



## Enhancing Students' Logical Thinking through Ethnomathematics-based Augmented Reality of Bola Soba Character Facades

Sartika Sari Dewi<sup>1</sup>, Andi Muhammad Irfan Taufan Asfar<sup>1\*</sup>, Andi Muhamad Iqbal Akbar Asfar<sup>2</sup>,  
Andi Nurannisa<sup>1</sup>, Wiwi Damayanti<sup>1</sup>, Nining Wahyuni<sup>1</sup>

<sup>1</sup>Faculty of Teacher Training and Education, Universitas Muhammadiyah Bone, Indonesia

<sup>2</sup>Chemical Engineering, Politeknik Negeri Ujung Pandang, Indonesia

\*Correspondence to: [tauvanlewisoo@gmail.com](mailto:tauvanlewisoo@gmail.com)

**Abstract:** Logical thinking skills are crucial for students to navigate increasingly complex learning processes, as these skills are part of Higher-Order Thinking Skills (HOTS). They involve analyzing problems scientifically and systematically to make informed generalizations. Unfortunately, national and international surveys show that students' logical thinking skills remain low. This study investigates how implementing ethnomathematics-based Augmented Reality through the façade of the Bola Soba character building can enhance students' logical thinking skills. A quasi-experimental research method with a non-equivalent control group design was applied at one public school in South Sulawesi, focusing on eighth-grade students. Two classes were sampled using purposive nonprobability sampling: 30 students in class VIII B as the experimental group and 30 in class VIII A as the control group. Results revealed a significant improvement in the experimental group, with a gain score of 0.70 (70%), categorized as high. This indicates that using ethnomathematics-based Augmented Reality significantly enhances students' logical thinking skills. The study contributes to the field by showing how local wisdom, represented by Bola Soba facades integrated with modern educational technology, can foster students' cognitive development.

**Keywords:** logical thinking, bola soba, ethnomathematics, augmented reality

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## INTRODUCTION

Logical thinking skills, as confirmed by Balakrishnan (2022), Ha et al. (2022), Cooke et al. (2022), and Santana and Cobo (2020), are some of the abilities that students must have. This ability is included in the higher-order thinking skills category, which includes a scientific and systematic thinking process before generalizing about a problem, as explained by Rashidov (2022), Halim et al. (2022), Asfar et al. (2019) and Maslihah et al. (2020). Logical thinking skills are fundamental because they allow students to gain a better perception and visualization of a problem by comparing previous information with new information so that they can reach the proper conclusion, as described by Batoul and Ambusaidi (2022). However, students in Indonesia still experience obstacles in developing logical thinking skills. This can be seen in the 2015 Trends in International Mathematics and Science Study (TIMSS) survey results, which placed Indonesia at the bottom with a score of 397 out of 51 participating countries, as reported by the International Association for the Evaluation of Educational Achievement (2016). Similar results were also seen in the Program for International Student Assessment (PISA), with 379 out of 487 international scores (OECD, 2019; Asfar et al., 2019). Apart from that, the national average score for the National Examination in Mathematics only reached 46.56, and for Bone Regency, it reached 46.15 (Puspendik, 2019). Problems with logical thinking skills were also observed in learning the Pythagoras theorem in class VIII, where students had difficulty understanding basic concepts, such as mathematical symbols, quadratic operations, and the longest side of a triangle, and experienced errors in applying the correct formula. as expressed in the results of the Minimum Competency Assessment with an average score of 65. This is because students have not been able to provide a concept for each side of a triangle and have difficulty making decisions in determining answers, which results in students not being able to connect the problem with the solution formula. Factors contributing to low logical thinking skills include a monotonous, teacher-centered learning approach and an emphasis on memorization rather than understanding concepts (Novitra, 2022; Asfar et al., 2020). Understanding visualization learning material is related to memorizing formulas and how students can understand and apply these formulas in solving existing problems.

