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Effects of Ethnomathematics-Based Problem-Based Learning on Students' Conceptual Understanding in Mathematics

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ABSTRACT

This study investigates the effect of an ethnomathematics-based problem-based learning (PBL) model on students' mathematical conceptual understanding. By integrating local culture into mathematics instruction, the model aims to facilitate more meaningful and contextual learning. A quantitative approach was employed using a quasi-experimental posttest-only control group design. Two classes were purposively selected: an experimental class with 20 students and a control class with 27 students, based on initial ability homogeneity and scheduling considerations. Data were collected through an essay test, developed from indicators of conceptual understanding, and supported by classroom observations. Data analysis involved prerequisite tests (normality and homogeneity) and hypothesis testing using the independent samples t-test. The results revealed a statistically significant difference between the experimental and control groups ($p < 0.05$), indicating that the ethnomathematics-based PBL model positively influences students' conceptual understanding. These findings highlight the potential of integrating cultural contexts into problem-based learning to enhance students' comprehension of mathematical concepts.

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Introduction

Mathematical understanding is one of the fundamental competencies in mathematics learning. This ability encompasses comprehension of subject matter, recall of formulas and concepts, as well as their application in simple or analogous situations (Jeanita Sengkey et al., 2023). In addition, mathematical understanding involves the ability to assess the validity of a statement and to employ formulas and theorems in problem solving. In the *Merdeka Curriculum*, the objectives of mathematics learning are reflected in the core and basic competencies at each level of education, which emphasize the importance of mathematical understanding for students (Khoerunnisa & Hidayati, 2022). By mastering mathematical concepts, students are able to develop other essential mathematical thinking skills.

This competency plays a crucial role in helping students understand and interpret learning materials (Sari & Tarihoran, 2024). Without a firm grasp of basic concepts, students may struggle to comprehend subsequent material, leading to ongoing confusion (Tauhid et al., 2024). This view is consistent with Rezkiyana's perspective, which highlights students' understanding as a key factor in achieving mathematics learning objectives. Students with sound conceptual understanding can be recognized through their ability to solve various mathematical problems. The National Council of Teachers of Mathematics (NCTM) also stresses that mathematical understanding is an essential aspect of mathematics learning principles (Widiani et al., 2025).

However, the reality in schools shows that students' mathematical conceptual understanding remains low. According to the 2022 PISA results, the average mathematics score of Indonesian students was 366, a decline from 379 in 2018, and well below the OECD average of 472. Data published by the Ministry of Education further highlight this gap, noting that Indonesia lags 106 points behind the global average. Moreover, only 18% of Indonesian students reached at least Level 2 in mathematics, which is regarded as the baseline proficiency in this assessment, compared with 69% of OECD students. Level 2 reflects students' ability to understand and represent simple situations mathematically (Dewi et al., 2025).

One factor contributing to this low achievement is students' negative perception of mathematics. Many view the subject as difficult due to its abstract, logical, and symbolic nature, which is often perceived as confusing (Buyung et al., 2022). This aligns with preliminary observations conducted in two eighth-grade classes at an MTs, involving 47 students through observation sheets and teacher interviews. The results indicated that learning remained teacher-centered. Students tended to be passive, merely taking notes and following worked examples without deeply understanding the underlying concepts. The observation instrument covered student activities, participation in discussions, and the ability to respond to teachers' questions. When given problems different from the examples, many students struggled, and some failed to summarize the material in their own words, reflecting a low level of conceptual understanding. Furthermore, innovative learning models such as problem-based learning (PBL) had not been implemented optimally. Teachers primarily relied on student worksheets (LKS) as the main learning resource, with little variation in instructional strategies. Teachers typically provided initial explanations, and when posing questions, most students remained silent, with only a few responding. Although group discussion was sometimes allowed, many students still found it difficult to resolve problems independently.

