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Developing Ethnomathematics-Based Outdoor PBL Materials for Mathematical Problem Solving

Amidi*, Zaenuri, & Scolastika Mariani
Department of Mathematics Education, Universitas Negeri Semarang, Indonesia

*Corresponding email: amidi@mail.unnes.ac.id

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Abstract: This study was motivated by the limited use of mathematics teaching materials that facilitate students' mathematical problem-solving abilities through contextual learning experiences. As a result, students often have difficulty understanding concepts and solving mathematical problems systematically. This research aimed to develop comparative and scale teaching materials with ethnomathematical nuance, integrated with Problem-Based Learning (PBL) and outdoor learning strategies; to determine the feasibility and readability of the developed materials; and to describe students' mathematical problem-solving abilities after the implementation of the teaching materials. This study employed a Research and Development (R&D) method using the 4D development model, which consisted of define, design, and develop stages. The research subjects were 30 seventh-grade students (N = 30) at one of the junior high schools in Semarang Regency. Data were collected through expert validation sheets, readability questionnaires, mathematical problem-solving tests, and documentation. The feasibility test involved two mathematics education lecturers and two junior high school mathematics teachers. The findings showed that the developed teaching materials were deemed feasible based on expert validation results across content, presentation, and language. The readability test also indicated that the teaching materials were easy for students to understand. Furthermore, the pretest and posttest analysis showed an improvement in students' mathematical problem-solving abilities, with an N-gain score of 0.66, placing it in the medium category. Most students' posttest scores were higher than their pretest scores after learning using the developed teaching materials. Therefore, the developed teaching materials demonstrated validity and practicality and showed potential to support improvements in students' mathematical problem-solving abilities through contextual ethnomathematics-based learning activities.

Keywords: mathematics problem-solving, ethnomathematics, outdoor learning, PBL.

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INTRODUCTION

Recent international assessments indicate that Indonesian students still have difficulty solving contextual mathematical problems. The Programme for International Student Assessment (PISA) 2018 ranked Indonesia 72nd out of 78 participating countries in mathematics, with a score of 379, which was still below the OECD average of 489 (OECD, 2019). Similarly, the Trends in International Mathematics and Science Study (TIMSS) 2015 reported that Indonesian students scored 397 in mathematics, far below the international average of 500 (Mullis et al., 2016). Mathematical literacy involves the ability to formulate, employ, and interpret mathematics in various real-world contexts (OECD, 2019). Therefore, students' difficulties in solving contextual and non-routine problems indicate that their mathematical literacy skills still need improvement. Previous studies have also reported that junior high school students' mathematical problem-solving abilities remain weak, especially among SMP/MTs students (Tong et al., 2023). Suraji et al. (2018) found that the mathematical problem-solving abilities of class VIII students at SMP IT Dar Al-Ma'arif on the topic of System of Linear Equations in Two Variables (SPLDV) were categorized as low based on problem-solving indicators. Preliminary observations and interviews with mathematics teachers also revealed that students often have difficulty understanding contextual problems, constructing mathematical models, and applying mathematical concepts to real-life situations. These findings indicate the need for learning approaches and teaching materials that help students connect mathematical concepts to meaningful real-world contexts.

Mathematics is an important discipline taught at every level of education because it is closely related to logical thinking, reasoning, and problem-solving abilities. Mathematics consists of interconnected concepts and processes that enable students to build meaningful relationships among mathematical ideas and their applications in various contexts (National Council of Teachers of Mathematics, 2000). Strong mathematical mastery can help students solve personal, social, scientific, and workplace problems in daily life (OECD, 2019). Therefore, mathematical problem-solving ability is considered an important competency that students must master to improve their understanding of mathematics (Sugiharti et al., 2026; Tong et al., 2023). Problem-solving also serves as the basis for measuring students' thinking abilities and their capacity to develop new strategies in solving mathematical problems (Amalina & Vidákovich, 2023; Mangilala & Cajandig, 2025).

