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Ethnomathematics-Collaborative Augmented Reality: An Innovative Framework to Enhance Problem-Solving Skills in Elementary Geometry

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ABSTRAK

Penelitian ini dilatarbelakangi oleh pentingnya pengembangan kemampuan pemecahan masalah pada siswa sekolah dasar sebagai landasan fundamental dalam mendukung proses pembelajaran yang efektif. Penelitian ini bertujuan untuk menganalisis efektivitas framework *geometri berbasis* ethnomathematics-collaborative augmented reality *dalam meningkatkan kemampuan pemecahan masalah siswa sekolah dasar. Jenis penelitian ini merupakan eksperimen dengan pendekatan kuantitatif dan menggunakan desain* one group pre-test post-test*. Subjek penelitian terdiri dari 30 siswa kelas IV Sekolah Dasar. Pengukuran efektivitas dilakukan melalui metode tes sebelum dan sesudah penerapan framework. Analisis data menggunakan teknik analisis deskriptif dan inferensial dengan Uji-t sampel berkorelasi (*Paired Sample T-Test*) yang diolah menggunakan IBM SPSS Statistics versi 21.0. Hasil penelitian menunjukkan adanya perbedaan signifikan pada kemampuan pemecahan masalah siswa sebelum dan sesudah penerapan* framework *geometri berbasis* ethnomathematics-collaborative augmented reality*. Rata-rata hasil* post-test *lebih tinggi dibandingkan dengan* pre-test*, yang menunjukkan peningkatan kemampuan pemecahan masalah siswa. Penerapan* framework *ini efektif dalam menciptakan pengalaman belajar yang kontekstual, kolaboratif, dan berbasis teknologi, yang mampu meningkatkan keterampilan pemecahan masalah siswa. Dengan demikian,* framework *ini dapat menjadi inovasi yang relevan dalam pembelajaran geometri di sekolah dasar, sekaligus mendukung pengintegrasian nilai budaya lokal dalam proses pembelajaran*

ABSTRACT

This study addresses the urgent need to develop problem-solving skills among elementary school students as a fundamental basis for effective learning processes. The research aims to analyze the effectiveness of a geometry framework based on ethnomathematics-collaborative augmented reality in enhancing students' problem-solving abilities. This experimental research employs a quantitative approach with a one-group pre-test post-test design. The study involved 30 fourth-grade elementary school students as subjects. The effectiveness of the framework was measured using pre-test and post-test methods. Data analysis was conducted using descriptive and inferential statistics, with the Paired Sample T-Test applied to test the hypothesis, utilizing IBM SPSS Statistics for Windows version 21.0. The results indicated a significant difference in students' problem-solving abilities before and after the implementation of the geometry framework. The post-test results showed a notable improvement in students' problem-solving skills compared to the pre-test. The application of the ethnomathematics-collaborative augmented reality framework proved effective in providing contextual, collaborative, and technology-based learning experiences, which significantly enhanced students' problem-solving capabilities. Therefore, this framework offers a relevant innovation in geometry learning for elementary education, promoting the integration of local cultural values into the learning process and supporting students' cognitive development through problem-solving tasks.

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1. INTRODUCTION

This research is driven by an urgency about the importance of developing problem-solving skills in elementary school students as a fundamental foundation for an effective learning process (Nasution & Oktaviani, 2020; Utami & Wutsqa, 2017). Problem-solving skills play an important role in learning mathematics, especially when studying geometry material at the elementary school level. These skills include students' awareness of effective learning strategies, understanding of their own thinking processes, and the ability to monitor and regulate their cognitive activities (Siswanto & Ratiningsih, 2020; Tonsmann, 2014). Problem solving skills enable students to better understand basic geometric concepts, recognize patterns, and develop more efficient problem solving strategies (Fouze & Amit, 2021; Kartono, 2010). In addition, problem-solving skills also help students overcome difficulties and obstacles in understanding geometry materials, as well as giving them the confidence to explore new ideas and face mathematical challenges more confidently (Afriliziana, LA, Maimunah., & Roza, 2021; Fathimah & Ishartiwi, 2018). Thus, the development of problem-solving skills in elementary school students is crucial in creating a learning environment that is stimulating, supportive, and effective in strengthening their understanding of geometry materials. Problems that occur related to students' problem-solving abilities in mathematics learning, especially in geometry material in elementary schools, include students' lack of awareness of effective learning strategies, difficulties in organizing and monitoring their own thinking, and a tendency to rely on mechanical problem solving without understanding geometric concepts in depth (Arisetyawan et al., 2021; Nurmi et al., 2020). As a result, students often have difficulty in understanding complex geometric concepts and solving problems involving these concepts. In addition, the lack of supporting learning media that is oriented towards problem-solving skills is also a problem in itself (Nurhairunnisah & Sujarwo, 2018; Waruwu & Sitinjak, 2022).

