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INTEGRATION OF PROBLEM-SOLVING AND ETHNOMATHEMATICS APPROACHES TO ENHANCE STUDENTS' MATHEMATICAL REPRESENTATION ABILITY

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ABSTRACT

Mathematical representation ability is one of the fundamental skills needed by students to understand concepts and solve mathematical problems. However, the results of the study indicate that this ability is still low in most elementary school students. This study aims to develop a mathematics learning tool based on the Problem Solving approach and integrated with Ethnomathematics to improve students' mathematical representation ability. The study used the Research and Development (R&D) method with the Plomp development model consisting of three phases, namely initial research, development, and assessment. The research subjects were 30 students. The research instruments included validation sheets, teacher assessment sheets, student response sheets, implementation observation sheets, and mathematical representation ability tests (pre-test and post-test). The results showed that the developed learning tool met practical criteria with an average LKPD readability of 4.60 (very good category) and learning implementation of 94.5% (very good category), and was effective with an increase in the average pre-test score of 56.20 to a post-test of 83.87 and a gain score of 0.63 (medium-high category). Thus, there was a significant increase in the average post-test results of students' mathematical representation abilities, namely 83.87 through Problem Solving and Ethnomathematics-based learning devices.

INTRODUCTION

Mathematics is one of the subjects that plays an essential role in developing logical, systematic, critical, and creative thinking abilities. The National Council of Teachers of Mathematics (NCTM) emphasizes five process standards of mathematical proficiency that students must possess: problem solving, reasoning and proof, communication, connection, and mathematical representation. Representation is considered a fundamental foundation of all these abilities, as it enables students to construct, express, and visualize mathematical ideas through various forms such as pictures, symbols, tables, or mathematical statements (NCTM, 2000).

This view is consistent with Nashihah (2020), who emphasized that mathematical representation functions as the main medium for students to communicate mathematical ideas in a more structured and meaningful way. Similarly, Julaeha, Mustangin, and Fathani (2020) asserted that mathematical representation is an essential cognitive skill that supports connections between mathematical concepts and helps students understand the relationships among ideas.

Research Problems

Based on the background above, the research problems are as follows:

1. How is the process of developing mathematics learning tools based on the Problem-Solving approach integrated with Ethnomathematics to enhance students' mathematical representation ability?
2. What are the levels of validity, practicality, and effectiveness of the developed Problem-Solving and Ethnomathematics-based mathematics learning tools?
3. To what extent can the developed learning tools improve elementary students' mathematical representation ability?

Research Objectives

In line with the research problems, this study aims to:

1. Develop mathematics learning tools based on a Problem-Solving approach integrated with Ethnomathematics to improve students' mathematical representation ability.
2. Determine and analyze the validity, practicality, and effectiveness of the developed mathematics learning tools.
3. Describe the improvement in students' mathematical representation ability after participating in Problem-Solving-based learning integrated with Ethnomathematics.

This is supported by Eviyanti and Yerizon (2022), who demonstrated that mathematical representation plays a crucial role in facilitating students' development of adaptive learning strategies. Similarly, Cahyaningrum, Fuady, and Faradiba (2023) emphasized that both visual and symbolic representations can clarify students' thought processes in understanding mathematical transformation concepts.

The importance of mathematical representation is also highlighted by Miladiah, Nurhaida, and Karimah (2020), who explained that through creating, comparing, and utilizing various forms of representation, students can deepen their understanding of mathematical concepts and relationships. Furthermore, Srikandake, Daniel, and Gella (2022) stated that mathematical representation contributes to building students' mathematical thinking foundation, thereby supporting problem-solving abilities. This is reinforced by Azzahanty and Kumalasari (2023), who asserted that mathematical representation not only aids problem solving but also enhances the quality of conceptual understanding in mathematics.

According to Kumalasari (2022), indicators of mathematical representation include students' ability to transform problems into forms such as pictures, tables, symbols, or mathematical statements. Using these indicators, teachers can evaluate more precisely how well students understand and apply representation in mathematics learning.

In addition to representation skills, learning based on local wisdom has become an important focus in educational development. Maharani and Muhtar (2022) explained that learning grounded in local wisdom can utilize the cultural, linguistic, ecological, and technological strengths of a region to enhance students' competencies. Annisha (2024) added that integrating local wisdom into the *Merdeka Belajar* (Independent Learning) curriculum increases the relevance of learning materials to students' real-life contexts, thereby making learning more meaningful.

