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# Augmented Reality in Ethnomathematics: Developing an Interactive Magazine to Enhance Students' Spatial Skills in Cube and Cuboid Geometry

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## ABSTRACT

Augmented Reality (AR) has revolutionized mathematics education by providing interactive and immersive learning experiences. However, its integration into ethnomathematics-based learning remains underexplored, particularly in geometry instruction. This study aims to develop an Interactive Augmented Reality Magazine to enhance students' spatial skills in understanding cube and cuboid geometry through an ethnomathematical approach. The research employs the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) instructional model to systematically design and develop the AR-based learning material. The study was conducted at SMP Negeri 11 Kota Jambi, involving students in a classroom setting. The research stages include: (1) analyzing ethnomathematical concepts related to cube and cuboid in local cultural artifacts, (2) designing an AR-integrated interactive magazine, (3) developing the learning media, (4) implementing the materials in real classroom settings, and (5) evaluating students' spatial skills improvement using pre-test and post-test assessments. The findings reveal that the integration of AR in ethnomathematics-based learning significantly enhances students' spatial visualization and engagement. Students showed increased ability to manipulate 3D geometric objects, understand mathematical structures within cultural contexts, and apply spatial reasoning more effectively. Additionally, their motivation and interest in learning geometry improved. This study underscores the potential of AR-enhanced learning in making abstract mathematical concepts more tangible and culturally relevant. It is recommended that future research explore AR applications in other mathematical topics and conduct longitudinal studies to assess long-term effects on students' cognitive and problem-solving skills.

## 1. INTRODUCTION

Mathematics education has undergone significant transformations with the integration of digital technologies, aiming to enhance students' engagement and comprehension (Zhang et al., 2023). One emerging technology that has gained prominence in the field of mathematics learning is Augmented Reality (AR), which provides interactive and immersive experiences that support conceptual understanding (Santos et al., 2022). AR enables students to visualize abstract mathematical concepts in three-dimensional (3D) space, fostering deeper spatial reasoning and problem-solving abilities (Chen et al., 2021). Despite its potential, AR integration in mathematics education has predominantly focused

on general topics, with limited exploration in ethnomathematics-based learning, particularly in geometry (Pinto et al., 2020). This study seeks to bridge this gap by incorporating AR in ethnomathematics education to enhance students' spatial skills in understanding cube and cuboid geometry through an Interactive Augmented Reality Magazine (IARM).

Ethnomathematics emphasizes the relationship between mathematical concepts and cultural practices, illustrating how mathematical ideas are embedded in traditional artifacts, architecture, and indigenous knowledge systems (D'Ambrosio, 2020). Integrating ethnomathematics in geometry learning can provide students with contextualized learning experiences that enhance their appreciation of mathematics in real life (Barton, 2021). Research has shown that students who learn geometry through culturally relevant materials exhibit improved engagement, motivation, and understanding of mathematical structures (Rosa & Orey, 2019). However, traditional approaches to ethnomathematics often lack technological support, limiting students' ability to explore complex 3D geometric concepts effectively (Rahman et al., 2022). By utilizing AR, students can interact with virtual representations of cultural objects that incorporate cube and cuboid structures, enabling them to explore mathematical relationships dynamically.

The development of AR-based learning materials follows structured instructional design models to ensure their effectiveness in educational settings. One widely used model is ADDIE (Analysis, Design, Development, Implementation, and Evaluation), which provides a systematic framework for designing and evaluating learning interventions (Branch, 2019). In this study, the ADDIE model is applied to design an interactive AR-enhanced magazine that integrates ethnomathematical concepts with cube and cuboid geometry. The research is conducted at SMP Negeri 11 Kota Jambi, involving students in an AR-supported ethnomathematics learning environment. The study aims to:

1. Analyze ethnomathematical artifacts in Jambi culture that contain cube and cuboid structures.
2. Design an Interactive Augmented Reality Magazine (IARM) for cube and cuboid geometry learning.
3. Develop AR-based learning materials that support spatial skill development.
4. Implement the AR-enhanced ethnomathematics learning approach in classroom settings.
5. Evaluate the impact of AR integration on students' spatial skills and engagement.