Local wisdom is a form of cultural value that cannot be separated from the traditions and characteristics of each region and is the embodiment of a movement to build national identity (Asfar et al., 2022). The value of local wisdom must function as a character builder, which is the goal of national education and national identity

(Asfar & Asfar, 2021). The value of local wisdom in education will lead to an independent attitude full of initiative, politeness, and creativity to revitalize local culture (Nawas et al., 2022; Asfar et al., 2022). Therefore, an optimal way to introduce local wisdom as a basis for education is needed. One form of local wisdom that can be introduced in learning is the local wisdom "Bola Soba". Bola Soba, commonly called Saoraja, is a Bugis traditional house with unique architecture and a shape and structure that reflects the Bugis people's view of the spatial layout of the universe (macrocosm) and human life. The Bugis people have a cosmological view that the house is a microcosm, while Bola Soba is a macrocosm with complex shapes starting from Boting-Langi (upper world), Ale Kawa (middle world), and Buri Liung (underworld) (Hasbi & Badollahi, 2019; Marwati & Andriani, 2017). However, this complex part has not yet been fully explored regarding the value of each part and its forms, especially in education.

Therefore, a media innovation is needed to explore the value of Bugis local wisdom, "Bola Soba," in learning, especially in improving students' logical thinking skills using the Pythagoras theorem using Augmented Reality media. Augmented Reality is a technology that combines virtual objects with a physical environment to provide a live display that can help users visualize an object following the real world (Tan et al., 2022). Increasingly sophisticated technological developments strongly support this Augmented Reality media. They can be applied in the learning process as a visualization media, especially in this research, namely providing an accurate picture of the shapes and parts of Bola Soba into a learning design so that students will quickly understand the Pythagorean theorem material by exploring the cultural values in it. Therefore, this research will examine Augmented Reality-based learning designs in exploring the value of Bugis local wisdom, "Bola Soba", as a medium for improving students' logical thinking skills. Several studies have explored using Augmented Reality (AR) in education, highlighting its potential to enhance learning experiences. For instance, recent research by Alkhabra et al. (2023) emphasizes that AR technology significantly improves student engagement and understanding, particularly in mathematics and science education. They find that integrating AR with traditional learning allows students to visualize abstract concepts, leading to deeper comprehension and retention. Similarly, Bekele et al. (2018) and Ibanez and Delgado (2018) demonstrate that AR applications offer a unique blend of virtual and physical elements, making learning more interactive and appealing. Their research showed that AR promotes spatial thinking and critical reasoning skills, essential components of logical thinking, especially in STEM fields.

Another significant body of research has focused on integrating local wisdom in education to foster character-building and cognitive skills. For example, Tanase (2020) explores how local cultural values foster students' critical and creative thinking skills when integrated into educational curricula. Their findings suggest that introducing cultural elements in lessons makes learning more relatable and meaningful for students, encouraging active participation. Moreover, studies like those by Febrian et al. (2024) underline the importance of contextualizing learning within students' socio-cultural backgrounds, particularly in Indonesia, where local wisdom can bridge traditional knowledge and modern educational practices. This research aims to create an innovative learning design that combines Bugis local wisdom "Bola Soba" with Augmented Reality technology to improve students' logical thinking skills, specifically in understanding the Pythagorean theorem. The novelty of this study lies in its integration of cultural heritage with cutting-edge educational technology, which has not been fully explored in previous research. This study targets a significant improvement in students' logical thinking skills through a culturally enriched AR-based learning experience, making mathematics more accessible and engaging by linking abstract mathematical concepts with tangible cultural elements.

## METHODS

This type of research was quantitative descriptive with a quasi-experimental method and non-equivalent control group design (Asfar et al., 2021). The research design can be seen in Table 1 below.