The limited use of varied learning models contributed to difficulties in conceptual understanding, particularly in mathematics, ultimately leading to poor learning outcomes. In principle, PBL is effective because it encourages students to think critically and analytically (Lolita Anna Risandy et al., 2023). PBL is a student-centered model in which learners are confronted with real-world problems and attempt to solve them (Meilasari et al., 2020). Theoretically, PBL aligns with Piaget's constructivist view, which emphasizes the importance of direct experience in building conceptual understanding, as well as Vygotsky's zone of proximal development (ZPD), which underscores the role of social interaction and scaffolding in collaborative learning. Similarly, ethnomathematics is consistent with Freudenthal's Realistic Mathematics Education (RME), which highlights the use of real-life and cultural contexts in teaching mathematics to make learning more meaningful for students. In PBL, lessons are structured around problems that students are responsible for analyzing and solving, with the teacher acting primarily as a facilitator. Prior research has also found that students' critical thinking skills are enhanced through the application of PBL (Dewi, 2021). Studies on

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PBL typically begin with contextual problems, guide students' involvement in the learning process, provide group and individual support, and culminate in analyzing and evaluating problem-solving outcomes (Muhartini et al., 2023). PBL can be more effective when contextualized with problems from students' immediate environment.

The selection of problems may vary, ranging from purely mathematical tasks to real-life issues connected to mathematics, or cultural contexts rich in mathematical elements. The cultivation of a positive school culture is also expected to shape students' discipline and foster constructive attitudes in learning (Syafila et al., 2023). Cultural practices that embody mathematical concepts are often referred to as ethnomathematics. Ethnomathematics is the study of how mathematical ideas are integrated into cultural values and everyday practices (Saparuddin et al., 2019). Hence, mathematics instruction with an ethnomathematical orientation enables students to learn mathematics while simultaneously appreciating their cultural heritage. Local cultural elements can be utilized as learning resources to make mathematics learning more meaningful and memorable (Dalimunthe et al., 2022).

Previous studies have largely focused on the application of PBL to improve learning outcomes, motivation, and students' critical thinking skills (Ahdhianto et al., 2020). However, most have not specifically addressed conceptual understanding, which is a fundamental competence that underpins mathematics learning (Setiani et al., 2022). Conceptual understanding serves as the foundation for mastering more complex content and applying knowledge in real-life contexts. Several studies have also demonstrated that ethnomathematics can enhance conceptual understanding by linking mathematics with cultural practices, daily activities, and contextual experiences (Siregar et al., 2024). Nevertheless, much of this research has emphasized ethnomathematics in isolation, without integrating it into problem-oriented learning models such as PBL (Amalia et al., 2021). Integrating ethnomathematics into PBL has the potential to be more effective in fostering conceptual understanding while simultaneously cultivating critical thinking and problem-solving skills. Thus, prior studies appear fragmented: PBL research has primarily centered on motivation and achievement, whereas ethnomathematics research has focused on cultural contexts without embedding innovative instructional models.

Based on this review, the present study adopts a more engaging learning model to increase student participation and address difficulties in understanding mathematics. To achieve this, teaching methods need to be both appealing and relevant to real-life experiences. One promising approach is ethnomathematics-based problem-based learning (Nadya Refita Sandi et al., 2024). Novelty of this study lies in integrating problem-based learning with local ethnomathematics in mathematics instruction, specifically in the topic of the Pythagorean theorem. Previous studies generally examined the effectiveness of either PBL or ethnomathematics in isolation, whereas this study combines both to provide a more contextual, meaningful, and culturally relevant learning experience. Purpose of this article is to examine the effect of an ethnomathematics-based PBL model on students' mathematical conceptual understanding.

Method

Research Design

Data in this study were numerical in nature, obtained from students' responses; therefore, a quantitative approach with a quasi-experimental research design was employed. Specifically, a posttest-only control group design was applied. This design was chosen for practical and ethical considerations, as administering a pretest was deemed likely to influence the learning process (testing effect) and potentially bias the posttest results. Additionally, the limited instructional time in schools served as another factor in adopting the posttest-only design as the most suitable option for the present study. Research subjects were divided into two groups: an experimental group, which received ethnomathematics-based problem-based learning, and a control group, which was taught using conventional methods. Nonetheless, the use of a posttest-only design without a pretest carries a limitation in terms of internal validity, as there are no baseline data to ensure equivalence of initial ability between groups. To minimize this limitation, the researcher ensured that the two sampled classes had relatively similar characteristics, based on students' mathematics report card grades from the previous semester and consultations with the subject teacher.

Population and Sample

Population in this study consisted of all eighth-grade students at MTs Putra Al-Ishlahuddiy Kediri, totaling 193 students. Sample size was determined using purposive sampling, a technique in which samples are selected based on specific criteria (Lenaini, 2021). In this study, the criteria for sample selection were based on having the same mathematics teacher, relatively similar instructional schedules, and a balanced distribution of academic ability according to students' report card grades from the previous semester. These criteria were applied to minimize potential selection bias and ensure that the experimental and control groups had relatively equivalent initial characteristics.