However, mathematics learning in schools is still often dominated by conventional classroom activities that emphasize procedural understanding rather than contextual problem-solving. Students tend to feel bored and have limited opportunities to directly explore mathematical problems related to their daily experiences. Panhuizen's research suggested that students easily forget mathematical concepts and have difficulty applying them when mathematics learning is separated from their real-life experiences (Van den Heuvel-Panhuizen & Drijvers, 2020). One learning strategy that can provide direct learning experiences is outdoor learning (Waite, 2020). Outdoor learning connects theoretical concepts with real situations and objects encountered in the environment, allowing students to gain deeper learning experiences (Becker et al., 2017). In mathematics learning, contextual experiences help students connect abstract mathematical concepts with real-life situations and support conceptual understanding (Van den Heuvel-Panhuizen & Drijvers, 2020).

In addition to learning strategies, teaching materials also play an important role in supporting effective mathematics learning. Teaching materials are essential learning resources that help students understand concepts and assist teachers in implementing meaningful learning (Fan et al., 2013). Teaching materials can support students, especially those with limited prior learning experience related to the material being studied (Alp Christ et al., 2022). Furthermore, contextual teaching materials can help students connect mathematical concepts to real-life situations, thereby supporting conceptual understanding and motivation to learn (Pepin et al., 2013). However, currently available teaching materials in schools still tend to emphasize procedural exercises and rarely integrate contextual problems related to students' environments and experiences (Stefanutti et al., 2021). As a result, students have difficulty applying mathematical concepts to solve real-world problems.

Another important aspect that needs to be integrated into mathematics learning is culture (Harding-DeKam, 2014; Khairunnisa et al., 2025). In the era of globalization, preserving local cultural values has become an important concern in many societies. One effort to preserve cultural values is by integrating culture into the learning process (Sakti et al., 2024). Through culturally responsive learning, students can connect academic content with their cultural backgrounds and everyday experiences (Gay, 2018; Shih, 2024). Mathematics and culture can be connected through ethnomathematics, which emphasizes the relationship between mathematical ideas and cultural practices (Cimen, 2014; D'Ambrosio, 1999). According to D'Ambrosio (1999), ethnomathematics refers to mathematical practices that emerge from the cultural activities and experiences of specific social groups. The implementation of ethnomathematics in mathematics learning can help students understand mathematical concepts more easily because the learning materials are closely related to their social and cultural environments (Andang et al., 2025; Batiibwe, 2024; Gembong et al., 2023; Nuryadi et al., 2023). Therefore, ethnomathematics not only supports conceptual understanding but also helps preserve local cultural values.

Furthermore, the learning model implemented by teachers also influences students' mathematical problem-solving abilities. Conventional learning models are generally teacher-centered, causing students to become passive recipients of information (Nicholus et al., 2023). Consequently, students have limited opportunities to investigate, analyze, and solve problems independently. One learning model considered suitable for improving mathematical problem-solving ability is Problem-Based Learning (PBL). PBL is consistent with the student-centered orientation of the 2013 curriculum because it actively engages students in solving contextual problems through scientific inquiry processes. Problem-Based Learning (PBL) encourages students to actively engage in solving contextual problems and construct knowledge through meaningful learning experiences (Hmelo-Silver, 2004). Through this process, students are expected to develop their mathematical competencies and problem-solving abilities.

The integration of ethnomathematics, outdoor learning, and Problem-Based Learning (PBL) is theoretically expected to improve students' mathematical problem-solving abilities more effectively than conventional approaches. Ethnomathematics provides culturally relevant, contextualized mathematical situations familiar to students' daily lives, making mathematical concepts more meaningful and easier to understand (D'Ambrosio, 1999). Outdoor learning facilitates authentic learning experiences by allowing students to interact directly with real objects and environments (Asmara et al., 2018). Meanwhile, PBL guides students to investigate, analyze, and solve contextual problems collaboratively through student-centered learning activities (Hmelo-Silver, 2004). The combination of these three approaches creates a coherent learning framework in which ethnomathematics provides meaningful cultural contexts, outdoor learning provides authentic experiences, and PBL develops systematic problem-solving processes. Through this integration, students are expected not only to understand mathematical concepts theoretically but also to apply them meaningfully in real-life situations.

