive technologies.

Keywords: *Augmented Reality; Assemblr; Geometry; ADDIE Model; Innovative Learning; TPCK.*

1. Introduction

Education is a fundamental aspect of individual development, where mathematics plays a key role as the foundation for other sciences. However, preliminary observations conducted on August 12, 2024, at SD Negeri 3 Jagong revealed specific engagement issues. Data showed that only roughly 20% of students demonstrated active participation, while the remaining students struggled to focus, indicating a lack of motivation in learning mathematics. The instruction provided is often monotonous, lacking in media innovation, and perceived as boring. This condition demands teachers to innovate, one of which is by utilizing skills in using learning media. As emphasized by Razak, Sutrisno, and Kamaruddin (2021), the use of appropriate learning media in elementary schools is not merely a supplement but a necessity to bridge abstract concepts with students' concrete thinking abilities.

The problem of low motivation is closely related to the difficulty of the material. In geometry, students are required to visualize three-dimensional (3D) objects. Sutrisno, Kaharuddin, and Gupta (2025), in their analysis of student difficulties, found that a major hurdle in solving mathematical problems is the inability to grasp conceptual visualization, which often leads to errors in problem-solving logic. This is exacerbated when teaching methods are static. Therefore, the implementation of innovative learning models is crucial. Kaharuddin, Nazifah, et al. (2025) argue that in the digital era, innovative models that integrate technology are essential to accommodate diverse learning styles and create a dynamic learning environment.

Technological developments, particularly smartphones, have opened opportunities for using Augmented Reality (AR). AR combines virtual objects into the real world in real-time. Several studies have shown the potential of AR. Arbi (2022) found that AR features significantly influence students' descriptive abilities by providing clear visual stimuli. Similarly, Liana (2023) confirmed that AR-based media effectively increases student knowledge by making abstract information concrete. In the context of mathematics, interactivity is key. Pratiwi and Kaharuddin (2025) demonstrated that interactive applications like Quizizz significantly increase students' learning interest in integer materials. This principle applies to geometry: if students are interested and engaged, their understanding will improve.

Among various AR platforms, "Assemblr" offers ease of use for educational purposes. Previous research supports this choice; Oktaviana and Jasril (2023) successfully developed Assemblr-based media for electronics subjects, while Purnamira Tania et al. (2023) found that Assemblr Edu effectively improved learning outcomes in statistics. However, specific research developing AR for elementary geometry using the ADDIE model in Pangkajene is still limited.

The integration of such advanced media also touches upon teacher competence. Kaharuddin, García, et al. (2025) highlight the importance of the Technological Pedagogical Content Knowledge (TPCK) framework. They argue that for tools like Holograms or AR to be effective, teachers must possess validated competencies to blend technology, pedagogy, and content. Without this, technology remains a gimmick.

Based on this background, this study aims to develop AR media using Assemblr on geometry material that is valid, practical, and effective. This research is also aligned with the findings of Sutrisno (2024) and Sutrisno and Upu (2024), who emphasized the potential of combining AR with Realistic Mathematics Education (RME) approaches to enhance student activities and outcomes.

2. Method

This study uses the Research and Development (R&D) method. The development model adapted is ADDIE, which includes five systematic stages: *Analysis, Design, Development, Implementation,* and *Evaluation*. This model was chosen for its structured approach to ensuring product quality. As a reference for the R&D methodology, Sugiono (2016) states that this method is used to produce a certain product and test the effectiveness of that product.

The research was conducted in elementary schools in Pangkajene District. The trials were carried out in two stages:

- **Trial 1:** SDN 16 Bucinri (20 Grade VI students).
- **Trial 2:** SDN 18 Tumampua I (27 Grade V students).

Data were collected using:

1. **Validation Sheets:** For material and media experts.
2. **Response Questionnaires:** To measure practicality from teachers and students.
3. **Learning Tests:** Pretest-posttest to measure effectiveness.

For data analysis, the validity and practicality were analyzed descriptively. The effectiveness was analyzed using the Normalized Gain (N-Gain) and mastery learning criteria (KKM ≥ 75). To ensure the statistical rigor of the effectiveness claims, the principles of data analysis followed the guidelines by Kaharuddin (2024), ensuring that the interpretation of the increase in scores is statistically sound.

