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The Implementation of Ethnomathematics-Based Learning Using Blacksmith Tools on Students' Critical Thinking Skills

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ABSTRAK

Rendahnya kemampuan berpikir kritis matematis siswa memerlukan pendekatan pembelajaran yang inovatif dan kontekstual secara budaya. Penerapan pembelajaran matematika berbasis etnomatematika dengan konteks perkakas pandai besi bertujuan untuk mengembangkan kemampuan berpikir kritis siswa. Penelitian ini menggunakan metode eksperimen kuantitatif dengan melibatkan 82 siswa sebagai populasi dan 54 siswa sebagai sampel, yang dibagi menjadi dua kelompok: 28 siswa kelas 12 IPA 1 sebagai kelas eksperimen dan 26 siswa kelas 12 IPA 3 sebagai kelas kontrol. Model *post-test only control group design* ini menggunakan sebuah tes uraian sebagai instrumen penelitian dan telah melalui uji validitas, reliabilitas, indeks kesukaran, serta daya beda untuk menjamin kualitasnya. Data dianalisis secara kuantitatif menggunakan teknik statistik inferensial. Berdasarkan uji-t, terdapat perbedaan yang signifikan terhadap kemempuan berpikir kritis siswa antara kelas eksperimen dan kelas kontrol. Hasil penelitian menunjukkan bahwa pembelajaran berbasis etnomatematika mampu mengembangkan kemampuan berpikir kritis siswa.

Kata Kunci: Berpikir Kritis; Etnomatematika; Geometri; Pandai Besi

ABSTRACT

A well-prepared abstract allows the reader to quickly and accurately identify the basic content of the document, assess its relevance to their interests, and decide whether to read the document in its entirety. The abstract should be informative and self-explanatory, providing a clear statement of the problem, proposed approach, or solution, as well as the main conclusions. Typically, abstracts include sections such as Background, Objective, Methods, Results, and Conclusions (often abbreviated as IMRaD). An abstract in English should be between 100 and 200 words in length. Abstracts are written in the past tense for methods and results (since the study has already been conducted), but present tense for conclusions and implications; abbreviations should be avoided. Since there are no citations, the abstract does not reference literature. The keyword list offers an opportunity to include terms used by indexing and abstract services. Thoughtful keyword selection enhances the discoverability of our articles among interested readers.

Keywords: Critical Thinking; Ethnomathematics; Geometry; Blacksmith

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1. INTRODUCTION

Mathematics plays a vital role in all branches of science because it evolves from human thinking related to ideas, processes, and reasoning (Russell & Norvig, 2021). As such, it must be taught to all students to cultivate logical, analytical, systematic, and critical thinking ability, along with their skills to work (Lebid & Shevchenko, 2020). Mathematics is deeply embedded in various aspects of daily life, whether at home, at work, in rice fields, gardens, forests, or mountains (Utami et al., 2020; Susanto, Setiawan, & Daniaty, 2023). Closely tied to culture, several branches of mathematics, such as geometry, number theory, and measurement, have historically developed within cultural contexts (Sukirwan et al., 2023). Therefore, integrating mathematics with cultural elements is essential in everyday life, as it supports the development of character values and enhances students' critical thinking abilities (Nuryadi, 2022).

Critical thinking skills involve a logical and rational process grounded in beliefs, standards, and procedures for analysis, evaluation, and testing (Nasution et al., 2024; Saputra, 2020). In mathematics, critical thinking is categorized as a higher-order thinking skill, encompassing various abilities such as understanding, remembering, analyzing, reasoning, evaluating, and even hypothesizing (Ennis, 2018; Apiati & Hermanto, 2020) . It not only relies on logic but also on confidence in values, reasoning foundations, and beliefs before achieving logical reasoning (Partasiwi et al., 2023). Specifically, critical thinking in mathematics involves analyzing problems, selecting appropriate solutions, and applying interpretation, evaluation, and inference systematically and logically (Htria et al., 2024).