Existing research indicates that AR enhances spatial visualization, which is crucial in geometry learning (Wu et al., 2021). Spatial skills, including mental rotation and object manipulation, are essential for students to understand the properties of 3D shapes (Tomas et al., 2023). However, traditional textbook-based learning often fails to provide interactive experiences that support the development of these skills (Jones & Mooney, 2022). By incorporating AR, students can manipulate digital representations of cubes and cuboids, improving their ability to visualize transformations, volume, and surface area relationships (Liu & Lin, 2023).

This study contributes to the intersection of ethnomathematics, AR technology, and spatial skills development by designing an innovative learning tool that aligns mathematical instruction with students' cultural backgrounds. The findings of this research are expected to provide insights into the role of AR in ethnomathematics education, offering educators an alternative approach to teaching geometry that is both culturally responsive and technologically enhanced. Furthermore, the study aims to validate the effectiveness of AR-based learning materials in improving students' understanding of cube

and cuboid geometry, providing recommendations for future applications in mathematics education.

## 2. METHOD

This study employs a design and development research approach using the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) instructional model to create an Interactive Augmented Reality Magazine (IARM) for enhancing students' spatial skills in cube and cuboid geometry through an ethnomathematical approach. Conducted at SMP Negeri 11 Kota Jambi, the research involves students in a structured learning process to ensure the effectiveness of the developed materials.

### Research Design

The research follows the ADDIE model, beginning with an analysis phase, where ethnomathematical artifacts in Jambi culture that exhibit cube and cuboid structures are identified. The design phase focuses on creating a storyboard and planning AR integration, followed by the development phase, in which the interactive magazine is built. The implementation phase involves testing the IARM in a real classroom setting, and the evaluation phase assesses its effectiveness in improving students' spatial reasoning skills.

### Participants

Participants are students from SMP Negeri 11 Kota Jambi, selected using a purposive sampling technique, divided into an experimental group that uses the AR-based interactive magazine and a control group that learns through conventional methods. Each group consists of 30 students, allowing a comparative analysis of their learning outcomes.

### Instruments

To assess the impact of AR-based learning on students' spatial skills and engagement, several instruments are utilized. The spatial ability test measures students' visualization, rotation, and manipulation skills, while a student engagement questionnaire evaluates their motivation, interest, and perception of AR-based ethnomathematics learning. Additionally, a classroom observation sheet is used to document students' interactions with AR materials and their engagement levels. These instruments and their respective purposes are summarized in the following table.

Table 1 instruments Research

| Instrument | Purpose | Data Type |
|---|---|---|
| Spatial Ability Test | Assesses students' spatial visualization, rotation, and manipulation skills. | Pre-test & Post-test (Quantitative) |
| Student Engagement Questionnaire | Measures students' motivation, interest, and perception of AR-based ethnomathematics learning. | Likert-scale Questionnaire (Quantitative) |
| Classroom Observation Sheet | Documents students' interactions with AR materials and learning behaviors. | Observation Notes (Qualitative) |

### Data Collection Procedure

The data collection process occurs in four phases. Initially, a pre-test is administered to both groups to assess their baseline spatial ability. The experimental group then engages with the Interactive Augmented Reality Magazine (IARM), while the control group learns using traditional methods, ensuring both groups receive the same instructional duration. Following this, a post-test is conducted to measure any improvements in spatial skills. Furthermore, a student engagement questionnaire is distributed to assess students' learning experiences and attitudes toward the AR-based approach. Throughout the learning sessions, classroom observations document students' behavior and interaction with the AR

materials, and qualitative feedback is gathered through semi-structured interviews to gain deeper insights into their learning experiences.