The integration of cultural values in mathematics learning is also emphasized by Zulfah and Insani (2020), who argued that mathematics should be connected to community life realities to be more relatable to students. Supiyati, Hanum, and Jailani (2019) strengthened this perspective through their study of ethnomathematics in Sasak traditional architecture, where mathematical concepts are found in tangible cultural patterns. Similarly, Aprilianingsih and Rusdiana (2019) revealed that local cultural ethnomathematics can serve as an alternative contextual learning strategy relevant to 21st-century educational demands.

On the other hand, learning innovation requires active student engagement in building problem-solving skills. According to Saputri and Wardani (2021), the problem-solving approach has proven effective in improving elementary students' critical thinking and problem-solving abilities. This finding is supported by Daryati (2018), who discovered that problem posing serves as a medium to enhance students' problem-solving skills. Furthermore, Mubarrod and Abdullah (2024) emphasized that the use of problem-solving strategies in grade V mathematics classes positively affects students' learning outcomes.

Firda, Suryadi, and Dahlan (2023) described problem solving as a cognitive process that requires manipulation and reconstruction of students' knowledge to reach solutions.

This aligns with Pramestika, Suwignyo, and Utaya (2020), who stated that problem solving can be used both as a learning approach and as a learning goal in mathematics. Yuliyanti and Rahayu (2021) further noted that implementing problem solving combined with collaborative strategies can enhance students' critical thinking skills.

Moreover, Intaros, Inprasitha, and Srisawadi (2014) demonstrated that problem-solving classes with open-ended questions can foster students' creativity in generating various solving strategies. This is supported by Hwang, Chen, Dung, and Yang (2007), who found that elaboration ability and multi-representation skills significantly influence students' success in problem solving. Therefore, the combination of Problem-Solving and Ethnomathematics approaches is believed to strengthen students' mathematical representation skills while promoting contextual, meaningful, and culturally rooted learning.

RESEARCH METHOD

Type and Design of the Research

This study employed a *Research and Development (R&D)* approach, referring to the Plomp development model, which consists of three main phases: (1) the Preliminary Research Phase, (2) the Development or Prototyping Phase, and (3) the Assessment Phase (Sugiyono, 2019). This model was chosen because it is suitable for producing learning tools that are valid, practical, and effective in improving students' mathematical representation abilities.

Research Subjects and Location

The research was conducted at SD Pangeran Antasari Medan, involving 30 fifth-grade students during the odd semester of the 2025/2026 academic year. The research site was located in Medan City, North Sumatra Province. The location was chosen based on the availability of learning facilities, teacher support, and the relevance of Medan's local cultural context, which served as the foundation for the ethnomathematics-based approach.

Research Procedure

The stages of developing the learning tools were carried out as follows:

1. Preliminary Research Phase: including needs analysis, literature review, and identification of student characteristics and learning environment.

2. Development Phase: including the design of learning tools such as lesson plans, student worksheets, digital-based learning media, and assessment instruments. The prototype was validated by experts to obtain feedback for improvement.
3. Assessment Phase: the developed tools were tested through small-scale (individual) and large-scale (field) trials, followed by validity, practicality, and effectiveness analyses.

Type and Source of Data

The research data consisted of:

1. Quantitative data, including expert validation scores, teacher assessment scores, student response scores, lesson implementation scores, and pretest-posttest scores of students' mathematical representation abilities.
2. Qualitative data, including descriptions of observation results, interviews, and comments from validators, teachers, and students regarding the developed learning tools.

The data sources included subject-matter experts, learning experts, and media experts (for validation); teachers (for practicality evaluation); students (for trials); and observers (to assess lesson implementation).

Research Instruments

The instruments used in this study included:

1. Teacher Evaluation Sheet, Student Response Sheet, and Lesson Implementation Observation Sheet to assess the practicality of the developed tools.
2. Mathematical Representation Ability Test (pretest and posttest) to measure the effectiveness of the learning tools.

The test consisted of four open-ended questions based on the mathematical representation indicators proposed by NCTM. The test blueprint is presented in Table 2.