Participants and Trial Design

The study employed an iterative trial design. **Trial I** involved 20 Grade VI students at SDN 16 Bucinri. Grade VI was selected for this initial phase due to their higher cognitive maturity, which allows for more critical feedback regarding the application's usability and interface (Technical Testing). Based on revisions from Trial I, **Trial II** was conducted with 27 Grade V students at SDN 18 Tumampua I. Grade V was selected for this effectiveness phase because the geometry material (cubes and cuboids) specifically aligns with the Grade V curriculum objectives.

Data Collection Procedure

Data collection followed a chronological sequence aligned with the ADDIE stages:

1. Analysis Phase: Conducting observations and interviews to identify learning gaps.
2. Development Phase: Distributing validation sheets to material and media experts to assess content and design validity.
3. Implementation Phase (Trial I): Administering response questionnaires and limited testing to identify bugs.

4. Revision Phase: Improving the application based on Trial I data.
5. Implementation Phase (Trial II): Administering Pretest, Posttest, and questionnaires to measure final practicality and effectiveness.

Data Analysis

Data Analysis Technique "The data were analyzed quantitatively:

1. Validity & Practicality: Average scores were converted using a 5-point Likert scale, where a score of > 4.20 is categorized as 'Very Valid/Practical'.
2. Effectiveness: Analyzed using the Normalized Gain (N-Gain) formula: g = *(Posttest Score - Pretest Score) / (Ideal Score - Pretest Score)*. The improvement is considered significant if $g \geq 0.3$.

3. Results and Discussion

3.1. Development Process (ADDIE Stages)

Analysis Phase: The study began by identifying the core problem: the limitation of static visual aids in teaching geometry properties (e.g., volume, surface area). Students struggled to imagine "hidden lines" in 3D shapes.

Design Phase: A storyboard was created to map the user journey. The design included an intro menu, material selection (Cubes, Cuboids, Cylinders, etc.), AR camera mode, and interactive quiz sections.

Development **Phase:** The production utilized Assemblr Studio. Key activities included creating custom AR Markers, importing 3D assets, adding annotation texts, and programming interactive buttons.

3.2. Validity of the Product

The developed media underwent rigorous validation by experts. The results are presented below:

- Visual & Media Aspect: Scored 4.13 (Very Valid). Experts praised the color scheme and 3D rendering quality.
- Programming & Interaction: Scored 4.10 (Very Valid). Experts noted the stability of the AR tracking.
- Overall Validity: The average validity score was 4.12. This high score indicates that the media meets the academic and technical standards required for instruction.

3.3. Practicality of the Media

Practicality was assessed during the field trials through questionnaires.

- Teacher Response: Scored 3.71 (Trial I) and improved to 3.79 (Trial II). Teachers reported that the app helped explain concepts that were previously difficult to verbalize.
- Student Response: Scored 3.79 (Trial I) and 3.78 (Trial II). Students expressed high enthusiasm, stating that the application was easy to use and made learning fun.

3.4. Effectiveness and Revision (Cycle I to Cycle II)

The effectiveness test provided quantitative evidence of the media's impact.

- Trial I (SDN 16 Bucinri): The average score improved from 72.45 (Pretest) to 85.35 (Posttest). However, the classical mastery was 80% (16 out of 20 students passed). This fell short of the 85% success indicator. *Evaluation & Revision:* Qualitative feedback indicated that some students struggled with navigation buttons and some AR text annotations were obstructed by the 3D models when zoomed in. The researcher revised the "Nets of Cylinder" visualization and fixed the navigation bug.
- Trial II (SDN 18 Tumampua I): After revision, the media was tested on a larger group. The average score rose from 68.26 (Pretest) to 85.01 (Posttest).

