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The Effectiveness of Puzzle Game-Based Learning Media in Improving Mathematics Science Problem Solving Skills

Hidayatulloh[1*], Noerhasmalina[1]

[1] Mathematics Education, Universitas Muhammaiyah Pringsewu, Indonesia.

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Corresponding Author:
Hidayatulloh
hidayatulloh@umpri.ac.id

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Abstract: Problem solving ability is an important skill in learning mathematics, especially in geometry material that requires conceptual understanding and spatial analysis. This study aims to test the effectiveness of puzzle games in improving mathematical science problem solving abilities. The method used in this study was a quasi-experimental design with a pretest-posttest control group design. The research sample consisted of 60 grade XII students who were divided into two groups, an experimental group using ethnomathematics puzzle games and a control group using conventional methods. Data were obtained through problem solving tests before and after treatment, then analyzed using N-gain and t-test with SPSS to determine the significance of differences in learning outcomes between the two groups. The results showed that the experimental group experienced a significant increase compared to the control group ($p < 0.001$). The average N-gain value in the experimental group was 0.70 in the high category, while in the control group it was 0.46 in the moderate category. In addition, the effect size analysis of 1.39 showed that the use of ethnomathematics puzzle games had a major impact on improving students' mathematical science problem solving abilities. Puzzle games are an effective learning medium in improving students' mathematical science problem-solving abilities in geometry material. In addition, this approach can enrich students' learning experiences by connecting mathematical concepts with relevant cultural contexts. Therefore, the use of ethnomathematics puzzle games is recommended as an innovative learning strategy that can be applied in teaching mathematics at MAN 1 Tanggamus.

Keywords: Learning media; Mathematics science; Problem solving; Puzzle games.

Introduction

Mathematics and science is a fundamental discipline that plays an important role in developing critical thinking and analytical science skills (Alosaimi, 2013). One branch of mathematics that is often a challenge for students is geometry, which requires an understanding of spatial concepts and the application of effective problem-solving strategies (NCTM, 2020). Based on the 2022 Programme for International Student Assessment (PISA) report, Indonesia is still ranked low in mathematical science problem-solving skills, with a lower average score than other Southeast Asian countries (OECD, 2022). This indicates the need for a more innovative learning approach to improve students' understanding and problem-solving skills in mathematics, especially in geometry material. One of the main factors causing students' low problem-solving abilities is the use of conventional learning methods that do not actively involve students in the critical thinking process (Ahdhianto et al., 2020). Learning that is only centered on the teacher tends to make students passive and less able to connect geometric concepts with real situations (Rohmah & Surahmat, 2024). Therefore, a learning strategy is needed that is not only interactive but also relevant to students' experiences and culture (Hsu & Wang, 2018).

A preliminary study conducted at MAN 1 Tanggamus on 60 students of grade XII MIPA 1 and XII MIPA 2 showed that the majority of students had difficulty in solving geometry problem solving problems. The average score obtained was only 48.2, far

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below the Minimum Completion Criteria (KKM) set by the school, which was 75. Most students had difficulty in understanding geometry concepts abstractly and were unable to relate the problems in the questions to their daily lives. This shows that a more contextual and real-life experience-based learning approach is needed to improve students' understanding. Ethnomathematics is one of the right solutions to overcome this problem. This approach connects mathematical concepts with local culture so that it can increase student engagement and make learning more meaningful (Kadonsi et al., 2023). In many cultures in Indonesia, geometry concepts have long been used in various aspects of life, such as in batik patterns, traditional house architecture, and traditional games. By using ethnomathematics-based puzzle games, students can learn geometry through contexts that are closer to them, thereby improving their understanding of the concepts being taught. In addition, several previous studies have shown that the ethnomathematics approach can improve students' learning motivation and problem-solving skills (Iswara et al., 2022). Based on this background, this study aims to analyze the effectiveness of ethnomathematics puzzle games in improving students' problem-solving abilities in geometry material. This study is expected to contribute to the development of innovative learning models that are more effective in improving students' mathematics science learning outcomes.

Method

This study used a quasi-experimental method with a pretest-posttest control group design. This design was used to see whether the ethnomathematics puzzle game was more effective than conventional learning methods in improving students' problem-solving abilities.

The research sample consisted of 64 students of class XII MIPA 1 and XII MIPA 2 at MAN 1 Tanggamus. Students were divided into two groups, namely the experimental group was given treatment by being taught using the ethnomathematics puzzle game while the control group used conventional methods. The sample selection was carried out by purposive sampling, namely based on the similarity of the students' academic ability levels.