Based on this rationale, this study aims to develop comparative and scale teaching materials that integrate ethnomathematics nuances into the PBL model and outdoor learning strategy to improve students' mathematical problem-solving abilities. The research questions of this research are 1) how are comparative and scale teaching materials with ethnomathematics nuance integrated into the PBL model and outdoor learning strategy developed, 2) what is the feasibility level of the developed teaching materials, 3) what is the readability level of the developed teaching materials, and 4) how is the improvement of students' mathematical problem-solving abilities before and after the implementation of the developed teaching materials.

METHOD

This study employed the Research and Development (R&D) method using the 4D development model proposed by Thiagarajan et al. (1974), which consists of Define, Design, Develop, and Disseminate stages. However, this study was limited to the Develop stage due to time and cost constraints and limited research facilities.

Research Design

To determine the effectiveness of the developed teaching materials, this study used a One-Group Pretest–Posttest Design. In this design, students were given a pretest before the implementation of the teaching materials and a posttest after the learning process to measure the improvement in their mathematical problem-solving abilities.

Research Procedure

The research procedures in this study followed the 4D development model, which consists of the Define, Design, and Develop stages. In the Define stage, the researchers identified and analyzed fundamental problems in mathematics learning, particularly related to students' difficulties in solving mathematical problems. This stage included front-end analysis, student analysis, concept analysis, and task analysis, as well as the formulation of learning objectives on comparative and scale materials.

In the Design stage, the initial draft of the teaching materials was developed. This stage involved preparing mathematical problem-solving test instruments, selecting appropriate learning media, determining the format of the teaching materials, and designing the product by integrating ethnomathematics, the Problem-Based Learning (PBL) model, and outdoor learning strategies.

Furthermore, during the Develop stage, the teaching materials were evaluated and refined to produce a feasible, practical product. This process included expert validation conducted by lecturers and mathematics teachers, as well as readability testing involving students to assess the practicality of the materials. Revisions were made based on suggestions and feedback from validators and students to produce the final product. Afterward, a limited trial was conducted using a one-group pretest–posttest design to measure the effectiveness of the teaching materials in improving students' mathematical problem-solving abilities.

Research Subject

The subjects of this study comprised 30 seventh-grade students from a public junior high school in Semarang Regency, Indonesia, who participated in the implementation of the developed teaching materials. For instrument validation, 30 eighth-grade students from the same school participated in the readability test and instrument try-out because they had previously studied the comparison and scale material. This procedure was conducted to examine the validity, reliability, discriminating power, and difficulty level of the test items before implementation in the research class. The developed instruments were designed based on seventh-grade curriculum competencies and further validated by expert validators to ensure content suitability for seventh-grade students.

Data Collection

The data collection techniques in this study were questionnaires and tests. Questionnaires were used to collect data on the feasibility and the readability level of teaching materials. The test technique was used to collect data on the experimental class's ability to solve mathematical problems. The test was conducted twice: pretest and posttest, with descriptive questions.

The feasibility questionnaire was used to assess the appropriateness of the developed teaching materials and was adapted from teaching material assessment standards. The questionnaire covered three main aspects: content feasibility, presentation feasibility, and language appropriateness. The content feasibility aspect included the suitability of the material for basic competencies, learning indicators, and learning objectives; the accuracy of the material; the availability of supporting learning materials; and the up-to-dateness of the material. The presentation feasibility aspect included presentation techniques, presentation support, learning presentation, and completeness of presentation. Meanwhile, the language aspect assessed clarity, communicativeness, interactivity, suitability with students' developmental levels, coherence of ideas, and the use of terms, symbols, and icons. The feasibility assessment was conducted by four validators, including lecturers and mathematics teachers.