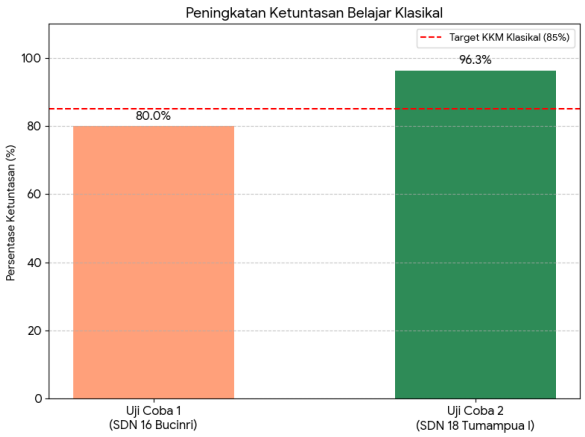

Figure 1. Comparison of Average Pretest and Posttest Scores in Trial I and Trial II.

Crucially, the N-Gain analysis showed that 92.59% of students experienced "Medium" to "High" improvement. The classical mastery reached 96.3% (26 out of 27 students passed), significantly surpassing the target.

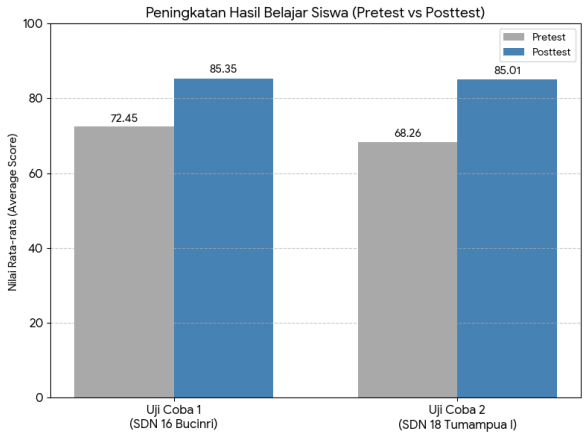

Figure 2. Improvement in Classical Mastery Learning Percentage against the Minimum Criteria (85%)

The findings of this study confirm that the Assemblr-based AR media is valid, practical, and highly effective for teaching geometry in elementary schools. The effectiveness of the media can be attributed to several pedagogical factors supported by recent literature.

Bridging the Visualization Gap The significant increase in N-Gain scores validates the hypothesis that visualization is the key bottleneck in geometry education. By using AR, abstract geometric concepts become concrete. This aligns with Sutrisno, Kaharuddin, and Gupta (2025), who argued that overcoming student difficulties requires scaffolding that targets specific conceptual weaknesses. The AR media acts as a "digital scaffold," allowing students to inspect 3D shapes from all angles, thus removing the cognitive load of imagining hidden sides.

Enhancing Interest through Interactivity The high practicality scores from students (3.78) and the observation of their enthusiasm align with the findings of Pratiwi and Kaharuddin (2025). Their research on Quizizz showed that interactive, gamified applications significantly enhance learning interest. Similarly, in this study, the "wow factor" of AR served as an intrinsic motivator. When students are interested, their attention span increases, leading to better retention of information. The interactive features of Assemblr transformed passive observation into active manipulation.

The Role of Teacher Competence (TPCK) The successful implementation of this media also underscores the importance of teacher readiness. While the app is user-friendly, the teacher's role in guiding the inquiry process is vital. As Kaharuddin, García, et al. (2025) suggest in their research on TPCK instruments for Hologram-based teaching, the integration of advanced visualization tools requires teachers to possess a blend of technological and pedagogical knowledge. This study contributes to that field by providing a validated tool that teachers can use to develop their TPCK in a practical setting.

The Necessity of Innovation Finally, this research supports the broader call for educational reform. Kaharuddin, Nazifah, et al. (2025) argued that innovative learning models are essential to meet the demands of the 21st century. This study provides concrete evidence that "innovation" does not always require expensive laboratories; it can be achieved through accessible mobile technology like Assemblr, provided it is developed through a rigorous R&D process like ADDIE.

4. Conclusion

Based on the results, it is concluded that: (1) The AR media developed using ADDIE is Valid (4.12); (2) It is Practical for teachers and students; and (3) It is Effective, increasing classical mastery to 96.3%. It is suggested that teachers utilize AR as an innovative alternative and that future research explores the TPCK aspects of AR integration

Declarations

Author Contributions

All authors contributed significantly to this work. The first author led the research design and media development. The second author assisted in data analysis and manuscript drafting. The third author supervised the field trials and validation process.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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