Table 2. Blueprint of the Mathematical Representation Ability Test

No	Aspect	Indicator	Pre-test Question Number	Post-test Question Number
1	Picture	Ability to translate mathematical problems into pictorial representations	1	1
2	Symbol	Ability to translate mathematical problems into symbolic representations	2	2
3	Table	Ability to translate mathematical problems into tabular representations	3	3
4	Mathematical statement	Ability to translate mathematical problems into mathematical statements	4	4

Data Analysis Techniques

Data analysis was carried out using both quantitative and qualitative descriptive methods, as follows:

1. Practicality Analysis: determined from teacher assessments, student responses, and lesson implementation observations. The learning tools were considered practical if the score met at least the "good" category and the lesson implementation reached a minimum of 80%.
2. Effectiveness Analysis: calculated from students' pretest and posttest results on mathematical representation ability. Improvement was measured using the *gain score*. The tools were considered effective if at least 80% of students reached the high category.
3. Qualitative Analysis: conducted on expert, teacher, and student feedback to complement the quantitative findings.

Validation of Learning Tools

Validation of the learning tools was carried out by three expert validators, consisting of one mathematics content expert, one instructional design expert, and one media expert. The assessment used a Likert scale of 1–5, with the following criteria:

1 = very poor,
2 = poor,
3 = fair,
4 = good,
5 = very good.

The learning tools were considered valid if the average score was ≥ 3.50 (categorized as "good") based on all validators' assessments. The validation results showed that the learning tools obtained an overall average score of 4.72, categorized as "very feasible" to be used in individual trials.

Gain Score Category Based on Hake (1998)

The gain value was calculated using Hake's (1998) formula:

$$g = \frac{(\text{Posttest score} - \text{Pretest score})}{(100 - \text{Pretest score})}$$

The gain score categories according to Hake (1998) are as follows:

$g \geq 0.70$ = High

$0.30 \leq g < 0.70$ = Medium

$g < 0.30$ = Low

RESULTS AND DISCUSSION

1. General Description of the Study

This study involved 30 students during the odd semester of the 2025/2026 academic year. The main focus of the research was to develop mathematics learning tools based on the integration of the *Problem-Solving* and *Ethnomathematics* approaches to enhance students' mathematical representation skills. The research process included several stages: learning design development, tool creation, expert validation, individual trials, field trials, and product revision.

To strengthen the descriptive findings, a statistical significance test was conducted to compare the pre-test and post-test scores using a paired sample t-test. This analysis aimed to determine whether the improvement in students' mathematical representation skills after participating in Problem-Solving-based learning integrated with Ethnomathematics was statistically significant.

The developed learning tools consisted of lesson plans (RPP), student worksheets (LKPD), digital-based learning media, and assessment instruments. All components were designed by integrating local cultural contexts such as *ulos* fabric motifs, traditional Batak house architecture, and traditional counting systems to strengthen the connection between mathematical concepts and students' real-life experiences.

2. Individual Trial Results

The individual trial was conducted with three students of varying academic abilities (high, medium, and low) to examine the readability of the LKPD and their responses to culturally-based media. The results are presented in Table 2.

Table 2. Results of Individual Trials of Learning Tools

No	Student Code	Academic Ability	Readability Score (Scale 1–5)	Response to Cultural Illustration (%)	Descriptive Narrative
1	S-01	High	4.80	100%	Quickly understood instructions and was enthusiastic in connecting 3D shapes with cultural motifs.
2	S-02	Medium	4.60	90%	Understood the concept well but needed minor clarification regarding cultural elements.
3	S-03	Low	4.40	80%	Understood basic ideas but still needed additional guidance regarding cultural terms.

Based on Table 2, the average LKPD readability score was 4.60, categorized as *very good*, while the average positive response to cultural illustrations reached 90%. This indicates that the developed learning tools were easy to understand for students of various ability levels. However, low-ability students still required additional guidance, particularly in linking mathematical symbols with cultural contexts.

3. Field Trial Results

The field trial involved all fifth-grade students to evaluate the implementation of the developed learning tools. The learning process was carried out over four sessions on the topic "Geometric Solids" based on ethnomathematics. The implementation data are presented in Table 3.