This study used a problem-solving test as a measuring tool. This test consists of several descriptive questions that measure the problem-solving indicators using indicators from Savage & Williams (1990), namely set up model, analyze the problem and interpret and validate. This test has been validated by experts to ensure that the questions used are in accordance with the research objectives. The research steps were carried out in several stages. First, a pretest was conducted to determine the students' initial abilities before being given treatment. After that, the experimental group was given learning using the ethnomathematics puzzle game, while the control group continued to use conventional methods. The learning process lasted for four meetings. After completion, students were given a posttest to see if there was an increase in their problem-solving abilities.

The data obtained were analyzed using several statistical techniques. The increase in student learning outcomes was calculated using N-gain. To find out if there was a significant difference between the experimental group and the control group, a t-test was used with the help of SPSS software. In addition, an effect size analysis was carried out to determine how much influence the use of ethnomathematics puzzle games had on improving students' problem-solving abilities. With this method, this study is expected to provide real evidence regarding the benefits of using ethnomathematics puzzle games in mathematics learning, especially in improving students' problem-solving abilities in geometry material.

Result and Discussion

Results

Learning implementation

Before carrying out learning activities, students in the experimental and control classes were given pretest questions to measure students' initial abilities. The results of initial abilities were analyzed based on problem-solving ability indicators which can be seen in Figure 1.

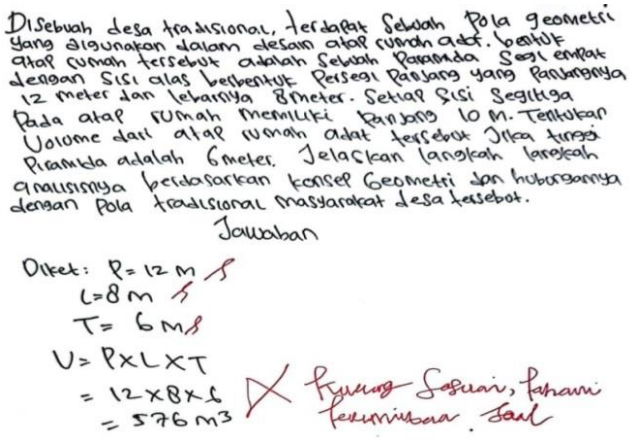

Figure 1. Results of problem solving analysis based on students' pretest answers

In Figure 1, it can be seen that problem solving ability, in the first problem solving indicator, namely set up model, students can already describe known

variables, but in the analyze the problem indicator, students have not mastered it because students have not been able to describe or plan solutions in solving problems and in the last indicator, namely interpret and validate, students have not been able to interpret and validate the results of the answers from the problem solving solution because the second indicator has not been fulfilled. From Figure 1, it can also be concluded that students' problem solving abilities are relatively low, so to improve these abilities, geometry material learning activities are carried out. The experimental class was given learning using ethnomathematics puzzle games and the control class used conventional methods to improve problem solving abilities. The ethnomathematics puzzle game used in this study is as shown in Figure 2.

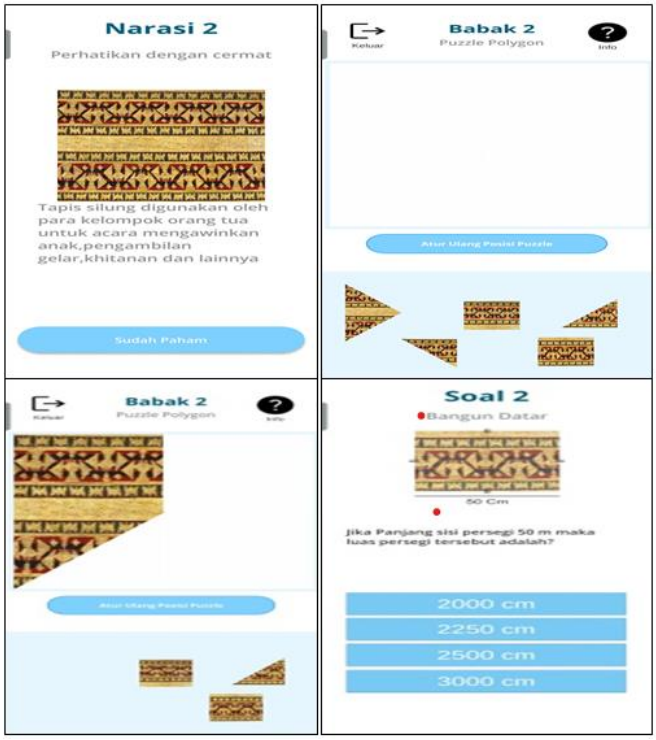

Figure 2. Example of the display and description of the ethnomathematics puzzle game on geometry material

The implementation of ethnomathematics game-based learning in the experimental class began with the teacher providing an introduction to the unique culture of Lampung tapis, a traditional cloth that has high cultural value in society. The teacher explained that tapis is not only used as traditional clothing, but also has deep meaning in each pattern and motif, which is usually associated with important events such as weddings, title taking, and circumcision. This explanation aims to attract students' attention while connecting mathematics learning with local culture that is familiar to their lives.