The readability questionnaire was administered to students to determine whether the developed teaching materials were easy to understand and use. The questionnaire included indicators related to language clarity, vocabulary and sentence readability, typography, spacing, writing accuracy, graphical appeal, presentation suitability, writing style, information density, use of standard Indonesian grammar, and systematic presentation of the material. These indicators were intended to evaluate students' ease of reading, understanding, and use of the developed teaching materials.

The mathematical problem-solving ability test consisted of essay questions developed based on Pólya's mathematical problem-solving framework. The indicators measured in this study included: (A) identifying known, asked, and sufficient elements in the problem; (B) determining appropriate approaches and methods for problem-solving; (C) applying problem-solving strategies; and (D) interpreting the obtained results. These indicators were used to assess students' abilities to understand problems, plan solutions, implement strategies, and interpret mathematical results in contextual situations. One example item required students to solve comparative and scale problems related to local cultural contexts integrated into ethnomathematics activities.

One example of the mathematical problem-solving test item used in this study involved the Dugderan tradition in Semarang Regency. Students were asked to determine the additional number of workers needed to complete the construction of the *Warak Ngendog* icon within a limited time using the concept of inverse proportion. Through this contextual ethnomathematics problem, students were expected to identify known and asked information, determine appropriate strategies for solving the problem, perform calculations systematically, and interpret the results in accordance with Pólya's problem-solving stages.

Prior to implementation, the mathematical problem-solving test items were analyzed for validity, reliability, discriminative power, and difficulty level. Consistent with educational measurement principles, the instrument try-out was conducted using students who had previously studied the tested content to obtain accurate estimates of item quality (Nitko & Brookhart, 2014). Item validity was examined using correlation analysis and interpreted based on validity coefficient criteria ranging from very low to very high. Meanwhile, instrument reliability was analyzed to assess the test's consistency in measuring students' mathematical problem-solving abilities, with reliability levels categorized from very low to very high. Only valid and reliable items were used in the implementation stage of the study.

Data Analysis

The data analysis used is the feasibility test, readability test, and effectiveness test. A feasibility test was conducted to assess the developed teaching materials. This analysis is calculated using the feasibility percentage according to the following formula (Sudjana, 2014).

$$P = \frac{f}{S_{max}} \times 100\%$$

Description
p : score percentage
f : total score obtained
S_{max} : maximum score

According to Niam & Asikin (2020), the criteria for the feasibility level of the teaching materials used are shown in Table 1 below.

Table 1. Criteria for the feasibility of teaching materials

Feasibility Level	Feasibility Criteria
$1\% < P \leq 50\%$	Not feasible
$50\% < P \leq 70\%$	Feasible enough
$70\% < P \leq 85\%$	Feasible
$85\% < P \leq 100\%$	Very feasible

The readability analysis was conducted to determine whether the developed teaching materials were easy for students to understand. The readability questionnaire employed a dichotomous response format consisting of "Agree" (1) and "Disagree" (0) responses. Therefore, the readability data were analyzed using Cochran's Q test. The test criteria were that if $Q_{count} \leq X^2{}_{critical}$ then H_0 was accepted and the formula is as follows (Dewi & Arini, 2018).

$$Q = \frac{(k-1)[k\sum_{j=1}^{k} C_j{}^2 - (\sum_{j=1}^{k} C_j)^2]}{k\sum_{i=1}^{N} R_i - \sum_{i=1}^{N} R_i{}^2}$$

Description
k : number of treatments
$\sum_{i=1}^{N} R_i$: total number of 1 in row i
$\sum_{i=1}^{N} R_i{}^2$: square of the total number of 1 in row i
$\sum_{i=1}^{N} C_j$: total number of 1 in row j
$\sum_{i=1}^{N} C_j{}^2$: square of the total number of 1 in row

The effectiveness of the teaching materials was assessed using a problem-solving ability test to determine the validity of the questions, including tests of validity, reliability, item discrimination power, and item difficulty level. Then, the data analysis regarding the results of mathematical problem-solving abilities in the pretest and posttest was carried out by (1) prerequisite test, (2) individual and classical learning mastery test, (3) paired t-test to determine differences between pretest and posttest mean scores, and (4) N-Gain test to measure the improvement in students' mathematical problem-solving abilities.