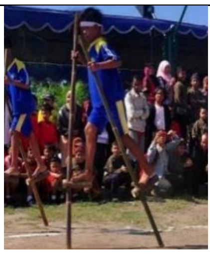
Table 1. Number of Eighth-Grade Students at MTs Putra Al-Ishlahuddiy Kediri

Class	Number of Students
VIII A	39
VIII B	27
VIII C	20
VIII D	34
VIII E	36
VIII F	37
Total	**193**

Instruments

Instruments employed was an essay test consisting of two items (Table 2). The instrument underwent a content validation process conducted by mathematics education lecturers and subject teachers. The validation aimed to evaluate the alignment of the items with the indicators being measured, the clarity of wording, and the accuracy of the concepts used. Based on expert judgment, the instrument was declared to have valid content. In line with previous views, an instrument that has been validated is deemed appropriate for use as a data collection tool in research.

Table 2. Posttest Questions on Conceptual Understanding Ability

No	Questions
1	 **Figure 1** *Engrang* Traditional Game Figure 1 shows a child playing engrang, a traditional game from Lombok that uses a pair of sticks of equal length with footrests attached, allowing the player to walk by alternately lifting the sticks. In the figure, the length of each stick is 170 cm, and the difference between the top end of the tilted stick and the top end of the upright stick is 20 cm. Redraw the engrang illustration according to the problem description. Explain how you would calculate the length of one step taken by the child while using the engrang.
2	Observe Figure 2.

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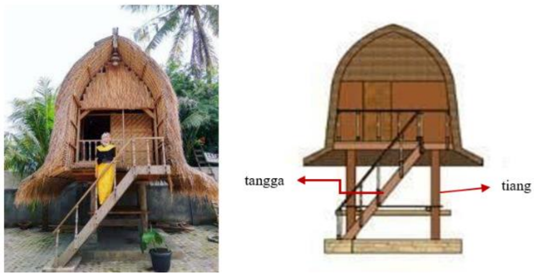

Figure 2. *Bale Lumbung* and Its Illustration
Source: https://www.kibrispdr.org/detail-24/nama-rumah-adat-sasak.html
Figure 2 depicts the traditional house of the Sasak tribe, known as *Bale Lumbung*. In the figure, a right triangle is formed by the pillar, the ladder, and the horizontal distance from the bottom of the pillar to the bottom of the ladder, which applies the Pythagorean concept. Determine:
Which of the three sides can be classified as the base, height, and hypotenuse in the Pythagorean theorem? Explain your reasoning.
Which of the following sets of measurements are possible, respectively, for the lengths of the pillar, the ladder, and the horizontal distance from the bottom of the pillar to the bottom of the ladder? Justify with calculations.

Observation sheet functioned as an instrument to monitor teacher and student activities during classroom instruction involving the implementation of the ethnomathematics-based problem-based learning model in teaching the Pythagorean theorem. The main purpose of classroom observation was to evaluate the effectiveness of this model in enhancing student engagement and conceptual understanding. Indicators included clarity of instructional goals delivered by the teacher, active student participation, and the use of culturally relevant examples.

Table 3. Classroom Observation Sheet

No	Aspect Observed	Indicator of Success
1	Teacher motivates students to engage in problem solving	Students listen attentively to the teacher’s motivation
2	Teacher provides an introduction and presents a contextual story or phenomenon to generate problems	Students respond to the introduction, story, and phenomenon to identify the problem
3	Teacher presents examples based on local culture	Students are able to connect the examples with the Pythagorean theorem
4	Teacher explains the steps involved in investigating the problem to be solved	Each student listens, observes, and understands the steps for investigating the problem
5	Teacher encourages students to gather information related to the problem under investigation	Students complete tasks and solve the problems provided
6	Teacher monitors students’ work	Groups deliver presentations and other groups provide appreciation
7	Teacher asks students to summarize the lesson	Students summarize the lesson content
8	Teacher refines students’ conclusions	Students receive refined conclusions from the teacher