Next, students are invited to enter a game that has been designed based on ethnomathematics. This game consists of several rounds. In the first round, students are given pieces of a tapis image that have been broken down into several polygon-shaped parts. The students' task is to rearrange the pieces into a complete image. This activity not only trains students' ability to recognize geometric patterns and shapes, but also improves logical and spatial thinking skills. In the process, students face the challenge of rearranging each piece precisely, which encourages them to use strategy and precision. After successfully completing the puzzle in the first round, students move on to the second round, which focuses more on solving mathematical problems. In this round, students are given questions that require them to calculate the area of a plane figure based on the sieve pattern they have previously arranged. For example, in the image shown, students are asked to calculate the area of a square with a certain side length. This question is designed to integrate the concept of the area of a plane figure that has been studied previously with the context of a sieve as a learning medium. With the available answer choices, students are trained to analyze information and make decisions quickly and accurately.

This learning process ends with evaluation and reflection. The teacher invites students to discuss their experiences while playing the game. The discussion focuses on how mathematical concepts, such as the area of flat shapes, can be applied in everyday life through local culture, such as the Lampung tapis. The teacher also provides opportunities for students to express the difficulties they face and how they find solutions during the game. Through this learning, students not only learn mathematics, but also understand the importance of local culture as part of their lives. Activities that combine culture with mathematical concepts are expected to stimulate students' problem-solving abilities creatively and critically. In addition, this game-based approach also aims to increase students' interest in mathematics by presenting interesting and relevant learning. Analysis of the implementation of learning is observed through observation sheets that include aspects of student involvement, smooth delivery of material, and the effectiveness of learning media. The results of the observation show that the implementation of learning in the experimental class reaches a high level of activity. Students are more motivated to complete challenges in the puzzle game and participate more in group discussions.

In addition, teachers also find it easier to facilitate learning because the media used attracts students' attention and helps them understand geometry

concepts more contextually. In contrast, in the control class using conventional learning methods, student engagement tended to be lower. Students received more explanations from the teacher directly using lecture methods and practice questions.

Active participation in class discussions was relatively less compared to the experimental class. Although students still showed an understanding of the material being taught, their level of enthusiasm in participating in learning was not as high as students in the experimental class. Some students also had difficulty in completing problem-solving questions independently without the support of interactive media as a stimulus. In terms of implementation time, learning in the control class also went according to plan, but provided less variation in the learning approach. This shows that although conventional methods can still be used in geometry learning, their effectiveness in increasing student engagement and problem solving is lower than the ethnomathematics puzzle game-based approach. After the learning was completed, a posttest was given with the aim of seeing how students' understanding was in solving geometry problems through problem-solving abilities in answering questions as in Figure 3.

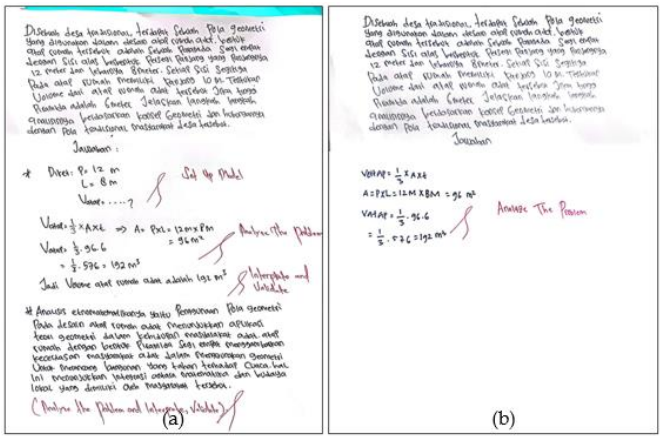

Figure 3. Post-test results (a) of experimental class students' problem solving, (b) control class problem solving.