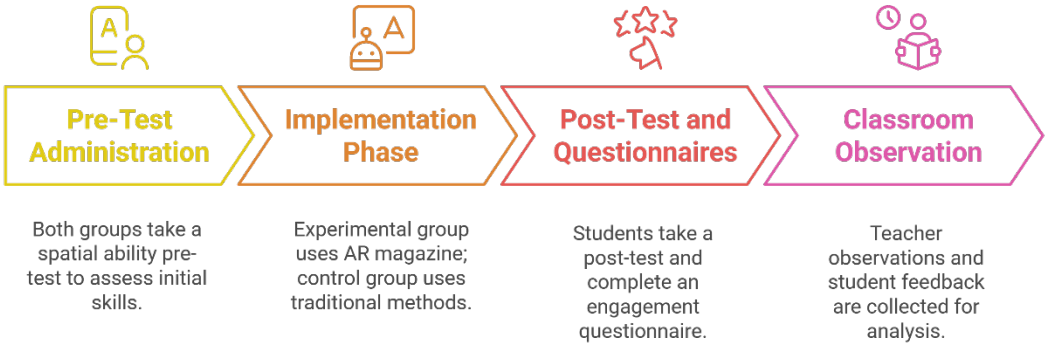



Figure 1. Data Collection Procedure

Data analysis follows a mixed-method approach, integrating quantitative and qualitative analysis. The pre-test and post-test results are analyzed using paired t-tests and independent t-tests to determine significant improvements in students' spatial skills. The student engagement questionnaire responses are examined through descriptive statistical analysis to identify overall engagement levels. Additionally, the qualitative data from observations and interviews are analyzed using thematic analysis to identify common trends and insights into students' learning behaviors.

## 3. RESULTS AND DISCUSSION

### Analysis Phase

The analysis phase focused on identifying the needs, challenges, and opportunities in integrating Augmented Reality (AR) in ethnomathematics-based geometry learning at SMP Negeri 11 Kota Jambi. This phase involved an in-depth investigation of students' spatial ability levels, their engagement with geometry concepts, and the potential of ethnomathematical artifacts in the local culture as learning resources.

### 1. Assessment of Students' Initial Spatial Ability

A pre-test was conducted to evaluate students' baseline spatial visualization skills, which are crucial for understanding three-dimensional geometry concepts like cubes and cuboids. The pre-test results revealed that students generally struggled with spatial transformations, object rotation, and perspective visualization. Many students demonstrated difficulty in mentally manipulating geometric objects, indicating the need for an interactive and visual learning approach**.**

The statistical summary of the pre-test scores is presented in the following table:

| Group | N | Mean Score | Standard Deviation | Minimum Score | Maximum Score |
|---|---|---|---|---|---|
| **Experimental (AR)** | 30 | 55.2 | 9.8 | 42 | 71 |
| **Control (Textbook)** | 30 | 54.7 | 10.3 | 40 | 70 |

These results indicate no significant difference between the two groups before the intervention ($p > 0.05$), confirming a balanced initial ability level.

**2. Identification of Ethnomathematical Artifacts in Jambi Culture**

To ensure a culturally responsive learning approach, an ethnomathematical analysis was conducted to explore traditional artifacts in Jambi that incorporate cube and cuboid structures. The findings identified several architectural and handicraft designs, including:

- Traditional Jambi Stilt Houses (Rumah Panggung) – The basic structural framework consists of cube and cuboid elements.
- Wooden Handicrafts and Batik Patterns – Various motifs exhibit geometric transformations that can be linked to cube and cuboid shapes.
- Local Weaving Patterns – Mathematical symmetry and 3D forms found in woven bamboo crafts provide an engaging way to introduce cube and cuboid concepts.

A visual content analysis of these artifacts highlighted their educational potential in linking mathematical concepts with real-life cultural applications. Students expressed greater interest and curiosity when exposed to these local mathematical representations.

