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TAMAN SARI ARTIFACTS IN PROBLEM BASED LEARNING: CULTIVATING MATHEMATICAL LITERACY THROUGH ETHNOMATHEMATICS

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Abstract: This study aims to improve the mathematical literacy of eighth-grade students through the implementation of a problem-based learning model based on ethnomathematics, utilizing Taman Sari artifacts. This study is a classroom action research carried out in 2 cycles. Each cycle consists of planning, action, observation, and reflection. The subjects were 30 of eighth-grade students at a school in Bantul. Research data were obtained through tests, interviews, and documentation. Data were analyzed using qualitative descriptive analysis techniques. Data validation employed method triangulation techniques. The study results demonstrated an increase in students' mathematical literacy after applying the problem-based learning model based on Taman Sari ethnomathematics. Specially, significant improvements were observed across all key mathematical literacy indicators, including formulate indicator (formulating problems), employ indicator (applying the concepts), and interpret indicator (interpreting and evaluating) with consistent progress noted from Cycle I to Cycle II. Based on these findings, it can be concluded that the application of a problem-based learning model based on Taman Sari ethnomathematics significantly improved students' mathematical literacy in mathematics lessons, particularly in the Pythagorean theorem material.

Keywords: classroom action research, ethnomathematics, mathematical literacy, problem-based learning model

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INTRODUCTION

Mathematics education plays a crucial role in developing human resources by fostering analytical, interpersonal, and information processing competencies (Yudha, 2019). The philosophy of mathematics significantly influences education and technology, thereby shaping our daily lives (Nyoman, 2022). In recent years, mathematical modeling has gained significant importance, especially in preparing students for international assessments such as TIMSS and PISA (Hartono & Karnasih, 2017). To align with global education trends, educators are encouraged to integrate mathematical modeling as a core skill into the Indonesian 2013 curriculum. (Hartono & Karnasih, 2017).

Mathematics education in Indonesia has evolved considerably, adapting to societal needs and technological advancements, transitioning from traditional to modern approaches. Furthermore, mathematics is fundamental for sustainable development, serving as a cornerstone for other sciences and holding a vital role in Education for Sustainable Development (ESD) (Widiati & Juandi, 2019). Its importance extends across education levels, from enhancing cognitive development through play practices in early childhood education (De Souza & Teixeira, 2021) to driving innovation and technological progress in developing countries (Pumwa & Mohamed, 2020).

Despite this, research on mathematics education for junior high school students in Indonesia reveals several challenges. Students often struggle with problem-solving skills, facing difficulties in understanding, identifying, and interpreting problems, as well as in creating mathematical models and executing solution strategies (Hadi, 2020). Contributing factors to student passivity and learning difficulties include monotonous teaching methods, low mathematical ability, lack of interest, and suboptimal classroom conditions (Hardianty M, 2017). Furthermore, students encounter issues such as limited learning resources, diverse learning patterns, and insufficient parental support. Internal factors like low interest, motivation, and material comprehension, alongside external factors such as family-related problems (Khairunnisa, Damris, & Kamid, 2021) also influence student difficulties. Supporting this, a study by Styawati & Nursyahida (2017) confirmed students' inability to correctly solve mathematical literacy problems, with many only capable of answering questions at Level 1. Similarly, Syawahid & Putrawangsa (2017) reported that students' literacy skills in the content domains of numbers, probability, and data were in the medium category, while algebraic content was low, and geometry was very low.

To address these challenges, Classroom action Research (CAR) is crucial for examining and resolving mathematics problems within the classroom setting. CAR has demonstrated its effectiveness in improving students' mathematical problem-solving skills through various pedagogical methods, such as the discovery method (Nurdiana & Noviyana, 2019), classroom management with Autograph-assisted learning media (Nurapriani. Hasibuan, & Siregar, 2024), and problem-based learning (Baharullah & Fitriani, 2012). This research approach also facilitates teachers in identifying and rectifying weaknesses in the teaching and learning process, thereby enhancing students' achievement (Yasna, Antara, & Nayun, 2022). Ultimately, mathematics performance is significantly influenced by the learning environment and teaching quality, which directly impact students' progress and their acquisition of essential skills for problem solving and innovation (Pumwa & Mohamed, 2020). Integrating cultural elements and folklore into mathematics education is important for the development of students' learning process (Fouze & Amit, 2023).