In Figure 3(a) it can be seen that students' problem-solving abilities using ethnomathematics puzzle game-based learning can improve each indicator. In the set up model indicator, students are able to model the variables involved appropriately, the analyze the problem indicator has also been mastered well, indicated by students being able to analyze problem solutions and their solutions well and finally in the interpret and validate indicator, students are able to interpret and validate correctly the results of solving the given questions and review them with ethnomathematics concepts in everyday life applications.

In Figure 3(b) it can be seen that students' problem-solving abilities using ethnomathematics puzzle game-based learning only improve the analyze the problem indicator. In the set up model indicator, students have not been able to model the variables involved appropriately, the analyze the problem indicator has also been mastered well, marked by students being able to analyze problem solutions and their solutions well and finally in the interpret and validate indicator, students have been able to interpret and validate correctly the results of solving the given problems and reviewing them with ethnomathematics concepts in the application of everyday life. From Figure 3(a)-3(b) it is concluded that geometry learning based on ethnomathematics puzzle games can improve problem-solving skills based on each indicator, while geometry learning with conventional learning is less able to improve problem-solving skills optimally because students only understand the solutions offered based on text books without understanding the meaning of understanding the concepts contained in the questions given. The results of the total pretest and post-test of students in the experimental and control classes were then analyzed to compare the level of effectiveness of the two learning methods. The results of the recapitulation of the total pretest and posttest scores of students can be seen in Table 1.

Table 1. Recapitulation of students' pre-test and post-test results

Group	Average of *pre-test*	Average of *post-test*
Experimental	45.2	80.5
Control	44.8	70.3

In Table 1, the recapitulation of pretest and posttest scores shows that there was a significant increase between the experimental group and the control group. The experimental group using ethnomathematics puzzle games obtained a higher average posttest score than the control group, this is because geometry learning with ethnomathematics puzzle-based games emphasizes problem-solving skills more than conventional methods because it involves exploring patterns, logic, and creative thinking strategies in a cultural context. Students are challenged to analyze, find solutions, and understand concepts visually and contextually, not just memorizing formulas. This approach also makes learning more interesting, increases motivation, and develops deeper critical and deductive thinking skills. While conventional learning only emphasizes solving approaches without understanding the meaning and application of geometric concepts in everyday life. Games and

cultural elements make learning more interesting and contextual, reducing the boredom that often occurs in conventional methods. Ethnomathematics puzzles require students to think abstractly, find patterns, and develop innovative solutions, which are useful in various aspects of life and work in the future. Through ethnomathematics, students are more familiar with the richness of mathematics in their culture, increasing their sense of pride and appreciation for the nation's intellectual heritage. The pre-test and post-test data were then statistically tested to obtain interpretive results related to the improvement of problem-solving abilities in the control and experimental classes. Before conducting the statistical analysis of the independent sample T-test, the pre-test and post-test data were tested for normality and homogeneity to ensure that the data had a normal distribution and homogeneous variance. The results of the normality and homogeneity tests can be seen in Table 2 and Table 3.

The results of the normality test in Table 2 show that the Kolmogorov-Smirnov significance value for both groups is greater than 0.05, so that the research data is normally distributed. The Levene's Test homogeneity test in Table 3 shows that the variance of both groups is homogeneous (p> 0.05), so that a parametric t-test statistical test can be carried out to analyze the differences between the two groups.

Table 2. Results of the normality test of students' pre-test and post-test data

Group	Sig. Pre-test Value	Sig. post-test Value	Conclusion
Experimental	0.200	0.150	Normal
Control	0.180	0.120	Normal

Table 3. Results of the homogeneity test of students' pre-test and post-test data

Variabel	F Value	Sig. Value	Conclusion
Pre-test	0,200	0,150	Homogen
Post-test	0,180	0,120	Homogen

The results of the t-test show that there is a significant difference between the two groups with a p value <0.05, which means that the use of ethnomathematics puzzle games has a significant effect on improving students' problem-solving abilities as in Table 4.

Table 4. Results of the t-test of students' pre-test and post-test data

Group	Mean	Std. Dev	Sig. (2-tailed)
Experimental	83.5	8.22	0.001
Control	70.3	9.15	

Table 4 shows that students who learn using ethnomathematics puzzle games experience a more significant increase compared to students who learn using conventional methods. In addition to the t-test, analysis of learning outcome improvements was also carried out by calculating the N-gain value. The N-gain value is used to see the level of improvement in students' mathematical science problem-solving abilities after treatment is given as in Table 5.

Table 5. Results of the N-gain test of students' pre-test and post-test data

Group	N-gain	Categories
Experimental	0.70	High
Control	0.46	Medium

The results of the N-gain calculation show that the experimental group with ethnomathematics puzzle game-based learning has a higher average N-gain value than the control group using conventional learning methods. Based on the N-gain classification, the category of increasing students' problem-solving abilities in the experimental group is included in the High category and is higher than the control group with a moderate category.