Many students still demonstrate low mathematical critical thinking skills (Afrianyah et al., 2021; Tajuddin et al., 2023; Luritawaty, & Rahmawati, 2024). Research by Septiana et al. (2019) revealed that junior high school students in Rancabali District, Bandung, scored only 50% on spatial geometry topics. Similarly, Maya et al. (2019) found that vocational students in Galanggang Village had a low percentage of critical thinking skills, at just 43%. This condition requires serious attention, particularly from mathematics teachers (Sarimanah, 2017; Ester & Litiani, 2023). Factors contributing to this issue include the nature of eacher-student interactions and the learning environment play a crucial role. A positive and supportive setting can boost students' engagement and concentration, while teaching methods also significantly influence the development of students' critical thinking skills (Hamidah & Ain, 2022).

Students' critical thinking skills can be improved by integrating culture into the learning process (Ambarwati & Wahyuni, 2023). Ethnomathematics-based learning enables teachers to relate mathematical concepts to local culture, making learning more contextual and meaningful (Ajmain et al., 2020). This approach serves as a bridge to enhance students' critical thinking. Supporting this, Sumiyati et al. (2018) found significant differences in critical thinking ability between students taught in ethnomathematics-based learning and those who were not, indicating its positive impact on mathematical critical thinking.

Integrates culture into mathematics learning to help students connect concepts with daily life and improve understanding (Kencanawaty & Irawan, 2017; Nursyamiah et al., 2024). Research shows that cultural artifacts, such as traditional buildings Zaenuri & Dwidayati (2018) and Krebet wooden batik Abdullah & Rahmawati (2021), contain various mathematical concepts like geometry, symmetry, and transformations. Utilizing such cultural elements in learning becomes a bridge to strengthen students' critical thinking. Mathematics and culture are inseparable, as culture shapes the way people live, while mathematics provides tools to solve real-life problems. According to Bishop, mathematics itself is a form of culture, reflecting procedures and processes closely tied to cultural practices (Sartika et al., 2023).

Culture-based mathematics learning will attract students' interest in learning and improve their learning outcomes (Vrasetya & Nasution, 2024). Blacksmithing is one of the local cultures that can be used as a concept of ethnomathematics in schools. This activity not only reflects local wisdom but also helps explain mathematical concepts contextually. The tools produced often resemble geometric shapes such as cylinders, rectangular prisms, cones, and trapezoids, making it easier for students to understand mathematics in a relevant and visual way. There is a blacksmith tool known as a quenching tank. The quenching tank serves as a water container to cool hot iron during the tool-making process. This rapid cooling process restores the hardness and strength of the iron. In terms of shape, the quenching tank resembles a block with rectangular sides, making it suitable for explaining mathematical concepts such as volume, surface area, and dimensional ratios.

Figure 1. Smelting Furnace

No research has been found that tests the implementation of ethnomathematics based on blacksmith tools in improving students' critical thinking skills. Most studies still focus on theory or general descriptions without direct experiments in the classroom. Generally, ethnomathematics is studied about the understanding of mathematical concepts, not on specific aspects like critical thinking. The cultural contexts used are more often in the form of batik, weaving, or traditional dances. Research specifically highlighting blacksmith culture is still very limited, even though this culture has great potential in mathematics education.

Based on the existing problems, the researcher conducted a study on the implementation of ethnomathematics-based learning using blacksmith tools to promote students' critical thinking skills. This approach aims to make mathematics learning more contextual and relevant to everyday life. Furthermore, this study contributes to educational innovation by integrating local cultural elements into mathematics learning. The use of ethnomathematics is expected to foster appreciation for local culture and inspire teachers to implement more innovative and inclusive teaching strategies.

2. METHOD

The study employs a quantitative experimental approach using a posttest-only control group design to assess the effect of integrating ethnomathematics-based blacksmithing instruction on students' critical thinking abilities in geometry. The research took place at SMA Negeri 1 Kerinci during the Even Semester of the 2024/2025 academic year.