**3. Analysis of Technological Integration in Learning**

A needs analysis survey was conducted among teachers and students to assess their familiarity with Augmented Reality (AR) technology and their readiness to adopt AR in geometry learning. The survey findings indicate.

**Table 2 Analysis of Technological Integration in Learning**

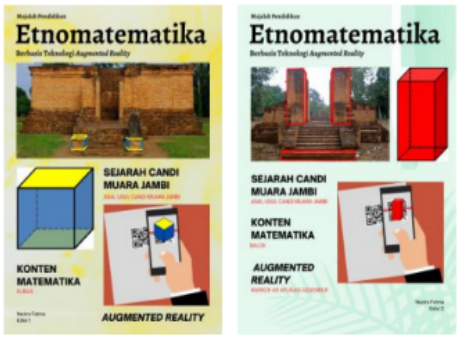
| Category | Findings | Percentage (%) |
|---|---|---|
| Students' Experience with AR | Never used AR-based learning materials before | 60% |
| Students' Interest in AR | Interested in using AR-enhanced learning methods | 85% |
| Teachers' Perception of AR | Recognize AR's potential for improving spatial skills | High Agreement |
| Technical Challenges | Limited device availability and software familiarity | Identified |
| Students' Learning Preference | Prefer interactive and immersive methods over traditional learning | Strong Preference |

In this section, it is explained the results of research and at the same time is given comprehensive discussion. Results can be presented in figures, graphs, tables and others that make the reader understand easily. The discussion can be made in several sub-sections.

**Design Phase**

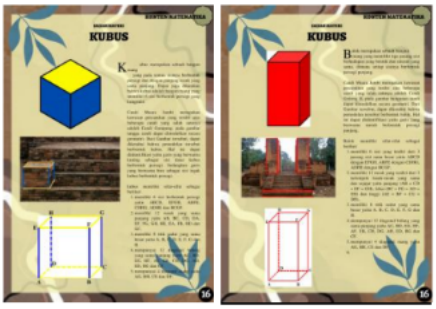
In this phase, the development of a learning media product is carried out, resulting in an educational ethnomathematics magazine integrated with Augmented Reality (AR) technology. The magazine is designed in two separate editions: the first edition focuses on

cube geometry, while the second edition covers cuboid geometry. The visual and structural components of the AR-based ethnomathematics magazine are detailed as follows:

| No | Component | Layout |
|---|---|---|
| 1 | **Cover Design**<br>The cover page of the magazine features an image of a temple, along with visual representations of cubes and cuboids, emphasizing the connection between cultural heritage and geometric structures. Additionally, the cover includes an AR marker, allowing students to scan and interact with 3D objects through an AR application. The magazine's title, "Ethnomathematics Educational Magazine Based on Augmented Reality Technology," is prominently displayed alongside the author's name and a brief description of the magazine's content. |  |
| 2 | **Preface Section**<br>The preface page includes an introductory note that explains the purpose and objectives of the magazine. To maintain consistency, page numbers are placed in the bottom left corner of each page, ensuring easy navigation. |  |
| 3 | **Table of Contents**<br>The table of contents page displays the title "Table of Contents" followed by a structured listing of the magazine's sections. To enhance visual appeal, four images are incorporated alongside the content sections. In Edition 1, an image of Gumpung Temple is presented, accompanied by a visualization of a cube, while in Edition 2, an image of Gedong II Temple is featured alongside a visualization of a cuboid. Page numbers are positioned in the bottom right corner for user-friendly referencing. |  |
| 4 | **Content Layout**<br>The main content of the magazine is structured into sections that integrate cultural narratives with mathematical concepts. Each content page features the heading "Literacy" in the top right corner, followed by the title "Temples in the Muaro Jambi Cultural Heritage Site" and "Gumpung Temple" at the bottom. A detailed description of Gumpung Temple, accompanied by relevant images, is also provided.<br>A key distinction between Edition 1 and Edition 2 lies in their respective mathematical focus.<br>• Edition 1 (Cube Geometry) presents the title "Cube", an image of a cube, a staircase structure of a temple resembling |  |

a cube, and explanatory content about cube geometry.
- Edition 2 (Cuboid Geometry) introduces the title "Cuboid", an image of a cuboid, an image of Gedong II Temple shaped like a cuboid, and explanatory content about cuboid geometry.