To determine the extent to which the use of ethnomathematics puzzle games influences the improvement of students' problem-solving abilities, an effect size calculation was carried out. The results of the effect size analysis show that the use of ethnomathematics puzzle games has a major impact on improving students' mathematical science problem-solving abilities with an effect size value of 1.39, which is included in the large effect category according to Cohen (1988) as shown in Table 6.

Table 6. Effect size results of students' pre-test and post-test data

Group	Mean	Std. Dev	Sig. (2-tailed)
Experimental	83.5	8.22	1.39
Control	70.3	9.15	

Thus, the results of the analysis show that the ethnomathematics puzzle game-based learning method has a significant effect on improving students' problem-solving abilities. The t-test proves that there is a significant difference between the experimental and control groups, while the N-gain value shows that the increase in students' problem-solving abilities is greater in the experimental group. In addition, the large effect size value indicates that the use of ethnomathematics puzzle games is very effective in improving student learning outcomes.

Discussion

The results of this study indicate that the use of ethnomathematics puzzle games has a positive impact on improving students' problem-solving abilities. This finding supports research Margolis (2020) on the Zone of Proximal Development, which states that students can learn more effectively if given a context that is close to their experience. Ethnomathematics puzzle games provide a more meaningful learning experience because they link mathematical concepts to local culture (Moser, 2023), in accordance with the principles of ethnomathematics developed by D'Ambrósio & Knijnik (2020). In addition, Savage & Williams (1990) theory on problem-solving steps supports that a culture-based approach can improve students' critical thinking skills. According to (Zubair et al., 2024), a game-based approach to learning can increase active student engagement and help them understand concepts better. Baroody (2017) also stated that concrete experiences in learning are very important for students' cognitive development. Furthermore, Yanti (2025) research on meaningful learning explains that students find it easier to understand new concepts if they are linked to previous experiences, which is relevant to the use of ethnomathematics in education.

According to Ghofur & Youhanita (2020), learning methods that involve interactive activities can increase students' learning motivation. Meanwhile, Dale & Maria (2020) in their social cognitive theory emphasize that learning through observation and social interaction can improve conceptual understanding more effectively. The constructivist approach developed by Jeyaraj. & Sekar (2019), is also in line with these findings, where experiential learning is more effective than conventional methods. Research by NCTM (2020) also shows that innovative learning strategies that link mathematics to real life can improve students' understanding. According to Munawaroh et al. (2022), the cooperative learning model can improve students' problem solving and communication skills. Furthermore, research by Sabon & Telussa (2024) shows that the ethnomathematics approach can improve students' motivation and understanding of mathematical concepts. According to Ahmad et al. (2021), the use of games in learning can help students achieve higher levels of thinking, such as analysis and evaluation. Thus, this study adds empirical evidence that the use of interactive culture-based learning media can provide more optimal learning outcomes than conventional methods.

Implication

The implications of this study indicate that the use of ethnomathematics puzzle games can be applied as an innovative learning strategy in mathematics learning (Idika & Oluwaseyi, 2024). The application of this method not only improves students' mathematical science problem-solving abilities but also develops critical and creative thinking skills that are greatly needed in the modern era (Bunt, 2019; Cholily et al., 2023; Hasna et al., 2021; Weng, 2022; Ziliwu & Anas, 2024). Teachers can use this approach to teach abstract mathematical concepts in a more contextual and easily understood way by students. In addition, the results of this study support educational policies that encourage the use of culture-based learning models in the curriculum. Thus, this approach can be an alternative in efforts to improve the quality of mathematics learning in schools.

Limitation and Suggestion for Further Research

This study has several limitations, namely the number of samples used is still limited to one school, so the results of this study cannot be generalized widely. In addition, the relatively short research time can affect long-term learning outcomes, so further studies are needed with a longer research period. For further research, it is recommended to involve more schools and students to get more representative results and develop variations of ethnomathematics-based puzzle games for other subject matter to see the effectiveness of this method in various mathematics topics.

Conclusion

Ethnomathematics puzzle game-based learning media is effectively applied to learning at school because it is able to improve students' mathematical science problem-solving abilities in geometry material with an average value of 83.5, and experiences an increase in learning in the high category with an N-gain of 0.70 with an effect size of 1.39 with this learning media category having made a major contribution in improving problem-solving abilities.

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Authors Contribution

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Conflicts of Interest
The researchers declare there is no conflict of interest.

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