The population consists of 82 students in the 12th grade who have a basic understanding of geometric concepts. The sample for this study is the XII IPA 1 class as the experimental group with 28 students and the XII IPA 3 class as the control group with 26 students. The sample selection was conducted using purposive sampling techniques so that more accurate data could be obtained regarding the impact of ethnomathematics-based learning through students' critical thinking ability in the concept of geometry.

The data collection technique employed a critical thinking skills test, using an essay-type instrument that underwent a comprehensive item analysis. The test was conducted based on mathematical critical thinking skills indicators and was tested for validity to ensure that the items accurately and precisely measure the intended constructs. Furthermore, the reliability of the instrument was assessed to confirm the consistency of the measurement results. An analysis of item difficulty was conducted to provide a balanced distribution of questions ranging from easy to hard, thereby accommodating the full spectrum of student abilities. In addition, item discrimination analysis was carried out to evaluate how well each question distinguishes between students with high and low levels of ability. Table 1 below displays the results obtained from the pilot testing of the mathematical critical thinking skills instrument.

Table 1. Validity, Reliability, Discriminatory Power, and Diffuculty Index

Number	Validity		Reliability	Discriminatory Power		Difficulty index	
1	0,789	Valid	0,544 Realiable	0,575	Enough	0,536	Currently
2	0,605	Valid		0,300	Enough	0,429	Currently
3	0,501	Valid		0,301	Enough	0,314	Currently
4	0,600	Valid		0,315	Enough	0,679	Currently

Number	Validity		Reliability	Discriminatory Power		Difficulty index	
5	0,457	Valid		0,564	Enough	0,550	Currently

This research instrument is declared accurate and reliable in measuring the variables being studied, based on the results of validity tests, reliability tests, difficulty index, and discrimination index that have been conducted.

The data were examined using quantitative methods through inferential statistical techniques. Descriptive statistics were applied to summarize the test results of both the control and experimental groups, including measures such as the mean, standard deviation, minimum, and maximum scores. This was done to obtain an overview of students' performance in each group.

Before hypothesis testing, prerequisite tests were conducted to validate the statistical assumptions. The normality of the data distribution was assessed using the Shapiro-Wilk test, where a significance value greater than 0.05 indicated that the data followed a normal distribution. Additionally, the homogeneity of variance between groups was examined using Levene's Test. A significance value above 0.05 suggested that the assumption of homogeneity was met.

An independent sample t-test was conducted to test the research hypothesis: there is a significant difference between students who study under ethnomathematics-based learning in the experimental groups and those who study under traditional learning in the control group. The purpose of this test was to determine whether there was a statistically significant difference in the final test scores between the experimental group, which received treatment using ethnomathematics-based learning, and the control group, which was taught with traditional methods. A significance level of 0.05 was set for this study. A significance value (Sig. 2-tailed) below 0.05 would indicate a significant difference between the two groups. All statistical analyses were carried out using SPSS

The systematic stages in the mathematics learning process can lead to an integrated understanding. According to Dominikus, there are several stages in ethnomathematics learning that we need to know. First, there is the Exploration stage, where students explore mathematical ideas within the culture. Second, the Mapping stage, where students create a map of the relationships between school mathematics concepts and ethnomathematics. Third, the Explanation stage, where students study school mathematics concepts and communicate what they have learned, share, and appreciate what has been learned in various forms. Finally, there is the Reflection stage, where students summarize what they have learned, both mathematical knowledge and life values (Ilmiyah et al., 2021).

The ethnomathematics-based learning applied in this study incorporates cultural elements derived from traditional occupations, specifically blacksmithing. There is a blacksmith tool known as a bellows, a vital tool in the blacksmithing process that functions to blow air into the furnace, thereby increasing the temperature of the fire. This pump plays an important role in the blacksmithing process as a tool to blow air into the furnace to increase the fire's temperature. Its shape is symmetrical and resembles a tube with two rounded ends and an elongated middle section, allowing air to be pumped efficiently. From a geometric perspective, this shape reflects the concepts of cylinder, symmetry, and volume, which are relevant in mathematics education.