Data Collection

In this study, data were collected using tests and observations. The purpose of the test was to obtain data on students’ abilities based on indicators of mathematical conceptual understanding in the topic of the Pythagorean theorem. The test consisted of essay-type questions developed according to the indicators of conceptual understanding, including the ability to restate a concept, classify objects according to specific properties, provide examples and non-examples of a concept, and represent the concept in mathematical form. Prior to its use, the test instrument was validated by two experts in mathematics education and piloted with students outside the research sample to ensure its content validity and reliability. Meanwhile, classroom observations were conducted using a structured observation sheet that covered teacher and student activities during the implementation of ethnomathematics-based problem-based learning (PBL). The PBL model was carried out over four sessions following the standard syntax: (1) orienting students to contextually cultural problems, (2) organizing students into groups, (3) guiding independent and group investigations, (4) developing and presenting student work, and (5) analyzing and evaluating the problem-solving process. At each stage, the teacher acted as a facilitator, providing guidance and stimulus in the form of prompting questions, while students actively engaged in analyzing, discussing, and finding solutions based on their experiences and the given cultural context.

Analysis

This study employed several types of data analysis, namely descriptive analysis, prerequisite tests, and hypothesis testing. Descriptive analysis was conducted to describe students' mathematical conceptual understanding in the experimental and control groups, including the calculation of the mean, standard deviation (SD), minimum, maximum, and score distribution. The results of this analysis provided an initial overview of the data trends before proceeding to inferential analysis. Prior to hypothesis testing, it was necessary to ensure that the data met the basic assumptions required for statistical testing by conducting prerequisite tests, including normality and homogeneity tests. The Kolmogorov–Smirnov test, assisted by SPSS software, was used to determine whether the data on students' mathematical conceptual understanding in the experimental and control groups were normally distributed (Quraisy, 2020). Subsequently, homogeneity of variance was tested using Levene's Test to assess whether the variances between the two groups were homogeneous (Nurhaswinda et al., 2025). Levene's Test was chosen because it can test variance equality without requiring the data to be normally distributed beforehand, making it a common choice in experimental data analysis.

To examine the extent to which the ethnomathematics-based problem-based learning model influenced students' mathematical conceptual understanding, inferential analysis was conducted using the Independent Samples t-test. This test was selected because the data consisted of posttest scores from two different groups: the experimental group and the control group. The choice of this test was based on the assumption that the data were normally distributed and had homogeneous variances, as confirmed by the prerequisite tests. The Independent Samples t-test was applied to compare the mean posttest scores of the experimental group, which received instruction through the ethnomathematics-based PBL model, and the control group, which received conventional instruction. The level of significance used in this analysis was set at 5% ($\alpha = 0.05$).

Results

This study aimed to examine students' conceptual understanding of mathematics through the implementation of an ethnomathematics-based problem-based learning (PBL) model. The results of the descriptive, normality, homogeneity, and hypothesis testing are presented below.

Descriptive Analysis

Descriptive analysis of students' conceptual understanding scores in the experimental and control groups is presented in Table 4.

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Table 4. Descriptive Analysis

Group	Mean	Std. Deviation	Variance	Min	Max	Skewness	Kurtosis
Experimental	7.95	2.395	5.734	4	12	0.244	-0.404
Control	4.26	1.831	3.353	1	9	0.438	0.545

The results show that the mean score of the experimental group taught using ethnomathematics-based PBL was 7.95, while the control group taught using conventional methods scored only 4.26. This indicates that ethnomathematics-based PBL was more effective in improving students' learning outcomes compared to conventional instruction. In terms of data distribution, the standard deviation and variance in the experimental group (SD = 2.395; variance = 5.734) were higher than those in the control group (SD = 1.831; variance = 3.353), suggesting a wider range of abilities in the experimental class, whereas the control class was relatively homogeneous, albeit at a lower average level.

The skewness value in the experimental group (0.244) was close to zero, indicating a relatively normal distribution, while the control group's skewness (0.438) suggested a slight right skew, meaning more students scored lower with fewer students scoring higher. The kurtosis value of the experimental group (-0.404) indicated a flatter distribution (platykurtic), showing scores were more widely spread, while the control group's kurtosis (0.545) suggested a distribution closer to normal, with scores concentrated around the mean.