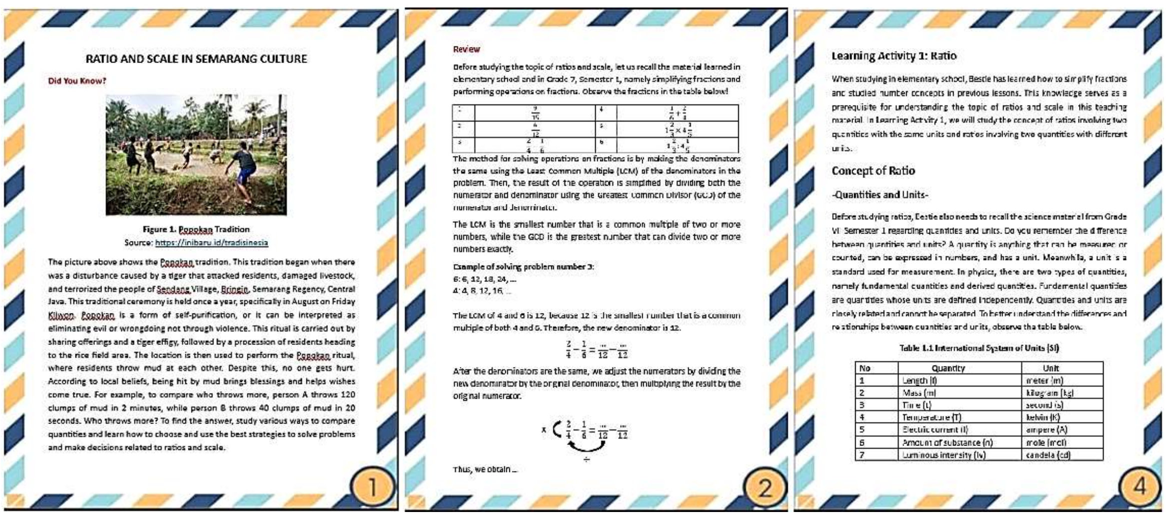
RESULT AND DISCUSSION

Characteristics of the Developed Teaching Materials

The developed teaching materials were designed using the 4D development model (Define, Design, and Develop stages) and integrated ethnomathematics contexts, Problem-Based Learning (PBL), and outdoor learning approaches on comparative and scale topics. The materials were systematically developed based on the 2013 Curriculum, including Core Competencies, Basic Competencies, learning objectives, and indicators of mathematical problem-solving ability.

The teaching materials consisted of three main sections: the introduction, content, and closing. The introductory section included cover pages, a foreword, a table of contents, descriptions and instructions for using the teaching materials, an overview of the PBL model, Core Competencies, Basic Competencies, learning objectives, concept maps, and motivational letters. The content section consisted of four learning activities that presented contextual ethnomathematical problems related to Semarang's local culture, including traditional games, culinary contexts, tourism, and local wisdom. Each activity was designed using PBL steps to guide students in identifying problems, determining solution strategies, solving problems systematically, and reflecting on their answers. In addition, students were provided with reminders of prerequisite material and exploration activities to support conceptual understanding. The closing section included summaries, competency tests, reflection activities, glossaries, references, and author profiles.

The developed teaching materials were also designed with visual illustrations and contextual images to increase students' motivation to learn and help them understand mathematical concepts more concretely. The layout and visual appearance of the materials were designed using Canva and compiled into digital teaching materials in PDF format. Examples of the content are shown in Figure 1.



RATIO AND SCALE IN SEMARANG CULTURE

Did You Know?