Elementary school students have difficulty in understanding abstract and theoretical geometric concepts. Conventional approaches to teaching geometry tend to be uninteresting and non-contextual, making it difficult for students to relate the concepts to their everyday experiences. This results in low interest and motivation in learning geometry, which in turn has a negative impact on their problem-solving abilities in the subject (Fitriani, 2014; Muhassanah et al., 2014). Ethnomathematics offers the potential to address this issue by linking mathematical concepts to students' local culture and experiences. By integrating cultural elements into geometry learning, students can see the relevance of mathematics in their everyday lives, thereby increasing their understanding and engagement (Risdiyanti & Prahmana, 2017; Yandani & Agustika, 2022). However, the application of ethnomathematics in geometry learning in elementary schools is still limited and requires support from technology to achieve optimal effectiveness. Lack of access to learning tools that encourage reflection, self-monitoring, and interactive exploration of mathematical concepts can hinder the development of students' problem-solving skills (Apriadi, 2021; Isroqmi, 2020). This causes geometry learning to tend to be passive and less stimulating, which in turn can limit students' understanding and interest in the material. Therefore, efforts are needed to overcome these problems by developing a more interactive, supportive, and problem-solving-oriented learning approach to students, as well as by utilizing supporting media that allow students to be actively involved in the mathematics learning process, especially geometry.

This study aims to analyze the effectiveness of ethnomathematics-collaborative augmented reality-based geometry framework on elementary school students' problem-solving abilities. This framework offers a unique approach by combining the concept of ethnomathematics, which is a mathematical science rooted in local culture, into AR-based learning media. This allows students to understand geometry concepts through objects and patterns originating from local culture. This approach has not been widely implemented in technology-based learning, especially at the elementary school level.Different from AR research which is usually individual, this framework is designed with a collaborative approach, where students can work together in an AR environment to solve geometry problems. Students can see the same geometry objects in AR and discuss together, which is expected to improve their collaboration and communication skills.

2. METHOD

This research is an experimental research using a quantitative approach. The research design used in this study is one group pre-test post-test design. Based on this design, the research subjects will be given a pre-test before treatment. Furthermore, the research subjects are given treatment in the form of implementing learning using framework geometry based on ethnomathematics-collaborative augmented reality. This research was conducted in Singaraja City, Bali. The subjects of this research were 30 fourth grade students at SD 1 Kalibukbuk. Effectiveness of useframeworkgeometry based on ethnomathematics-collaborative augmented realitycan be measured using the test method. This method is carried out by giving

a pre-test and post-test to determine the level of success of student learning outcomes before and after the application of the E-Scrapbook media Containing HOTS-Based Questions. The instrument grid used in this study is presented in Table 1.

Table 1. The Indicators of Mathematics Problem Solving

Basic Competencies	Competency Indicators	Number of Questions
Math Problem Solving	Understanding the problem	3
	Planning a resolution strategy	3
	Implementing the strategy	3
	Evaluate and re-check	3
	Creativity and flexibility in problem solving	4
	Collaborative Problem Solving	4
Total		**20**

The data analysis method used in this study is descriptive and inferential analysis. The analysis technique used to test the hypothesis is the paired sample t-test. Hypothesis testing uses the assistance of the IBM SPSS Statistics for Windows version 21.0 program. Testing is determined by the significance value. This value then determines the decision taken in the study. If the significance value (2-tailed) <0.05 indicates a significant difference in the results of students' science learning before and after participating in learning using framework geometry based on ethnomathematics-collaborative augmented reality. If the significance value (2-tailed) > 0.05 indicates that there is no significant difference in the mathematical problem-solving abilities of students before and after participating in learning using framework geometry based on ethnomathematics-collaborative augmented reality. Hypothesis testing is preceded by analysis prerequisite tests which include data distribution normality tests and variance homogeneity tests.