**Table 1.** Non-Equivalent Control Group Design

| <b>Class</b> | <b>Pre-test</b> | <b>Treatment</b> | <b>Post-Test</b> |
|--------------|-----------------|------------------|------------------|
| Control      | O1              |                  | O2               |
| Experiment   | O3              | X                | O4               |

Information:

O1: Logical thinking skill of the control class before learning

O2: Logical thinking skill of the control class after learning

O3: Logical thinking skill of the experimental class before treatment

O4: Logical thinking skill of the experimental class after treatment

X: Application of Ethnomathematics-Based Augmented Reality of Bola Soba Character Facades

The sampling technique used purposive sampling and selected students from class VIII at one of the State Middle Schools in Bone Regency, with a classification of 30 students, namely control class VIII A and 30 experimental class VIII B. Data collection was carried out using a test in the form of 5 essay questions to test students' logical thinking skills according to indicators, namely 1) Consistency of Thinking, 2) Arguing Ability, and 3) Drawing Conclusions. Before being used to test the control or experimental classes, the test instrument was tested for validity and reliability. Validity testing used expert judgment techniques, while reliability testing was carried out by conducting trials on other classes not used in the research. The following is a description of indicators of logical thinking skills.

**Table 2.** Logical thinking skill Indicator

| Indicator               | Description                                                                                         |
|-------------------------|-----------------------------------------------------------------------------------------------------|
| Consistency of Thinking | Students can state all information from what is known and ask questions appropriately.              |
| Arguing Ability         | Students' ability to solve problems correctly at each step and provide arguments for each step used |
| Drawing Conclusions     | Students' ability to find and draw appropriate conclusions at the end of the answer.                |

The test was carried out twice, namely before giving treatment (pre-test) and after treatment (post-test). Pre-test scores are used to test whether the two groups have the same initial abilities. Meanwhile, the post-test scores are used to see whether there are differences due to the treatment used by the researcher. The data analysis techniques used in this research were normality and homogeneity tests, hypothesis testing, and gain score tests to see whether there are differences due to this treatment in increasing students' logical thinking skills in two classes, namely the control class and the experimental class. Data analysis can be seen in Table 3 and the description below.

**Table 3.** Interpretation of Logical thinking skill

| Mark (%)                  | Category |
|---------------------------|----------|
| $70 \leq \leq 100\bar{x}$ | High     |
| $50 \leq < 70\bar{x}$     | Middle   |
| $0 \leq < 50\bar{x}$      | Low      |

The data analysis in this research involved several key steps to assess the impact of using Augmented Reality (AR) based on ethnomathematics in improving students' logical thinking skills. The analysis began with a pre-test to evaluate the initial logical thinking skills of the control and experimental groups. The pre-test ensured that both groups were comparable in their baseline abilities before applying the experimental treatment. After the AR-based intervention, a post-test was conducted to measure any improvements in logical thinking skills. The difference between the pre-test and post-test scores helped quantify the treatment's effect. This study's primary data analysis techniques included 1) Normality Test: This test assessed whether the data from the control and experimental groups were normally distributed. A normal distribution was required for specific statistical tests, such as parametric hypothesis testing, to be valid; 2) Homogeneity Test: This test examined whether the variances between the control and experimental groups were similar. Ensuring homogeneity of variance is crucial when comparing groups, as it helps confirm that any observed differences are due to the treatment rather than variability in the data; 3) Hypothesis Testing: After confirming normality and homogeneity, hypothesis testing was conducted to determine if the differences between the control and experimental groups were statistically significant. The specific hypothesis tested was whether the AR intervention significantly improved students' logical thinking skills compared to traditional teaching methods used in the control group; 4) Gain Score Analysis: This analysis quantified the improvement in logical thinking skills between the pre-test and post-test. The gain score reflects the difference between post-test and pre-test results and is categorized into three levels: high (70-100%), medium (50-70%), and low (below 50%). This rigorous analysis allows the researchers to assess the effectiveness of the AR-based learning intervention in enhancing logical thinking skills. It provides a clear statistical foundation for concluding the study's outcomes.

## RESULT AND DISCUSSION

This research was carried out at one state high school to see students' logical thinking skills after implementing learning through the Ethnomathematics Augmented Reality-based Buckwheat Ball Facade in mathematics subjects on the Pythagoras theorem. Based on the analysis that has been carried out, the following results were obtained. The normality test was carried out to test whether the data samples in the two classes in this study were normally distributed or not. The normality test was carried out using the Shapiro-Wilk test. Normality test results can be seen in Table 4.