Figure 2. Blacksmith's Bellows

The shape of the bellows is symmetrical and resembles a cylindrical form with two rounded ends and a narrower middle section, allowing it to effectively channel airflow. From a geometric perspective, this shape demonstrates concepts such as cylinder geometry, symmetry, and volume, all of which are fundamental in mathematics learning. By analyzing the bellows, students can visualize and connect abstract geometric principles to real-world, culturally significant objects.

This learning framework leverages the cultural context of blacksmithing to create a meaningful and engaging geometry learning experience. Through this integration of cultural context and mathematics, the ethnomathematics-based learning media serve not only as a bridge between tradition and education but also as an effective tool for developing students' understanding of geometry in a more engaging and meaningful way.

3. RESULT AND DISCUSSION

a. Research Findings

The test on students' mathematical critical thinking skills was conducted to assess the impact of ethnomathematics-based geometry learning media in the experimental class and the conventional teaching approach in the control class on students' mathematical critical thinking abilities. The average test scores for students' mathematical critical thinking skills are summarized in Table 2.

Table 2. Test Results

Class	X_{maks}	X_{min}	$\bar{x}$
Experimental	100	60	80,89
Kontrol	80	20	61,25

According to Table 2, the experimental class outperformed the control class. The highest score in the experimental class was 100, whereas the control class’s highest score was 80. Additionally, the lowest score in the experimental class was 60, which was higher than the control class's lowest score of 40. This difference shows that ethnomathematics-based learning has a greater positive impact on students' abilities, with more optimal learning outcomes and a more even distribution of grades.

In this study, a total of 54 students were sampled and divided into two groups: a control class and an experimental class. The main objective of this research is to test the effectiveness of ethnomathematics-based learning in improving students' critical thinking skills. Data from both groups were analyzed and presented in table form to provide a detailed overview. Data analysis was performed using normality tests, homogeneity tests, and t-tests.

A normality test using the Shapiro-Wilk method was performed to assess whether the data from both groups follow a normal distribution. This test was selected due to its reliability for small to medium-sized samples. The test was applied to the scores of mathematical critical thinking skills in both the experimental and control classes, with the results shown in Table 3.

Table 3. Analysis of Normality Test Results

Class	Normality Test Results	Explanation
Eksperimen	0,154	Normal
Kontrol	0,118	Normal

The Shapiro-Wilk test was applied using a 0.05 significance level. Table 3 showed that the significance value for the experimental class was 0.154, while the control class showed a value of 0.118. Because the significance values are above 0.05, the data in both the experimental and control classes are considered to be normally distributed. Therefore, the analysis could proceed to the next step, which is the homogeneity test.

To examine the equality of variances between the two groups, Levene’s Test was utilized. The homogeneity test is used to ensure that both sample groups have the same variance, which is important to meet the assumptions of the t-test (Sumiyati et al., 2018). This test was applied to mathematical critical thinking ability scores in the experimental and control groups. Table 4 presents the test of the homogeneity of variance.

Table 4. Test of Homogeneity of Variance

		Levene Statistic	df1	df2	Sig.
Test Results for Control and Experimental Class	Based on Mean	0,069	1	54	0,793

The results of the homogeneity test showed significance (Sig) values of 0.793 in both the control and experimental classes. Since the value is greater than 0.05, it can be inferred that the data exhibits a homogeneous distribution. This result meets the assumption required for parametric testing using a t-test.

An independent t-test was carried out to determine whether ethnomathematics-based learning has a significant impact on students' critical thinking skills compared to traditional teaching methods. The results are presented in Table 5.