Table 3. Implementation of Learning During Field Trials

No	Learning Stage	Implementation Percentage (%)	Category
1	Problem Orientation	96	Very Good
2	Explanation of New Concepts	91	Very Good
3	Exploration of Solution Strategies	95	Very Good
4	Group Discussion	94	Very Good
5	Reflection	97	Very Good
	Average		**94.5**

Table 3 shows that the average implementation of the learning process reached 94.5%, categorized as *very good*. The reflection stage obtained the highest score (97%), indicating that students were actively expressing their understanding both verbally and in writing. The new concept explanation stage received the lowest percentage (91%), suggesting that additional media were needed to facilitate students' understanding of abstract concepts.

4. Analysis of Students' Mathematical Representation Improvement

Students' mathematical representation ability was measured using pre-test and post-test instruments based on NCTM indicators. The results are summarized in Table 4.

Table 4. Pre-test, Post-test, and Gain Scores of Mathematical Representation Ability

Description	Average Score	Category
Pre-test	56.20	Moderate
Post-test	83.87	High
Gain Score (Hake)	0.63	Moderate–High
Percentage of Students in High Category	>80%	Effective

Table 4 shows that the average pre-test score was 56.20 (moderate category), while the average post-test score increased to 83.87 (high category). This improvement resulted in an average gain score of 0.63, categorized as moderate-high. These findings demonstrate that the Problem-Solving and Ethnomathematics-based learning tools effectively enhanced students' mathematical representation skills.

To further illustrate the improvement, this study presented a comparison graph of pre-test and post-test scores across three NCTM representation indicators: visual, symbolic, and verbal representations. The visualization aimed to provide a comprehensive picture of students' performance changes before and after Problem-Solving-based learning integrated with Ethnomathematics.

The analysis showed consistent improvement across all indicators as follows:

1. Visual representation increased from an average of 55.10 to 87.90 (gain = 0.72, high category).
2. Verbal representation increased from an average of 57.30 to 83.50 (gain = 0.63, moderate category).
3. Symbolic representation increased from an average of 56.20 to 80.30 (gain = 0.58, moderate category).

The comparison of improvements for each indicator is presented in Figure 4.5 below.

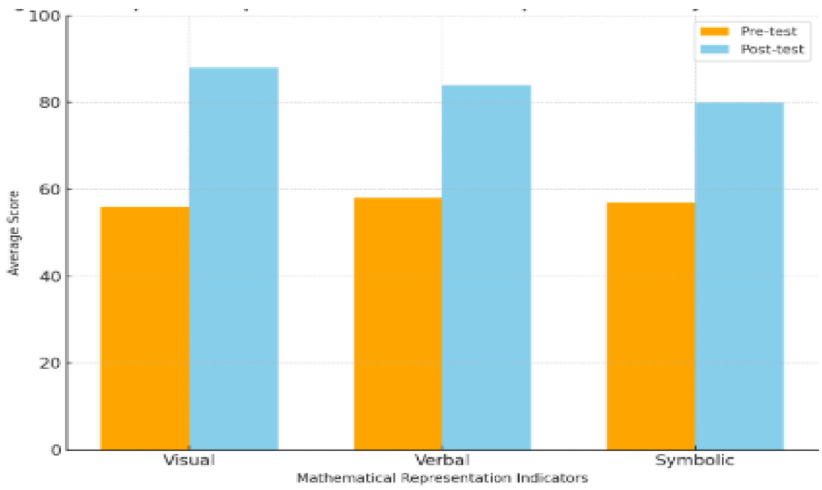

Figure 1. Graph of the Improvement in Mathematical Representation Ability by Indicator

Discussion

The significant improvement in students' mathematical representation ability was not only the result of the Problem-Solving approach but also influenced by the instructional design's integration of cultural contexts (*ethnomathematics*). Cultural contexts such as *ulos* motifs, Batak traditional houses, and woven patterns provided concrete visual stimuli that helped students connect abstract concepts to real-life experiences. This aligns with Vygotsky's constructivist theory, which emphasizes that knowledge is constructed through social interaction and culturally relevant contexts.

Additionally, the structure of Problem-Solving-based learning, which includes the stages of problem orientation – strategy exploration – problem solving – and reflection, promotes students' active cognitive engagement. This process fosters *metacognitive engagement*, where students do not merely memorize formulas but engage in higher-order thinking (HOTS) such as analyzing, synthesizing, and evaluating solutions.

The combination of these two approaches creates a meaningful learning environment, motivating students to understand mathematical concepts deeply. Consequently, the significant improvement in mathematical representation ability can be seen as a logical outcome of a culturally grounded, problem-oriented, and student-centered learning design.