Ethnomathematics, defined as the integration of cultural and mathematical practices, has yielded significant results in the teaching of various mathematical concepts, particularly geometric shapes. Its application has been explored across diverse contexts, including Jepara carvings (Aminah & Syamsuri, 2022), Islamic ornaments (Shahbari & Daher, 2020), local cultural practices (Mukwambo, Zulu, & Kayangula, 2023), and Kalimantan batik motifs (Sudrajat, Winarto, & Wicaksono, 2023). Research by Marsigit & Rusli (2021) further demonstrates how mathematical concepts embedded within the Riau Malay tribe's culture can introduce and facilitate understanding of mathematical ideas through local wisdom. The ethnomathematics approach offers benefits such as enhanced comprehension of geometric concepts, improved proof processes, and richer learning experiences. As a pedagogical approach, ethnomathematics enables teachers to leverage students' prior knowledge and cultural context, thereby making mathematics more relevant and meaningful (Mukwambo et al., 2023; Shahbari & Daher, 2020). Strategies for implementation often involve the exploration of cultural artifacts, analysis of geometric shapes in traditional designs, and the use of local terminology to clarify mathematical concepts (Aminah & Syamsuri, 2022; Sudrajat et al., 2023). This approach aligns with Marsigit, Setiana, & Hardiarti (2018) the inherent nature of school mathematics and student learning processes, ultimately allowing students to better understand and apply mathematical concepts in daily life, potentially improving their overall comprehension and recall, especially in flat shape learning.

The integration of the ethnomathematics approach with a problem-based learning (PBL) model is highly applicable in the teaching and learning process. Numerous studies confirm that synergy enhances students' mathematical understanding and problem-solving skills. For instance, research by Perdana & Isrokatun (2019) and Maharani & Waluya (2024) demonstrates that ethnomathematics-based PBL is more effective than conventional methods in fostering mathematical comprehension. The combined approach has also been shown to boost student engagement and improve mathematical learning outcome (Widana & Diartiani, 2021). Furthermore, developing valid, practical, and effective open ethnomathematics-based teaching materials can significantly enhance learning activities and achievement (Suryawan, 2018). Specifically, integrating ethnomathematics-such as Sundanese culture into geometry and measurement learning can sharpen students' problem-solving skills and cultural awareness (Permana, 2023). This approach provides a more contextualized and culturally relevant learning experience.

The integrated ethnomathematics and PBL model has consistently yielded positive results in improving students' mathematical literacy and overall learning outcomes. Studies affirm its effectiveness in enhancing mathematical literacy skills (Prihatiningtyas & Buyung, 2023; Qauliyah, Nizaruddin, & Shodiqin, 2022) and general learning outcomes (Agusdianita, Supriatna, & Yusnia, 2023). By integrating ethnomathematics, mathematics become more meaningful and contextual, effectively bridging the gap between abstract mathematical concepts and students' cultural experiences (Surat, 2018). This motivates students to actively engage in the learning process, solving authentic problems rooted in their cultural context (Agusdianita *et al*., 2023). Evidence suggests that students exposed to ethnomathematics-based PBL environments outperform those in traditional settings (Prihatiningtyas & Buyung, 2023; Qauliyah *et al*., 2022). Moreover, this methodology cultivates high-level thinking skills, independence, and self-confidence among students (Agusdianita *et al*., 2023).

Given the aforementioned problems and the compelling evidence from prior research, this study therefore conducted a Classroom Action Research (CAR). This research aimed to improve mathematical literacy skills among eight-grade students by employing an ethnomathematics approach, which underscores the significance of innovative teaching methods, culture integration, and effective pedagogical leadership in enhancing mathematics learning outcomes. Consequently, this classroom action research sought to answer the following questions:

1) How is the application of problem-based learning based on ethnomathematics of Taman Sari artifacts implemented for the Pythagorean theorem material in eight-grade students?

2) Can the application of problem-based learning based on ethnomathematics of Taman Sari artifacts improve the mathematical literacy skills of eight-grade students?