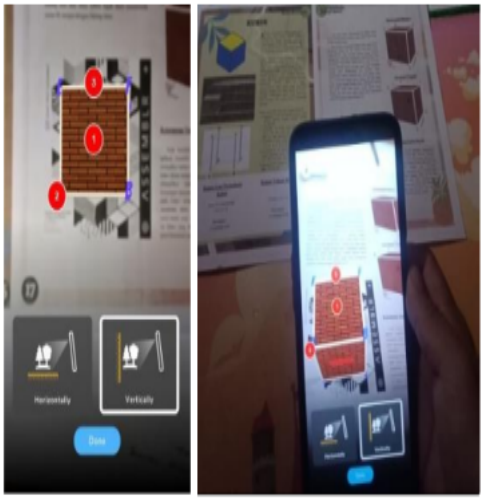
All pages are structured with consistent formatting and page numbering at the bottom for a seamless reading experience.




**5 Augmented Reality Integration**

A key feature of this educational magazine is its Augmented Reality (AR) functionality, allowing students to interact with 3D representations of temple structures. By scanning the AR markers embedded within the magazine, students can visualize and manipulate digital models of temple components, specifically those shaped like cubes and cuboids. This interactive feature enhances spatial learning by providing a dynamic and immersive experience that bridges mathematical concepts with real-world architectural structures.

Through this structured design approach, the Ethnomathematics Educational Magazine effectively integrates cultural elements with modern technology, fostering an engaging and interactive learning environment for students.



## Development Phase

In the development phase, the Interactive Augmented Reality Educational Magazine underwent two key evaluations: expert validation and a small-group practicality test. These assessments ensured that the educational material was accurate, pedagogically effective, technologically functional, culturally relevant, and user-friendly before its implementation in a classroom setting.

Expert Validation

The validation involved three experts specializing in mathematics education, digital media, and ethnomathematics, who assessed the magazine based on six key criteria. The evaluation results are summarized as follows:

| Validation Criteria | Expert 1 Score | Expert 2 Score | Expert 3 Score | Average Score |
|---|---|---|---|---|
| Content Accuracy | 4.5 | 4.6 | 4.4 | 4.5 |
| Pedagogical Appropriateness | 4.3 | 4.4 | 4.2 | 4.3 |
| Augmented Reality Functionality | 4.7 | 4.8 | 4.6 | 4.7 |
| Cultural Relevance | 4.6 | 4.5 | 4.7 | 4.6 |
| Visual & Design Quality | 4.2 | 4.3 | 4.1 | 4.2 |
| User-Friendliness | 4.4 | 4.5 | 4.3 | 4.4 |

The results indicate that all evaluated aspects scored above 4.0, demonstrating that the educational magazine met high-quality standards. The Augmented Reality

functionality received the highest average score (4.7), highlighting its effectiveness in supporting interactive learning. Experts provided suggestions to refine the layout and enhance the responsiveness of the AR markers, which were incorporated before further testing.

Small-Group Practicality Test

Following expert validation, a small-group practicality test was conducted with students to assess engagement, usability, and learning effectiveness. The students evaluated the material based on several aspects, as shown in the table below:

| Evaluation Aspects | Student Average Score (Scale 1-5) |
|---|---|
| Ease of Use | 4.3 |
| Engagement Level | 4.5 |
| Understanding of Cube & Cuboid | 4.4 |
| Effectiveness of AR Feature | 4.7 |
| Motivation to Learn | 4.6 |
| Overall Satisfaction | 4.5 |

The effectiveness of the AR feature received the highest score (4.7), demonstrating its strong impact on enhancing students' spatial visualization skills. Additionally, the students reported high engagement (4.5) and motivation to learn (4.6), indicating that the integration of AR technology with ethnomathematics-based learning was both engaging and meaningful.