**Table 4.** Normality Test Results

| Class                     |                      | Kolmogorov-Smirnov |    | Shapiro-Wilk |            |    |      |
|---------------------------|----------------------|--------------------|----|--------------|------------|----|------|
|                           |                      | Statistics         | df | Sig.         | Statistics | df | Sig. |
| Learning outcomesLearners | Experiment Pre-test  | .116               | 30 | ,200*        | ,917       | 30 | ,053 |
|                           | Experiment Post-test | .133               | 30 | ,188         | ,932       | 30 | ,056 |
|                           | Control Pre-test     | ,112               | 30 | ,200*        | ,968       | 30 | ,488 |
|                           | Control Post-test    | ,148               | 30 | ,091         | ,953       | 30 | ,204 |

\*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Based on data analysis using the Shapiro-Wilk test in the experimental class, the pre-test data obtained a significance value of 0.053, indicating that the pre-test data was normally distributed. Then, a significance value of 0.056 was obtained for the post-test data, meaning the data was normally distributed. Then, the control class pre-test data obtained a significance value of 0.488, while the post-test data value was 0.204, indicating that both data were normally distributed. Based on the test results, the data in the experimental and control classes are parametric. Thus, the process of determining hypotheses is carried out using parametric statistics (Independent T Test). The homogeneity test is conducted to examine whether the variance (difference in data distribution) of two groups or data samples is the same or homogeneous. The homogeneity test was carried out using the Levene test. The results of the normality test can be seen in [Table 5](#).

**Table 5.** Homogeneity Test

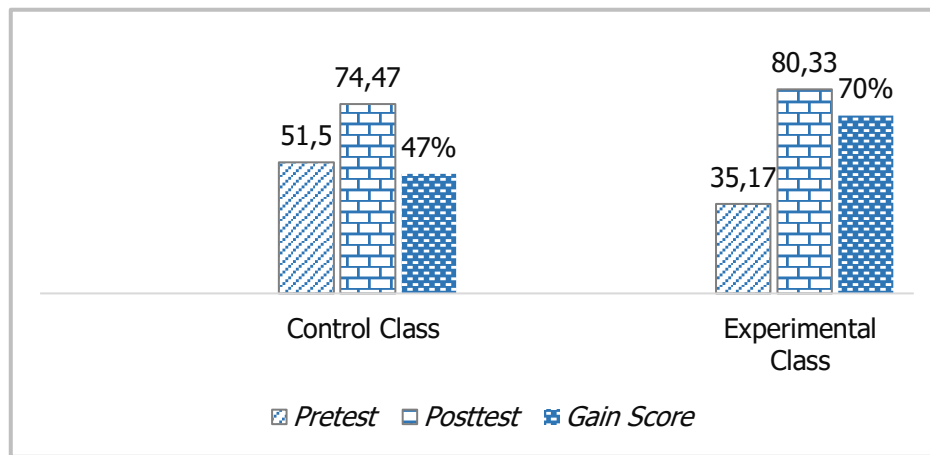
|                   |                                          | Levene Statistics | df1 | df2    | Sig. |
|-------------------|------------------------------------------|-------------------|-----|--------|------|
| Learning outcomes | Based on Mean                            | 1,728             | 1   | 58     | ,194 |
|                   | Based on Median                          | 1,196             | 1   | 58     | ,279 |
|                   | Based on the Median and with adjusted df | 1,196             | 1   | 57,634 | ,279 |
|                   | Based on trimmed mean                    | 1,692             | 1   | 58     | ,198 |

The homogeneity test results are used to determine whether the two data have the same variance in the control and experimental classes with a significance level ( $\alpha$ ) = 0.05. Based on the output, the significance value of Based on Mean is 0.194 > 0.05, so it can be concluded that the variance of the experimental and control class post-test data is the same or homogeneous. Hypothesis testing uses parametric statistics, namely the Independent Sample T Test. The following is a table of the hypothesis testing results obtained.