METHOD

This research is a Classroom Action Research (CAR) with the aim of improving students' mathematical literacy skills through the implementation of problem-based learning models focusing on the Pythagorean theorem material. The research was conducted in an eight-grade class at a school in Bantul. Following the model developed by Kemmis and Mc. Taggart (1988) the CAR was carried out in two cycles. Each cycle comprised distinct stages: planning, action, observation, and reflection. Data derived from each cycle's reflection was subsequently described and analyzed qualitatively, based on the observed fact and circumstances within the classroom. This cyclical Kemmis and McTaggart CAR design facilitated a systematic approach to improving the learning process as illustrated in Figure 1:

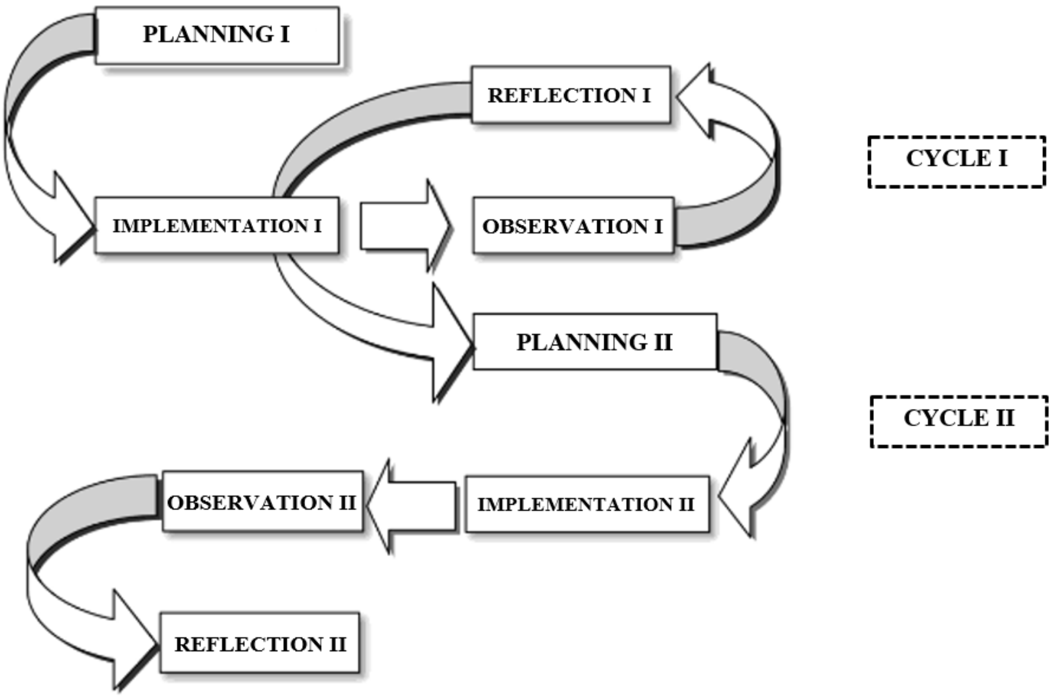


Figure 1. Kemmis and McTaggart model car design

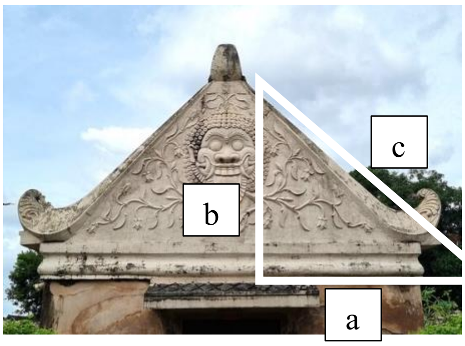
Planning activities encompassed the preparation of all necessary instruments. The learning instruments developed included teaching materials based on Taman Sari ethnomathematics artifacts, student worksheets, and assessment sheets. Concurrently, research instruments such as mathematics ability tests for the Pythagorean theorem material, observation sheets for learning process implementation, student and teacher interview guidelines, and documentation equipment were prepared. Action implementation involved applying the problem-based learning model, integrated with Taman Sari ethnomathematics, to the Pythagorean theorem material to enhance students' mathematical literacy skills. Observations specifically focused on the fidelity of the problem-based learning model's syntax implementation within the Taman Sari ethnomathematics framework. The reflection stage constituted a critical analysis of how the ethnomathematics-based problem-based learning model was applied to the

Pythagorean theorem material in eight-grade students. Findings from this reflection phase served as the foundational basis for planning actions in the subsequent cycle.