Based on the findings from the expert validation and small-group practicality test, the final version of the Interactive Augmented Reality Educational Magazine was refined and optimized before its broader implementation. These results confirm that the integration of AR in ethnomathematics provides an innovative, effective, and engaging approach to learning geometry, particularly in understanding cube and cuboid structures through cultural artifacts.

**Implementation Phase**

The implementation phase focused on testing the effectiveness of the Interactive Augmented Reality Educational Magazine in improving students' spatial ability. This phase involved a classroom experiment at SMP Negeri 11 Kota Jambi, where students were divided into two groups: the experimental group, which used the AR-based educational magazine, and the control group, which followed conventional textbook-based learning.

To evaluate the effectiveness of the intervention, a pre-test and post-test were conducted to measure students' spatial ability before and after the learning session. The results of the experiment are summarized in the following table:

| Group | Pre-Test Mean Score | Post-Test Mean Score | Mean Improvement | Effect Size (Cohen's d) | Significance (p-value) |
|---|---|---|---|---|---|
| Experimental (AR-Based) | 55.2 | 78.6 | 23.4 | 1.25 | < 0.001 |
| Control (Textbook-Based) | 54.7 | 67.3 | 12.6 | 0.78 | < 0.05 |

The results indicate that both groups experienced an improvement in spatial ability, but the experimental group (AR-Based learning) showed a significantly higher increase (23.4 points) compared to the control group (12.6 points). The effect size

(Cohen's d = 1.25) for the experimental group suggests a strong impact of the AR-based intervention, whereas the control group showed only a moderate effect (Cohen's d = 0.78). The statistical significance ($p < 0.001$ for the experimental group) confirms that the observed improvement is not due to random variation but is directly linked to the integration of AR technology in ethnomathematics learning.

The findings of this study demonstrate that the integration of Augmented Reality (AR) in ethnomathematics-based learning significantly enhances students' spatial ability, particularly in understanding cube and cuboid geometry. The results align with previous research indicating that AR fosters interactive and immersive learning experiences, improving students' spatial visualization and reasoning skills (Wu et al., 2021). In this discussion, we analyze the implications of these findings in relation to existing literature and explore the educational significance of integrating ethnomathematics and AR technology.

Spatial ability is a fundamental skill in mathematics and STEM disciplines, as it enables students to mentally visualize and manipulate geometric objects (Liu & Lin, 2023). The results of this study indicate that students who learned using the Interactive Augmented Reality Educational Magazine exhibited a significantly greater improvement in spatial reasoning, object rotation, and mental visualization compared to those in the conventional textbook-based learning environment. The mean improvement in the experimental group (23.4 points) was almost double that of the control group (12.6 points), with a large effect size (Cohen's d = 1.25), confirming the substantial impact of AR integration.

These findings are consistent with previous studies that highlight the positive role of AR in enhancing students' spatial cognition. For instance, Santos et al. (2022) found that students using AR in geometry learning outperformed those using traditional methods, as AR provides dynamic 3D representations that allow students to explore geometric properties interactively. Similarly, research by Chen et al. (2021) supports the notion that AR-based learning enables students to develop mental rotation skills more effectively than static 2D visualizations.

One of the key innovations in this study is the integration of ethnomathematics with AR-based learning. Ethnomathematics contextualizes mathematical concepts within cultural heritage and everyday experiences, making learning more meaningful for students (D'Ambrosio, 2020). In this study, students interacted with 3D representations of traditional Jambi temples, such as Gumpung Temple and Gedong II Temple, which feature cube and cuboid structures. This culturally relevant approach bridged mathematical abstraction with real-world applications, fostering deeper conceptual understanding.