**Table 6.** Independent Sample T Test

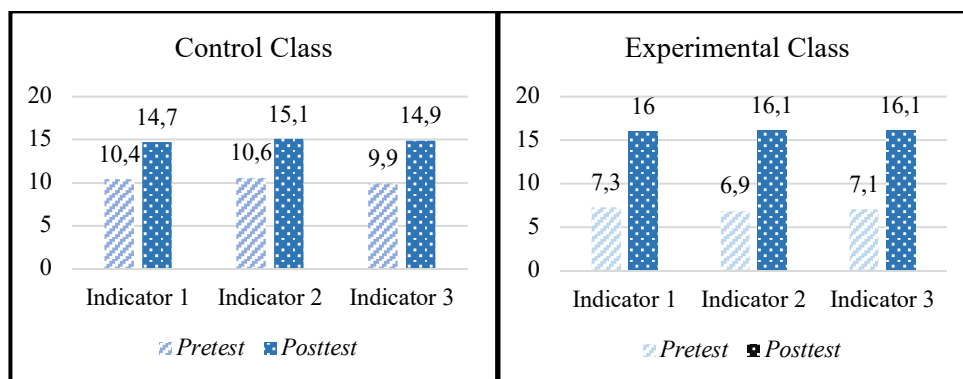
|                   |                             | <b>Levene's Test<br/>for Equality of<br/>Variances</b> |      | <b>t-test for Equality of Means</b> |        |                        |                    |                          |                                                 |       |
|-------------------|-----------------------------|--------------------------------------------------------|------|-------------------------------------|--------|------------------------|--------------------|--------------------------|-------------------------------------------------|-------|
|                   |                             | F                                                      | Sig. | t                                   | df     | Sig.<br>(2-<br>tailed) | Mean<br>Difference | Std. Error<br>Difference | 95% Confidence<br>Interval of the<br>Difference |       |
|                   |                             |                                                        |      |                                     |        |                        |                    |                          | Lower                                           | Upper |
| Learning outcomes | Equal variances assumed     | 1,728                                                  | ,194 | -                                   | 58     | ,020                   | -5,000             | 2,082                    | -9.168                                          | -.832 |
|                   | Equal variances not assumed |                                                        |      | -                                   | 57,022 | ,020                   | -5,000             | 2,082                    | -9,169                                          | -.831 |

The Independent T Test results obtained a sig (2-tailed) value of 0.020. These results show that the significant value is smaller than the critical limit (0.05), so it can be concluded that H0 is rejected and H1 is accepted, which means there are differences between the two groups. The Gain Score test was carried out to determine whether there were differences in the abilities and improvements in the logical thinking skills of students in the experimental class and control classes after being given treatment. The differences between the two classes can also be seen in the increase in student learning outcomes, as proven through the gain score test, which can be seen in [Figure 1](#).



**Figure 1.** Comparison of Control Class and Experimental Class

Based on the gain score test results in Figure 1 above, the percentage increase in the control class is 0.47 or 47%, and the experimental class is 0.70 or 70%. This increase was obtained from the pre-test results in the experimental class, namely 35.17, then the pre-test results in the control class were 51.50. The results in the control class are higher compared to the experimental class. However, after being given treatment in the experimental class, these results increased in the post-test by 80.33 compared to the control class, which was only 74.47. So, students' logical thinking skills based on the results of this analysis have increased in both the control and experimental classes. However, a significant increase in ability occurred in the experimental class. This shows that integrating the shape of the Bola Soba building character facade based on Augmented Reality ethnomathematics in the experimental class is more effective. The improvement can also be seen from the analysis of logical thinking skill indicators, which consist of 3 indicators: Consistency of Thinking, Arguing Ability, and Drawing conclusions. Visually, the improvements can be seen in the following image.