Research data was collected both before and after the intervention through pretest and posttest of mathematical literacy, supplemented by observations and interviews. Specifically, students' mathematical literacy scores were gathered as quantitative data from the pretest and posttest results. In total, three distinct data collection methods were employed: observation, interviews, and documentation. The mathematical literacy ability test for the Pythagorean theorem material consisted of descriptive questions. The primary objective for research achievement was to demonstrate an increase in the average results of the mathematical literacy ability test for eight-grade students compared to the pre-cycle phase. For data analysis, a quantitative approach was adopted, where mathematical literacy test results were analyzed by calculating the average score increase in each cycle. Both pretest and posttest data were further analyzed using percentage increase and by comparing average learning outcomes.

RESULTS AND DISCUSSION

This classroom action research, conducted in two cycles, aimed to determine the improvement of students' mathematical literacy skills in the Pythagorean theorem material. For mathematics learning, Taman Sari artifacts were incorporated, specifically utilizing buildings and structures that naturally form right triangles, such as the upper wall and the slope of the Taman Sari stairs. The study's focus material was the Pythagorean theorem, covering its definition and Pythagorean triples. An example of a right-triangle model found in Taman Sari artifacts is presented in Figure 2.



Description:
a = base of a right triangle
b = height of a right triangle
c = hypotenuse of a right triangle

Figure 2. Right triangle concept in *taman sari* artifacts

Building upon the right-triangle concept, these artifacts were further developed into learning scenarios for the Pythagorean theorem material. Figure 3 illustrates how the Pythagorean theorem concept is integrated with Taman Sari artifacts.

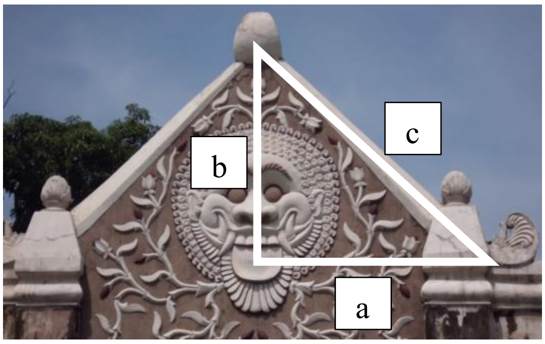


Figure 3. The concept of the pythagorean theorem in *taman sari* artifacts

In a right triangle with side lengths a, b, c and c as the hypotenuse (the longest side), then the following applies:

$c^2 = a^2 + b^2$

This formula is known as the Pythagorean Theorem:

"The square of the hypotenuse = the sum of the squares of the sides of the right angle"

During Planning Stage I, the researcher developed a Problem-Based Learning (PBL) module integrated with Taman Sari ethnomathematics artifact. This teaching module was designed to facilitate the exploration of the Pythagorean theorem concept through real-world problems linked to the structure of Taman Sari artifacts, such as the triangular shape of the Taman Sari Gate. An evaluation instrument, comprising pretest and posttest, was also developed to measure mathematical literacy skills. Additionally, coordination with the mathematics teacher ensured smooth implementation of the action.

Implementation Stage I consisted of two meetings. The first meeting began with an introduction to learning objectives, followed by a pretest. During this meeting, students were introduced to the basic concept of the Pythagorean theorem through exploring the Taman Sari building. The teacher presented contextual problems, such as measuring the gate's height, utilizing a mathematical approach associated with the Pythagorean theorem formula via the Taman Sari ethnomathematics context.The second meeting in Cycle I, involved implementing problem-based learning based on Taman Sari ethnomathematics, discussing how to calculate the side lengths of a right triangle using the Pythagorean theorem. In this meeting, students worked individually to solve the given problems, with the teacher acting as a facilitator. At the end of the learning session, students took a test to measure their mathematical literacy.