Figure 1. Popokan Tradition
Source: https://inibaru.id/tradisinesia

The picture above shows the Popokan tradition. This tradition began when there was a disturbance caused by a tiger that attacked residents, damaged livestock, and terrorized the people of Sendang Village, Bringin, Semarang Regency, Central Java. This traditional ceremony is held once a year, specifically in August on Friday Kliwon. Popokan is a form of self-purification, or it can be interpreted as eliminating evil or wrongdoing not through violence. This ritual is carried out by sharing offerings and a tiger effigy, followed by a procession of residents heading to the rice field area. The location is then used to perform the Popokan ritual, where residents throw mud at each other. Despite this, no one gets hurt. According to local beliefs, being hit by mud brings blessings and helps wishes come true. For example, to compare who throws more, person A throws 120 clumps of mud in 2 minutes, while person B throws 40 clumps of mud in 20 seconds. Who throws more? To find the answer, study various ways to compare quantities and learn how to choose and use the best strategies to solve problems and make decisions related to ratios and scale.

1

Review

Before studying the topic of ratios and scale, let us recall the material learned in elementary school and in Grade 7, Semester 1, namely simplifying fractions and performing operations on fractions. Observe the fractions in the table below!

1	$\frac{9}{15}$	4	[illegible]
2	$\frac{6}{12}$	5	$1\frac{2}{3} \times 4\frac{1}{5}$
3	$\frac{3}{4} - \frac{1}{6}$	6	$1\frac{2}{3} : 4\frac{1}{5}$

The method for solving operations on fractions is by making the denominators the same using the Least Common Multiple (LCM) of the denominators in the problem. Then, the result of the operation is simplified by dividing both the numerator and denominator using the Greatest Common Divisor (GCD) of the numerator and denominator.

The LCM is the smallest number that is a common multiple of two or more numbers, while the GCD is the greatest number that can divide two or more numbers exactly.

Example of solving problem number 3:
6: 6, 12, 18, 24, ...
4: 4, 8, 12, 16, ...

The LCM of 4 and 6 is 12, because 12 is the smallest number that is a common multiple of both 4 and 6. Therefore, the new denominator is 12.

$$\frac{3}{4} - \frac{1}{6} = \frac{...}{12} - \frac{...}{12}$$

After the denominators are the same, we adjust the numerators by dividing the new denominator by the original denominator, then multiplying the result by the original numerator.

$$\times \; \frac{3}{4} - \frac{1}{6} = \frac{...}{12} - \frac{...}{12} \; \div$$

Thus, we obtain ...

2

Learning Activity 1: Ratio

When studying in elementary school, Bestie has learned how to simplify fractions and studied number concepts in previous lessons. This knowledge serves as a prerequisite for understanding the topic of ratios and scale in this teaching material. In Learning Activity 1, we will study the concept of ratios involving two quantities with the same units and ratios involving two quantities with different units.

Concept of Ratio

-Quantities and Units-

Before studying ratios, Bestie also needs to recall the science material from Grade VI Semester 1 regarding quantities and units. Do you remember the difference between quantities and units? A quantity is anything that can be measured or counted, can be expressed in numbers, and has a unit. Meanwhile, a unit is a standard used for measurement. In physics, there are two types of quantities, namely fundamental quantities and derived quantities. Fundamental quantities are quantities whose units are defined independently. Quantities and units are closely related and cannot be separated. To better understand the differences and relationships between quantities and units, observe the table below.

Table 1.1 International System of Units (SI)

No	Quantity	Unit
1	Length (l)	meter (m)
2	Mass (m)	kilogram (kg)
3	Time (t)	second (s)
4	Temperature (T)	kelvin (K)
5	Electric current (I)	ampere (A)
6	Amount of substance (n)	mole (mol)
7	Luminous intensity (Iv)	candela (cd)

4

Figure 1. Example of the developed teaching material content

Figure 1 presents an example of the developed teaching material content integrating ethnomathematics contexts into comparative and scale learning activities. The materials were designed using Problem-Based Learning (PBL) steps and contextual problems to support students' mathematical problem-solving abilities. Overall, the developed teaching materials were designed to provide structured learning experiences that connect mathematical concepts with real-life and cultural contexts, enabling students to actively construct their mathematical understanding.