**Figure 2.** Analysis of Logical Thinking Skill Indicators

The results of the analysis of indicators of students' logical thinking skills based on the research can be described as follows. The ability of control class students to state all the information from what was known and asked in the pre-test questions obtained an average score of 10.4. In this indicator, students have identified the relationship between the concepts given, but organizing ideas clearly in the problem-solving process is still challenging. After the post-test, students showed an increase in coherent thinking by detailing their thoughts better, but the results did not show a significant increase from their initial ability of 14.7. Meanwhile, the ability of students in the experimental class to think sequentially and solve problems in the pre-test questions was still in the low category, with an average score of only 7.3. After implementing the exploration media in the form of the Bola Soba building facade based on Augmented Reality ethnomathematics in learning, the student's ability to state all the information from what is known and ask appropriately about a problem/problem faced increased to 16 with a high category. Students who were initially only able to understand the essence of a problem can now detail thoughts better, identify more complex relationships between the concepts given and the sequence of thinking, and organize ideas more systematically according to the overall structure of the problem. This is created when students are exposed to real-life concepts that are easy to understand,

The ability of students in the control class to solve problems correctly at each step by providing arguments (opinions) in the problem-solving step obtained an average score on the pre-test of 10.6 and increased on the post-test to 15.1. Students' abilities in this indicator show the medium category; namely,

students can formulate logical arguments and support claims with sufficient appropriate evidence. The pre-test results of experimental class students in measuring indicator 2 (argument ability) were 6.9. This result has increased, as seen from the post-test, to 16.1. Exploring the shape of the Soba Ball facade character based on ethnomathematics Augmented Reality can improve students' problem-solving skill by providing arguments for each step used in the Pythagoras theorem material. Students in the experimental class showed progress, where initially, the students needed help understanding, analyzing, and evaluating the arguments given for each answer to a problem. However, after carrying out a series of learning by exploring the shape of the Soba Ball facade character based on Augmented Reality ethnomathematics and linking it to the material concept of the Pythagoras theorem. The ability of control class students to find and draw appropriate conclusions at the end of the answer connecting cause and effect based on their own point of view is still very low, as seen from the pre-test results; students only got an average score of 9.9. The results obtained in the experimental class also showed a low category, namely only 7.1. After implementing the problem-based learning model in the control class, students' ability to conclude increased to 14.9. This increase is still in the moderate category. Meanwhile, the experimental class experienced an increase of 16.1 in the high category.

The logical thinking skills of students in this study from the pre-test results show that students are still weak in understanding the concepts of the material provided. This factor can be explained by teachers' current practice of using less diverse methods for students. Even though some teachers have tried to involve question-and-answer interactions in the learning process, the response to this approach is only seen in some students with a higher level of ability and competence. On the other hand, other students tend to be more passive and less focused on the material being presented. As a solution, to increase students' interest and motivation in studying the Pythagoras theorem material, this can be done by integrating learning with everyday situations or students' contextual experiences through an ethnomathematics learning approach, mainly traditional Soba Ball building forms into the learning process. In this media, students carry out activities to identify the shape of the facade of the Bola Soba building with a triangular shape and, at the same time, determine the relationship between the sides in the triangle presented. So, students will indirectly understand the concept of the material provided. In this media, students carry out activities to identify the shape of the facade of the Bola Soba building with a triangular shape and, at the same time, determine the relationship between the sides in the triangle presented. So, students will indirectly understand the concept of the material provided. In this media, students carry out activities to identify the shape of the facade of the Bola Soba building with a triangular shape and, at the same time, determine the relationship between the sides in the triangle presented. So, students will indirectly understand the concept of the material provided.

The results of this research are in line with the findings of [Mawaddah \(2018\)](#) and [Asfar et al. \(2021\)](#), which explain that the integration of local wisdom in the learning process using an ethnomathematics approach is an alternative step that can be applied to train students' ability to think, especially the logical thinking aspect. Apart from improving logical thinking skills, applying this learning can also improve other abilities, such as increasing students' understanding of local wisdom, which can be applied in learning to become a forum for cultural preservation and support existing cultural resilience. Apart from that, research conducted by [Damayanti et al. \(2022\)](#), [Asfar et al. \(2022\)](#), [Nurannisa et al. \(2021\)](#), and [Nurannisa et al. \(2021\)](#), the application of learning based on local wisdom has a quite good influence on the learning process, so that it can improve students' learning achievement in mathematics subjects such as congruency and congruence material. This research also found that the application of learning with the integration of local wisdom is also able to improve students' complex problem-solving skills by having learning activities while playing so that the learning process carried out is not only meaningful (meaningful learning) but also able to create enjoyable learning (joyful learning).