During Observation Stage I, the learning process revealed initial findings: 1) Students showed initial interest in learning the Pythagorean theorem using the Taman Sari ethnomathematics approach. However, some students struggled to grasp the connection between the artifact and application of the Pythagorean theorem. A comparison of post-test results in Cycle I revealed a significant improvement: the average students score increased from 39.27 (pre-test) to 59.67 (post-test Cycle I). Reflection Stage I yielded several key notes: 1) Students' worksheets needed redesign to be group-oriented to better foster student discussion. 2) Strategies to enhance active student involvement through more varied discussion techniques were required. 3) Additional time was necessary for students with lower abilities to complete the questions. Consequently, the researcher planned to allocate additional time in the next cycle. Following the completion of Cycle I, Cycle II was initiated based on these reflective insights.

Based on the reflection of cycle I, Planning Stage II involved refining the ethnomathematics-based student worksheets to include contextual problems designed for group work. Cycle II focusing on the application of the Pythagorean theorem to Taman Sari buildings. Following the learning activities, evaluation test questions for Cycle II were administered. Throughout this stage, the researcher facilitated learning as planned, presenting students with contextual problems derived from Taman Sari artifacts relevant to the Pythagorean Theorem. The teacher guided students through the PBL stages: understanding the problem, collecting data, analyzing, and presenting solutions. Group-based learning was emphasized to foster discussion and collaboration. Learning activities underscored active student engagement in connecting mathematical concepts with cultural artifacts, promoting a contextual understanding of the material.

Observation Stage II results significant improvements: 1) Active student involvement surged to 75%, with many students enthusiastically presenting their group discussion outcomes. 2) The average posttest score rose to 74.14%, signifying a better understanding of the Pythagorean theorem. The researcher observed the progression of students' mathematical literacy skills through their engagement in discussions, their ability to explain Pythagorean concepts using artifact contexts, and their performance on worksheets. Observation data indicated increased student enthusiasm for mathematics, as the ethnomathematics approach was perceived as more engaging and relevant. However, a persistent challenge was identified: some students still found it difficult to logically integrate artifact data with mathematical concepts.

During Reflection Stage II, the researcher evaluated the actions taken based on both observational and test data. The findings consistently showed a significant increase in students' mathematical literacy skills, particularly in understanding and applying the Pythagorean Theorem concept. Students also demonstrated improved critical thinking when solving contextual problems. These results affirm that applying ethnomathematics to mathematics learning, especially the Pythagorean theorem material, effectively makes learning more contextual and comprehensible for students. The material aligns with the teaching module specifically designed and implemented for eighth-grade students. The average percentage of mathematical literacy achievement for class VIII is presented in Figure 4.

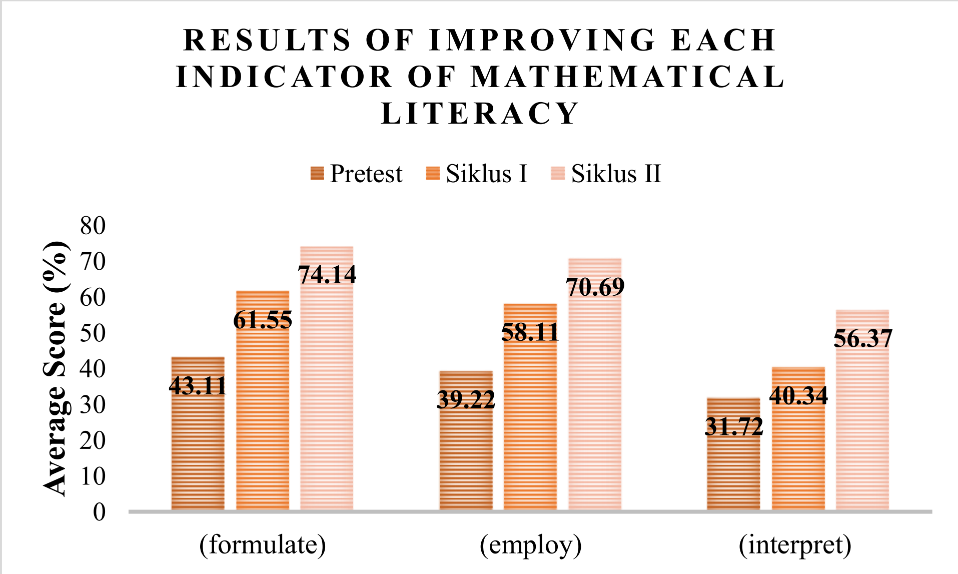


Figure 4. Average percentage of achievement of each mathematical literacy indicator