Normality Test

Results of the normality test using the Kolmogorov–Smirnov test showed that the significance values for both groups, experimental and control, were all above 0.05. For the experimental class, the significance value was 0.200, while for the control group it was 0.068. The distribution of data for both groups was considered normal based on these values, indicating that there was not enough evidence to reject the null hypothesis. Therefore, the data met the basic assumption of normality required for the use of parametric statistical analysis, such as the t-test and linear regression, which rely on normal data distribution to produce valid and reliable analysis results.

Table 5. Normality Test (Kolmogorov–Smirnov)

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
Group	Statistic	df	Sig.	Statistic	df	Sig.
Experimental	.154	20	.200*	.934	20	.184
Control	.162	27	.068	.943	27	.146

Homogeneity Test

The results showed that all significance values were above the threshold of 0.05 according to Levene's Test of homogeneity of variance, conducted using various methods including mean, median, median with adjusted degrees of freedom, and trimmed mean. These findings indicate that there were no significant differences in variance between the compared groups. Therefore, the variances were considered homogeneous. Meeting the assumption of homogeneity is essential for the use of parametric statistical techniques, such as the independent samples t-test, since both methods require equality of variances to ensure that the analysis results are valid, accurate, and reliable in the context of hypothesis testing..

Table 6. Homogeneity Test (Levene's Test)

Test	Levene Statistic	df1	df2	Sig.
Based on Mean	1.148	1	45	.290
Based on Median	1.101	1	45	.300

Based on Median and with adjusted df	1.101	1	40.979	.300
Based on trimmed mean	1.156	1	45	.288

Hypothesis Testing

The significance value shown in Table 7 from the independent samples t-test analysis was 0.000, far below the significance level of 0.05. The results indicate that there was a statistically significant difference in the mean scores between the two groups analyzed. The mean difference of 3.691 points reflects that the difference was not random or accidental but rather a real and substantively meaningful difference. Thus, these results provide strong empirical evidence that the variable studied had a different effect on each group, and the difference can be statistically justified within the scientific analysis framework applied in this study.

Table 7. Independent Samples t-test

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	**Sig.**	**t**	**df**	**Sig. (2-tailed)**	**Mean Difference**	**Std. Error Difference**	**95% Confidence Interval of the Difference Lower**	**Upper**
Equal variances not assumed			5.758	34.320	.000	3.691	.641	2.388	4.993

Discussion

Problem-based learning (PBL) is an innovative instructional approach that emphasizes students' active engagement through solving real-world problems. In practice, PBL presents contextual problems that require students to analyze, discuss, and find solutions both independently and collaboratively. To make mathematics learning more meaningful, however, PBL needs to be integrated with ethnomathematics, which examines mathematical ideas rooted in culture, traditions, and daily practices of the community. Through this integration, students are not only confronted with abstract problems but also with issues closely related to their own lives. For example, the Pythagorean theorem can be introduced through the traditional game *engrang*, in which bamboo poles used as supports and footholds form a right triangle with the ground. Such examples provide concrete illustrations for students, showing that mathematics does not exist in isolation but is embedded in cultural and social practices familiar to their lives.

By incorporating local cultural contexts, ethnomathematics-based PBL creates a more engaging, enjoyable, and relevant learning environment. Students not only acquire conceptual understanding but also gain meaningful learning experiences by seeing how mathematical concepts are applied in everyday life. This aligns with the goals of mathematics education, namely to develop critical, creative, and logical thinking skills through contextual learning experiences. Moreover, this approach fosters students' appreciation of local wisdom, allowing them to learn mathematics not merely as an abstract discipline but also as part of the living culture around them. Thus, the integration of PBL and ethnomathematics not only enhances students' conceptual understanding but also enriches their perspectives, increases learning motivation, and strengthens cultural identity in the educational process.

Findings of this study confirm these advantages. Based on data analysis, a significant difference was found between the conceptual understanding of students taught using ethnomathematics-based PBL and those taught through conventional instruction. Importantly, this difference was not only statistically significant but also demonstrated a considerable effect size, indicating that the influence of ethnomathematics-based PBL on students' conceptual

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understanding was substantive rather than marginal. This was evidenced by the independent samples t-test results, which yielded a significance value of $0.000 < 0.05$, thus supporting the research hypothesis. The main finding is that the application of ethnomathematics-based PBL had a positive and significant impact on improving students' mathematical conceptual understanding. The key factor contributing to this success was the integration of local cultural contexts into the learning process, which made students feel more connected to the material, more engaged in discussions, and better able to grasp abstract concepts through concrete examples from everyday life.