However, if the learning process is only based on local wisdom, integrating technology into its application is necessary for some students to be active. Thus, the innovation applied in this research is combining Augmented Reality technology in an integrated learning process of local wisdom. Augmented Reality (AR) is a technology that combines virtual objects with natural objects ([Hutahaeen et al., 2022](#)). In education, this technology is used as a visualization tool to make students better understand the concepts of the material provided. Apart from that, using augmented reality can increase interest in learning because it can directly build the imagination of a natural environment. So, with Augmented Reality-based learning media, we can create meaningful learning by utilizing existing technological resources. The stages of implementing Ethnomathematics Augmented Reality-based learning media are by exploring the shape of the facade of the Bola Soba building character in mathematics subjects, especially in the Pythagoras theorem material. Students are directed to make connections between the pattern of the facade shape of the Buckwheat Ball character and the concept of the Pythagoras theorem, then understand the formula that will be used. Several prior studies emphasize the significance of incorporating cultural elements into modern education. For example, research by [Suherman and Vidakovich \(2022\)](#) highlights how ethnomathematics, when contextualized in local wisdom, not only preserves cultural heritage but also significantly enhances students' cognitive skills, particularly problem-solving skills. Using ethnomathematics has fostered a deeper understanding of mathematical concepts by connecting abstract

ideas to tangible, real-life contexts, thereby improving learning outcomes. This aligns with the findings of Hsu & Hsu (2024), who found that incorporating local cultural elements into the curriculum, primarily through digital platforms, enhances students' engagement and retention of complex concepts, such as geometry and algebra. In addition, integrating technology, particularly Augmented Reality (AR), with ethnomathematics elevates students' cognitive and analytical abilities. Singh et al. (2024) emphasized that AR fosters an interactive learning environment that enhances spatial reasoning, problem-solving, and logical thinking. This technology makes abstract mathematical concepts more accessible by allowing students to visualize and manipulate virtual objects in real-time. Similarly, Wu et al. (2024) find that AR-based learning significantly improves students' ability to grasp complex mathematical theories by making the learning process more engaging and intuitive.

The novelty of this research lies in its unique combination of ethnomathematics and AR, which is explicitly applied to the study of the Pythagorean theorem through the cultural context of the Bola Soba building. While previous studies have explored AR's impact on education, few have combined it with local wisdom to enhance students' logical thinking skills. This study contributes to the growing body of research by showing that integrating local culture with modern technology preserves cultural values and enhances mathematics learning outcomes. The research is innovative in using AR to make traditional wisdom accessible and relevant to modern educational contexts, demonstrating a significant advancement in how local wisdom can be integrated into 21st-century learning. Based on the findings of this study, future researchers are encouraged to explore further the integration of diverse cultural contexts with modern technology to expand the scope of ethnomathematics in education, creating adaptable models that combine AR and local wisdom across various mathematical topics. Educators should consider utilizing AR to contextualize mathematical concepts within the local culture, as this approach has shown the potential to enhance students' understanding and appreciation of both the subject and their heritage. Policymakers are advised to support the development of educational materials incorporating AR and cultural relevance and promote policies that foster innovative, culturally integrated technology in curricula. Such efforts can create a learning environment that not only preserves cultural values but also advances educational outcomes in a meaningful, contemporary way.

## CONCLUSION

The study significantly improves students' logical thinking skills, particularly in the Pythagoras theorem material. While the control and experimental groups showed progress, the experimental group, which utilized the Ethnomathematics-Based Augmented Reality of Bola Soba Character Facades, experienced a more substantial increase. This indicates that integrating AR and local cultural elements can enhance students' engagement, motivation, and problem-solving skills. These findings suggest that AR-based ethnomathematics, such as the Bola Soba facade, can be effectively integrated into mathematics education to improve learning outcomes, especially for abstract concepts like the Pythagoras theorem.

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