The collected data reveals a progressive increase across all mathematical literacy indicators. For the 'formulate' indicator (formulating problems), pretest results of 43.11% increased to 61.55% in Cycle I and further to 74.14% in Cycle II. In the 'employ' indicator (applying concepts), pretest results of 39.22% rose to 58.11% in Cycle I and reached 70.69% in Cycle II. For the 'interpret' indicator (interpreting and evaluating), pretest results of 31.72% increased to 40.34% in Cycle I and 56.37% in Cycle II. A comprehensive comparison of the average percentage of overall mathematical literacy skill achievement across Pre-Cycle, Cycle I, and Cycle II is presented in Figure 5:

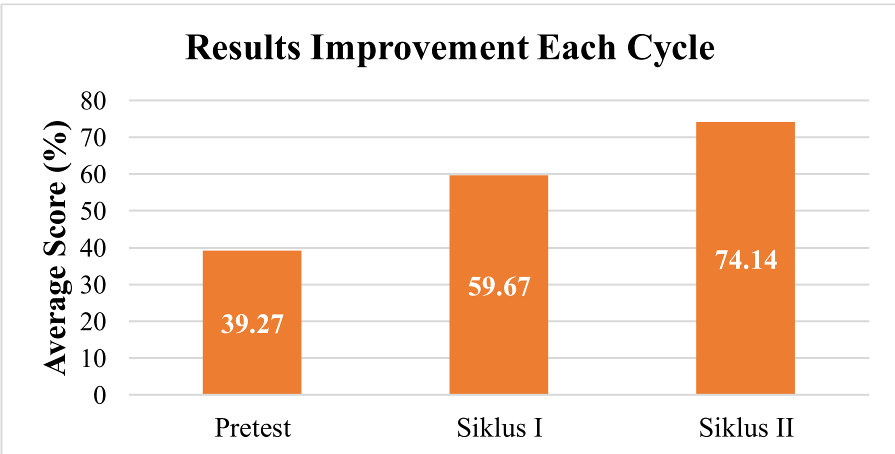


Figure 5. Comparison of the average percentage of achievement of mathematical literacy skills in each cycle

The analysis of the results from Cycle I and Cycle II indicates that the application of the problem-based learning model based on Taman Sari ethnomathematics effectively improved students' mathematical literacy skills. Measures of mathematical literacy at the end of the action showed the overall achievement percentage for eighth-grade students. In Cycle I, out of 30 students, the average score was 59.29, with a highest score of 90 and a lowest score of 20. Only 10 students met the KKM (Criteria for Minimum Completeness), while 17 were incomplete, and 3 students did not participate in the mathematical literacy test. This resulted in a classical mastery of 33.3% and 66.6% incomplete.

In Cycle II, for the same 30 students, the average score increased to 74.14, with a highest score of 95 and a lowest score of 30. The number of students achieving a score of ≥ 70 significantly rose to 18, while 9 students remained below the KKM, and 3 did not participate. This signifies a substantial improvement in students' literacy skills, with classical mastery reaching 60%, an increase of 27% from the previous cycle. These findings suggest that the implementation of ethnomathematics-based problem-based learning using Taman Sari artifacts enhanced students' mathematical literacy skills because each PBL syntax incorporated activities designed to train students' mathematical abilities. Moreover, external factors such as student motivation, additional teacher support, and active student involvement may have also contributed to the improved outcomes. The model encourages students to leverage their own experiences, acquired through practical activities, and others' experiences, gained from reading, to construct new knowledge.