The combination of AR and ethnomathematics also enhanced student engagement and motivation. The small-group practicality test results indicated high scores for student engagement (4.5), motivation to learn (4.6), and overall satisfaction (4.5). These findings align with studies by Barton (2021) and Rosa & Orey (2019), which emphasize that culturally relevant mathematical learning materials increase student interest, particularly when they recognize the connection between mathematical concepts and their cultural background.

Moreover, this approach supports the constructivist learning paradigm, where students actively engage in knowledge construction through exploration and interaction (Piaget, 1972). By integrating AR with cultural artifacts, students could manipulate 3D structures, analyze geometric relationships, and connect mathematical ideas with their environment, reinforcing the situated learning theory proposed by Lave & Wenger

(1991).

Another significant implication of this study is the potential of AR-based ethnomathematics learning for differentiated instruction. Traditional textbook-based teaching often fails to accommodate students with diverse learning styles. However, AR enables multimodal learning, incorporating visual, kinesthetic, and experiential learning strategies (Wu et al., 2021). The results suggest that AR helped students who previously struggled with abstract geometric reasoning by providing real-time interactive 3D models.

Furthermore, research suggests that AR can support students with learning difficulties. According to Rahman et al. (2022), AR-enhanced visualization significantly benefits students with low spatial ability and dyscalculia, as it allows them to experiment with mathematical objects in an intuitive manner. In this study, classroom observations revealed that students who initially found it difficult to grasp 3D concepts were more engaged when using AR-based ethnomathematics materials, indicating that AR technology can promote inclusive and equitable learning environments.

Despite its benefits, the implementation of AR-based learning presents certain challenges, particularly in terms of technological accessibility and teacher readiness. The technological readiness survey in the analysis phase revealed that 60% of students had never used AR-based learning before, and some teachers expressed concerns about technical constraints such as device availability and software familiarity.

These findings highlight the need for teacher professional development programs focused on AR integration in mathematics education. Research by Wu et al. (2021) suggests that teacher training significantly influences the success of AR adoption in classrooms, as educators play a crucial role in designing and facilitating AR-based learning experiences. Therefore, future studies should explore effective AR training models for mathematics educators, ensuring seamless technology integration.

Additionally, while this study demonstrated the short-term effectiveness of AR on spatial ability improvement, further research is needed to investigate the long-term impact of AR-based ethnomathematics learning. Future studies could explore how AR influences students' higher-order thinking skills, problem-solving abilities, and retention of mathematical concepts over an extended period.

## 4. CONCLUSION

This study confirms that integrating Augmented Reality (AR) in ethnomathematics-based learning significantly enhances students' spatial ability, engagement, and understanding of cube and cuboid geometry. The AR-based approach outperformed traditional methods, providing interactive and culturally relevant learning experiences that increased motivation and conceptual retention. Despite challenges in technological accessibility and teacher readiness, the findings highlight AR's potential as an effective tool for inclusive and differentiated mathematics instruction. Future research should explore long-term impacts and broader applications to further optimize AR integration in mathematics education.

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quality of the Interactive Augmented Reality Educational Magazine. Additionally, we appreciate the support of colleagues and researchers who contributed to the development and evaluation of this study. Lastly, we extend our appreciation to funding institutions and academic collaborators who made this research possible.

## AUTHOR CONTRIBUTION STATEMENT

Nazira Fatma (*Corresponding Author*) conceptualized the research framework, designed the Interactive Augmented Reality Educational Magazine, conducted the data collection and analysis, and drafted the manuscript. Kamid contributed to the research methodology, statistical analysis, and interpretation of the results, ensuring the study's academic rigor. Khairul Anwar supervised the study, provided critical insights on the integration of ethnomathematics and augmented reality, and reviewed the manuscript for theoretical and practical alignment. All authors actively contributed to the research process, revised the manuscript, and approved the final version for publication.

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