Table 5. Independent t-test

	t	Sig.	df
Test Results for Control and Experimental Class	- 4,811	0,000	54

H_0 : There is no significant difference between the control and the experimental scores.
H_1 : There is a significant difference between the control and the experimental scores.

Based on the results of the Independent Sample t-test, a significance value of 0.000 was obtained, which is lower than the threshold of 0.05. This indicates that the null hypothesis (H_0) is rejected, and the alternative hypothesis (H_1) is accepted. In other words, there is a statistically significant difference between the scores of students in the control class and those in the experimental class. These findings suggest that the treatment applied in the experimental class of ethnomathematics-based learning, has a positive impact on promoting students' critical thinking skills

b. Discussion

Based on the results of the Independent Sample t-test, a significance value of 0.000 was obtained, which is lower than the threshold of 0.05. This indicates a statistically significant difference between the scores of students in the control class and those in the experimental class. The higher scores in the experimental class suggest that the implementation of ethnomathematics-based learning has a positive effect on students' critical thinking skills. This may be due to the contextual and culturally relevant nature of ethnomathematics, which enables students to connect abstract mathematical concepts with real-life experiences, thereby fostering deeper understanding and analytical thinking. The results of this study are consistent with the findings of Sastrawati & Guspita (2022), who found that ethnomathematics-based learning significantly enhances students' critical thinking abilities. Similarly, (Martir et al., 2024) emphasize that ethnomathematics supports the development of various aspects of critical thinking: to identify, interpret, and apply mathematical ideas and symbols.

The researcher applied the steps of etnomathematics-based learning on the stages proposed by Dominikus, which consist of four stages of ethnomathematics. The first stage, Exploration, invites students to explore mathematical concepts through cultural contexts or everyday life. The second stage, Mapping, connects those findings with formal mathematical concepts. The third stage, Explanation, involves the teacher explaining the concept in more detail. The fourth stage, Reflection, students reflect on and relate their learning to real-life applications.

In the Exploration stage, the researcher begins the learning process by introducing various forms of blacksmith tools, such as pumps, chisels, and anvils, through visual displays. Next, students are invited to observe and answer questions related to the geometric shapes of these tools, such as circles, squares, and triangles. The goal of this stage is to build students' curiosity and introduce mathematical concepts contextually through familiar objects in everyday life.

The presence of the exploration stage in ethnomathematics-based learning it greatly helps students in constructing their thinking or understanding through identification and exploration. This is more useful than providing direct understanding/introduction because students only understand in abstract form and do not understand in concrete form (Lusiana et al., 2019).

At the Mapping stage, the author continues the learning process by bringing images of blacksmith tools that have been previously introduced into the context of mathematical concepts, particularly three-dimensional shapes. The author begins to explain slowly how each of these tools can be connected to three-dimensional shapes in geometry. Like the shapes of the anvil and the pump that resemble a cylinder, and the shape of the old man's hat that resembles a rectangular prism.

Pak Andi akan membuat sebuah pipa besi berbentuk tabung seperti gambar berikut ini:

Dengan panjang pipa 2 meter
Diameter luar adalah 10 cm dan diameter dalam 8 cm

Berapakah luas penampang melintang dari pipa besi tersebut?

Figure 3. A Base That Resembles the Shape of a Cylinder

At the Exploration stage, the researcher begins the learning process by introducing various forms of blacksmith tools, such as pumps, chisels, and anvils, through image displays. Next, students are invited to observe and answer questions related to the geometric shapes of these tools, such as circles, squares, and triangles. The goal of this stage is to build students' curiosity and introduce mathematical concepts contextually through familiar objects in everyday life.

In the reflection stage, the researcher administers a test to students as a form of evaluation to assess their level of understanding after participating in ethnomathematics-based learning. This stage aims to identify various dynamics and events that occur during the learning process (Martir et al., 2024). The questions are designed to test students' ability to connect mathematical concepts, particularly three-dimensional shapes, with real objects that have been introduced previously, such as blacksmithing tools. The test question results have to evaluate the implementation of the applied learning method and to identify aspects that need improvement.