The results show that the Problem-Solving and Ethnomathematics-based learning tools are valid, practical, and effective in enhancing students' mathematical representation ability. The most significant improvement was observed in visual representation, where students successfully connected the symmetrical patterns of *ulos* cloth with concepts of reflection and rotation.

Theoretically, these findings support Vygotsky's view of the importance of socio-cultural context in knowledge construction. Integrating local culture helped students better understand abstract concepts. Furthermore, the Problem-Solving approach fostered learning independence and critical thinking, as evidenced by students' active participation in group discussions.

Practically, this learning tool can serve as an innovative alternative in elementary mathematics instruction, as it not only enhances cognitive skills but also strengthens students' cultural identity. However, this study's limitations include the short learning duration and small number of participants, suggesting that future research with broader scope and duration is highly recommended.

Research Limitations and Practical Implications

a. **Research Limitations**

This study had several limitations that need to be acknowledged:

1. The research subjects were limited to 30 fifth-grade students of SD Pangeran Antasari Medan, so the findings cannot yet be generalized to a wider population.
2. The learning implementation lasted only four sessions, which did not allow for measuring long-term retention or concept transfer effects.

3. The study focused solely on improving mathematical representation skills and did not examine other aspects such as mathematical communication or connections.
4. The use of Medan's cultural context may not be entirely relevant if applied in regions with different cultural backgrounds.

Nevertheless, these limitations do not undermine the validity of the findings; instead, they provide a foundation for future research with broader coverage and longer duration.

b. **Practical Implications for Elementary School Teachers**

The results of this study provide several important implications for elementary school teachers in teaching practice:

1. The integrated Problem-Solving–Ethnomathematics model can serve as an alternative to improve the quality of contextual, engaging, and meaningful mathematics learning.
2. Teachers can use local cultural elements as concrete media to bridge abstract mathematical concepts such as symmetry, geometry, and ratios.
3. Problem-based learning within cultural contexts can increase students' learning motivation, active participation, and sense of cultural belonging.
4. Teachers should be trained to develop culture-based student worksheets (LKPD) so that students not only understand mathematics cognitively but also appreciate the cultural values embedded in it.
5. The findings can serve as materials for *Teacher Professional Development* programs to enhance pedagogical competence and innovation in elementary school mathematics instruction.

CONCLUSIONS AND SUGGESTIONS

Conclusion

Based on the results and discussion of the study, several conclusions can be drawn as follows:

1. Practicality of the Learning Tools

   Individual and field trials indicate that the developed learning tools are practical to use in classroom activities. The average readability score of the Student Worksheet (LKPD) reached 4.60 (very good category), with 90% of students responding positively to the cultural illustrations. The average learning implementation percentage was 94.5%, categorized as very good, indicating that the tools are easy for teachers to apply and for students to understand.
2. Effectiveness of the Learning Tools

The results of the mathematical representation ability test showed a significant increase from a pre-test average of 56.20 to a post-test average of 83.87, with a gain score of 0.63 (medium-high category). This increase proves that the developed learning tools are effective in improving students' mathematical representation abilities, particularly in visual, verbal, and symbolic aspects.

3. Research Contribution

   This research makes a tangible contribution to the development of culturally based mathematics learning tools. The integration of ethnomathematics makes learning more contextual and meaningful, while simultaneously strengthening students' cultural identity. Moreover, the combination with the Problem-Solving approach fosters critical, collaborative, and creative thinking skills that align with 21st-century educational demands.

Suggestions

1. For Teachers

   The Problem Solving and Ethnomathematics-based learning tools can serve as an alternative strategy for teaching mathematics in elementary schools. Teachers are advised to adapt the cultural contexts within the tools to match their local environment, making learning more relatable to students' daily lives.

2. For Schools

   Schools should encourage the use of culture-based learning tools as part of curriculum innovation. Integrating local wisdom into mathematics learning not only enhances academic achievement but also nurtures students' appreciation and respect for national cultural heritage.

3. For Future Researchers

   This study was limited to one school with a relatively small number of participants and a short implementation period. Therefore, further studies are recommended to include a wider scope, involving multiple schools and diverse cultural backgrounds, as well as a longer time frame to measure the long-term impact on students' mathematical representation abilities.

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