This finding is consistent with the argument of Giriansyah et al. (2023), who state that conceptual understanding is a fundamental competency in mathematics learning. By employing PBL, students are encouraged to actively participate in the learning process, from analyzing problems and discussing alternative solutions to drawing conclusions. This process requires students not only to memorize formulas but also to understand and apply concepts in real-life contexts. The integration of ethnomathematics further strengthens the connection between mathematical content and students' daily lives, thereby facilitating the internalization of concepts. From a theoretical perspective, the results of this study support Skemp's view of relational understanding, where students go beyond mastering procedures (instrumental understanding) to grasping the reasons behind concepts. Moreover, ethnomathematics-based PBL aligns with Vygotsky's Zone of Proximal Development (ZPD), in which collaborative discussions and scaffolding from teachers and peers help students achieve higher levels of understanding. In addition, this approach resonates with Freudenthal's Realistic Mathematics Education (RME), which emphasizes the importance of real-life and cultural contexts in building mathematical understanding.

The results of this study are also consistent with the findings of Yuningsih et al. (2024), who reported that ethnomathematics-based PBL enhances students' mathematical communication and curiosity. Similarly, Sodikin (2022) found that PBL is more effective than conventional learning in improving students' conceptual understanding. The distinction between these studies lies in their focus: Yuningsih emphasized communication skills, while this study focuses on conceptual understanding; Sodikin examined the general effectiveness of PBL, whereas this research incorporates ethnomathematics as a contextual reinforcement. These differences highlight the unique contribution of the present study, namely extending the empirical evidence on the effectiveness of PBL by introducing cultural contexts as a key variable. Thus, this study strengthens the empirical basis that PBL, particularly when integrated with ethnomathematics, plays a significant role in improving the quality of mathematics learning.

Ethnomathematics-based PBL offers tangible benefits. Students become more active, creative, and motivated as they are challenged with problems closely related to their daily experiences. Teachers, in turn, can utilize local cultural elements as engaging teaching resources, making the learning process more interactive and enjoyable. A further impact of this approach is the increased self-confidence of students in tackling mathematical tasks, as well as the development of positive attitudes toward mathematics, which is often perceived as a difficult subject (Ahnaf et al., 2024). Theoretically, this study contributes to the literature on mathematics education by demonstrating that integrating PBL and ethnomathematics is not only relevant in practice but also reinforces theoretical frameworks on how students build mathematical understanding through contextual, collaborative, and meaningful experiences.

Conclusion

Based on the findings and discussion, it can be concluded that the use of an ethnomathematics-based problem-based learning (PBL) model generally enhances students' mathematical conceptual understanding. This study affirms that ethnomathematics-based PBL is effective in helping students develop critical and logical thinking skills, as well as in connecting mathematical concepts with everyday contexts. The findings contribute to the literature on PBL and ethnomathematics by demonstrating that their integration strengthens students' relational understanding (Skemp), facilitates interaction within the zone of proximal development (Vygotsky), and supports the principles of Realistic Mathematics Education (Freudenthal), which emphasize the importance of real-world contexts in mathematics learning. Accordingly, this research provides empirical evidence while expanding the theoretical framework on how ethnomathematics-based PBL can serve as a strategic approach to improving the quality of mathematics instruction and fostering more meaningful and applicable learning. The limitation of this study is that it was conducted in a single school and restricted to one topic, namely the Pythagorean theorem. Therefore, generalizing the findings to other educational levels or mathematical topics should be done with caution. Future research is recommended to broaden the scope by involving more schools and different mathematical topics, as well as by developing a wider variety of ethnomathematics-based media and instructional strategies.

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Conflict of Interest

The authors declare that there is no conflict of interest.

Authors' Contributions

Author R.W. contributed to the development of the research instrument, research design, theoretical framework, data collection, data analysis, presentation of results and discussion, revision of the manuscript, and alignment of all sections of the article. Author M.H.H.P. contributed to the theoretical development and approval of the final version of the manuscript. Author H.R.P.N. contributed to the theoretical development and approval of the final version of the manuscript. The percentage contributions of each author to the conceptualization, drafting, and revision of this article are as follows: R.W.: 60%, M.H.H.P.: 20%, and H.R.P.N.: 20%.

Data Availability Statement

The authors declare that the data supporting the findings of this study will be made available by the corresponding author, [R.W.], upon reasonable request.

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