3. RESULT AND DISCUSSION

Result

Descriptive Analysis

The results of the descriptive analysis of the pretest and posttest data in this study are presented in Table 2.

Table 2. The Results of Descriptive Analysis

Statistics	Pretest	Posttest
Mean	3.70	11.30
Median	4.00	11.00
Variance	1.81	4.51
Std. Deviation	1.35	2.12
Minimum	1.00	8.00
Maximum	6.00	15.00

Prerequisite Analysis Test Results

The prerequisite tests conducted in this study include the normality test of data distribution and the homogeneity test of variance. Based on the results of the normality test analysis using the assistance of the IBM SPSS Statistics 21.0 for Windows program. The results of the normality test are shown in Table 3.

Table 3. Normality Test Results

Test	Statistical Values	p-value	Conclusion
Pre-test	0.947	0.752	Normal data
Post-test	0.967	0.925	Normal data

Based on Table 3 shows the results of the normality test conducted using the Shapiro-Wilk test, it can be concluded that the data for the pretest and posttest are both normally distributed. The Shapiro-Wilk statistical value for the pretest is 0.947 with a p-value of 0.752, while for the posttest the statistical value is 0.967 with a p-value of 0.925. Since both p-values are greater than 0.05, we fail to reject the null hypothesis that the data are normally distributed. This indicates that the distribution of pretest and posttest scores does not deviate significantly from the normal distribution, which means that the data can be further

analyzed using parametric techniques that assume normality, such as the t-test for comparison of pre- and post-scores. Thus, we can continue the analysis without having to worry about violating the normality assumption. The results of the homogeneity of variance test using the Levene test, obtained an F statistic value of 4.15 with a p-value of 0.05. Because the p-value is greater than the significance level commonly used (0.05), this means that there is no significant difference between the pretest and posttest variances, so it can be concluded that the variances of the two groups are homogeneous or the same. Thus, the pretest and posttest data have similar variance distributions, which meets the assumptions for further statistical analysis that requires equality of variance.

Hypothesis Test Results

Based on the results of the paired sample t-test analysis using the IBM SPSS Statistics 21.0 for Windows program, a significance value (Sig. 2-tailed) of 0.000 was obtained. Based on these results, it can be seen that the Sig. value <0.05. So it can be concluded that H_0 is rejected and H_a is accepted. In other words, there is a significant difference between the problem-solving abilities of students before and after participating in learning usingframeworkgeometry based on ethnomathematics-collaborative augmented reality. Thus, this model is effective in improving student learning outcomes. Based on the results of the paired t-test, there is a significant difference between the pretest and posttest scores ($t = 15.24$, $df = 19$, $p < 0.001$). The average posttest score (Mean = 10.7, SD = 2.25) is significantly higher than the average pretest score (Mean = 3.3, SD = 1.53), which indicates an increase in participants' understanding after participating in the learning or training process. A very small p-value ($p < 0.05$) indicates that these results did not occur by chance, so it can be concluded that the training or learning provided has a positive effect in significantly increasing participants' scores.

Discussion

Students' mathematical problem-solving abilities are still relatively low, especially when faced with complex problems that require more than one solution step. Teachers reported that students often have difficulty understanding story-based problems, especially in identifying important information and determining the initial steps for solving. This shows that students have limitations in analytical thinking and choosing the right strategy to solve problems (Atmaja, 2021; Dinarti & Qomariyah, 2022). Students' dependence on conventionally taught methods without critical thinking skills or exploration of new strategies becomes an obstacle in the development of their problem-solving skills. In addition, the lack of student learning motivation is also a major obstacle. Students often feel that the mathematics material taught is not relevant to their daily lives, so they are less interested in exploring further or finding more creative solutions. Teachers observed that learning methods that tend to be conventional and minimal application of technology and local cultural contexts also contribute to low student motivation (Dwiyono & Tasik, 2021; Tasya & Abadi, 2019). When students are unable to see a direct connection between mathematical concepts and real life, they are more likely to memorize formulas rather than truly understand the concepts. This results in confusion when faced with problems that require more flexible application of formulas (Dewi & Agustika, 2020; Septiani & Purwanto, 2020).