The scores of each student experienced different increases. Most experienced an increase in their score achievement, but some students' scores were unstable in a certain cycle. Students who experienced continuous improvement were due to getting used to and being able to follow the learning model applied. Based on the results of interviews with students whose scores continued to increase, it was found that students stated that they were more enthusiastic about learning the problem-based learning model based on ethnomathematics of Taman Sari artifacts, because they felt more involved during the lesson, and they were interested in the problems in the reading presented in the implementation of Taman Sari artifacts as a learning medium with an ethnomathematics approach. Problem-based learning (PBL) integrated with ethnomathematics has shown increased results in improving mathematical literacy and student learning outcomes. This is in accordance with the results of research by Agusdianita *et al.* (2023) stating that learning the problem-based learning model based on ethnomathematics can improve students' literacy skills. Other studies have also shown that the ethnomathematics approach effectively improves mathematical literacy skills (Prihatiningtyas & Buyung, 2023; Qauliyah *et al.*, 2022). According to Surat (2018), ethnomathematics integration makes mathematics more meaningful and contextual, bridging the gap between mathematical concepts and students' cultural experiences.

Classroom action research with an ethnomathematics approach has been proven effective in improving students' mathematical literacy. Ethnomathematics, which integrates local cultural elements into mathematics learning, makes the material more relevant and easier for students to understand. This is in line with research conducted by Ajmain, Herna, & Masrura (2020) at MTs Yayasan Perama Tutallu showing that the application of an ethnomathematics approach in mathematics learning can improve student learning outcomes in triangle and quadrilateral material. In addition, ethnomathematics-based learning models are also effective in improving students' mathematical literacy and understanding. As explained in the research of Auliya, Suyitno, & Asikin (2020) which found that problem-based learning models with an ethnomathematics approach were effective in improving students' mathematical literacy. In addition, Fitriatunnisa Hastuti, & Mariyati (2024) also explained a significant increase in mathematical literacy skills through an ethnomathematics approach in the traditional game Congklak. By linking mathematical concepts to students' culture and daily lives, the ethnomathematics approach not only improves conceptual understanding but also fosters interest and motivation to learn. This in turn contributes to increased mathematical literacy, enabling students to become more proficient in formulating, using, and interpreting mathematics in a variety of contexts.

Based on the results of interviews, students who continued to experience improvement admitted that they felt happier with the problem-based learning model based on ethnomathematics of Taman Sari artifacts, because they were interested in the problems in the reading presented. According to interviews with students who experienced a decrease in the achievement score of mathematical literacy skills, the Pythagorean theorem material was more complex and broad so that students had difficulty adapting to the new learning model. Some students obtained unstable achievement scores for mathematical literacy skills, and some remained the same as the previous cycle.

Based on observations, students whose scores fluctuate and those who remain show a less enthusiastic attitude during learning so that the score in the observation sheet is not as high as students who experience continuous improvement, so that the results of the literacy ability test do not increase linearly. This statement is in accordance with Chozaipah (2018), which states that students who are less participative usually get lower scores than students who are actively participating. According to the results of interviews, some students whose scores were unstable admitted that students were sometimes confused during the learning process because the teacher did not explain directly and completely as is usually done. Other causes of student score instability include more complex learning materials that certain students find difficult, poor student conditions during the learning process, students concerned do not attend all class hours, some students are bored, and feel forced to read which results in not maximizing the student's participation in learning so that they do not read the readings seriously and do not participate in group discussion activities properly, and students have not been able to understand the material independently and wait for teacher explanations. Therefore, less than optimal student readiness can also affect student performance in class.

To continuously maximize mathematical literacy skills, future efforts should include providing gradual and periodic practice questions, thereby accustoming students to regular training and problem-solving. This approach must be complemented by consistent teacher supervision. Ideally, teachers should monitor all students, not just a select few, to identify individual deficiencies and track the progression of each student's abilities comprehensively.

CONCLUSION

Based on the findings of this classroom action research, the following conclusions can be drawn: 1) The problem-based learning (PBL) model, when integrated with Taman Sari ethnomathematics artifacts, was successfully implemented in teaching Pythagorean theorem material to eighth-grade students. The implementation involved structured stages of planning, action, observation, and reflection across two cycles. 2) The application of this ethnomathematics-based problem-based learning model significantly improved students' mathematical literacy skills. This improvement was evident across all indicators of mathematical literacy (formulate, employ, and interpret) and was reflected in the increased average scores and classical mastery percentage from Cycle I to Cycle II. 3) The integration of local cultural artifacts made the mathematical concepts more contextual, relevant, and engaging for students, fostering greater interest and active participation in learning. Further in-depth exploration is recommended to ensure students fully immerse in the cultural context and to explore the long-term development of their mathematical thinking.

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