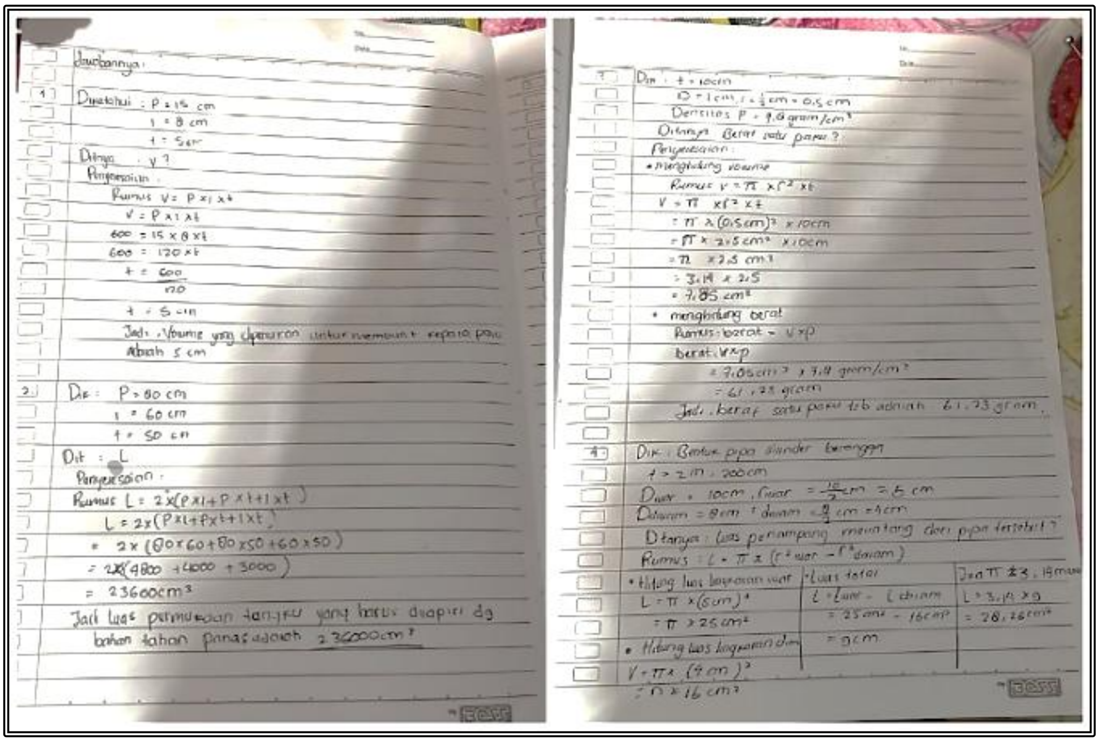

Figure 4. Student Answer Sheet

In the picture above, there is an answer sheet from one of the students working on the test questions. In the picture, it can be seen that the student is already able to calculate the volume and cross-sectional area of the blacksmith's tools quite well. This shows that the students have understood the basic concepts of geometric calculations related to the shape and size of the object. In addition, students are also able to apply the relevant formulas accurately to obtain precise results.

4. CONCLUSION

Based on the prerequisite test results, the test data are normally and homogeneously distributed, thus meeting the assumptions for parametric statistical analysis. The t-test measures the test scores between the control class and the experimental class. The test results rejected $H_{0;}$ therefore, there is a significant difference between the classes. The ethnomathematics-based learning can promote the students' critical thinking skills. The ethnomathematics-based learning approach is not only effective in helping students understand mathematical concepts but also capable of encouraging students to think more analytically and critically. This reflects the success of this learning method in integrating local cultural contexts with mathematical concepts, thereby enabling students to develop higher-order thinking skills relevant to real-life situations. The results also provide empirical evidence that ethnomathematics-based learning can be an innovative and effective strategy in improving the quality of mathematics education.

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