Furthermore, other factors that contribute to low problem-solving abilities are weak understanding of basic mathematical concepts, especially in geometry, lack of student involvement in collaborative learning, and minimal application of mathematics in real-life contexts (Mawaddah & Anisah, 2015; Qodr et al., 2021). The low level of collaboration in the classroom causes students to rarely engage in discussions that can encourage them to think more critically and creatively. To overcome this problem, a learning framework based on ethnomathematics and collaborative augmented reality is expected to be a solution (Gk & Prahmana, 2019; Risdiyanti & Prahmana, 2017). This approach allows students to learn mathematics through relevant local cultural contexts, increases their engagement and motivation with more interactive methods, and encourages collaboration among students so that their problem-solving abilities can be significantly improved.

Frameworkethnomathematics-collaborative augmented reality-based geometry is a new innovation in geometry learning at the elementary school level. The main novelty of this innovation lies in the integration of two key elements: the ethnomathematics approach and collaborative augmented reality technology (Fatra et al., 2022; Yao & Manouchehri, 2020). The ethnomathematics approach allows students to explore geometric concepts through the lens of their local culture, thereby increasing students' connectedness to the subject matter. Meanwhile, the use of collaborative augmented reality technology provides a more interactive and immersive learning experience, allowing students to collaborate in exploring geometric concepts in a real-world context (Mida Astarina et al., 2023; Mursyidah, D. & Saputra, 2022).

This innovation has the potential to create a stimulating and meaningful learning environment for elementary school students, where they can strengthen their understanding of geometry while developing problem-solving skills effectively. The advantages of this innovation include student-centered learning experiences, increased student engagement in the learning process, and the use of modern technology potential to support the development of students' problem-solving skills holistically (Nursyifa et al., 2020; Yao & Manouchehri, 2020). The results of this study provide important implications for educators and curriculum developers, especially in the context of mathematics learning in elementary schools. The low problem-solving abilities of students indicate the need for innovation in learning methods. Conventional approaches that only focus on the application of formulas and procedural steps are not effective enough in developing students' critical and analytical thinking skills. By integrating Ethnomathematics-based learning and Collaborative Augmented Reality, teachers can help students better understand mathematics in the context of their local culture and daily lives. This can also increase student motivation because they see the direct relevance between the concepts learned and the real world. Furthermore, collaborative learning is expected to be able to encourage interaction between students, so that critical thinking and problem-solving skills can be further honed. This study has several limitations that need to be considered. First, the number of respondents interviewed was limited to only a few teachers, so the results may not fully represent the perceptions of all teachers or schools. Second, this study did not involve direct observation of the classroom learning process, which could provide a clearer picture of how students interact with materials and teachers when facing mathematical problems. Third, the proposed ethnomathematics and collaborative augmented reality approaches have not been directly tested in this study, so the effectiveness of these approaches is still theoretical and requires further research to test the results in real contexts. Finally, because this study was conducted in elementary schools in a specific area, the results may not be generalizable to all elementary schools in Indonesia or elsewhere with different educational conditions.

4. CONCLUSION

This study concludes that elementary school students' mathematical problem-solving abilities are still low, especially in problems that require analytical understanding and the application of more than one solution step. Students tend to rely on formulas without understanding basic concepts, have difficulty in identifying important information, and are less motivated because they feel that mathematical material is not relevant to their daily lives. Factors such as conventional learning methods, lack of student involvement in collaborative learning, and minimal application of mathematics in real contexts contribute to worsening this situation. The implication of these findings is the need for learning innovations, such as the use of Ethnomathematics and Collaborative Augmented Reality approaches, which can increase students' motivation, involvement, and problem-solving abilities through more relevant and interactive learning.

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