Feasibility and Readability of Teaching Materials

The feasibility of the teaching materials was evaluated by four expert validators, comprising two university lecturers and two junior high school mathematics teachers. The evaluation was conducted three aspects: content feasibility, presentation feasibility, and language feasibility. Based on supervisor's suggestions, the researcher validated the teaching materials with four expert validators, comprising two mathematics lecturers and two junior high school mathematics teachers, and the results are presented in Table 2.

Table 2. Feasibility test of teaching materials by validator result

No.	Validator	Institution	N(%)	Criteria
1	Validator I	UNNES Mathematics Lecturer	88.93	Very Feasible
2	Validator II	UNNES Mathematics Lecturer	82.69	Feasible
3	Validator III	Mathematics teacher at one of the JHS in Semarang Regency	91.31	Very Feasible
4	Validator IV	Mathematics teacher at one of the JHS in Semarang Regency	87.47	Very Feasible

Based on Table 2, the results indicate that the four expert validators categorized comparisons and scales of teaching materials with ethnomathematical nuance as feasible to use in mathematics learning. It can also be seen from the results of the feasibility test of teaching materials in each aspect. The results of the feasibility test of teaching materials in each aspect are presented in Table 3 below.

Based on Table 3, the results of the feasibility test of teaching materials in each aspect are very feasible. The highest feasibility score was obtained across all content feasibility aspects, indicating that the developed materials were relevant to learning objectives, mathematical concepts, and contextual ethnomathematical integration, so that the comparative and scales teaching materials with ethnomathematical nuance are suitable for use in mathematics learning.

Table 3. The results of the feasibility test of teaching materials in each aspect

Aspects Observed	N(%)	Criteria
Content Feasibility	88.25	Very Feasible
Presentation Feasibility	87.05	Very Feasible
Language Feasibility	87.50	Very Feasible

The practicality test was conducted by administering a readability questionnaire to 30 students of class VIII G. The readability questionnaire employed a dichotomous response format consisting of "AgrSee" (1) and "Disagree" (0) responses. The analysis using Cochran's Q test showed that $Q_{count} = 14.318$, which was lower than the Chi-Square critical value at a ($\chi^2_{0.05;9} = 16.92$) significance level of 0.05 with 9 degrees of freedom. The test also produced a p-value of 0.114, which was greater than 0.05. Therefore, H_0 was accepted, indicating that there were no significant differences in students' responses regarding their understanding of the comparative and scale teaching materials with ethnomathematics nuance. This result indicates that the developed teaching materials were practically understandable by students. The results of the readability test administered to the thirty students are presented in Table 4.

Table 4. The readability test of teaching materials results

Item Number	Results
1	96.67%
2	93.33%

3	100%
4	86.67%
5	100%
6	96.67%
7	100%
8	96.67%
9	96.67%
10	100%
Cochran's Q Test	Q = 14.318; p = 0.114

Based on Table 4, the average percentage of students' agreement across the ten readability indicators reached 96.67%. Furthermore, Cochran's Q test result $(Q = 14.318; p = 0.114)$ indicates that students showed consistent responses across all readability indicators. These findings suggest that the developed teaching materials were easy for students to understand and practically usable.

Effectiveness Test Result

Before the implementation stage, the teaching materials were revised based on suggestions from supervisors, expert validators, and students' responses to the readability test. The revised product was then implemented in mathematics learning to examine students' mathematical problem-solving abilities. The effectiveness test consisted of four stages: the preparation stage, the pretest stage, the learning implementation stage, and the posttest stage.

Preparation stage

At this stage, it is done by giving test questions to students who had obtained comparative and scale material in class VIII G. The results of the analysis of the test questions are presented in Table 5 below.

Table 5. Results of testing questions analysis

No	Validity	Reliability	Difficulty Level	Distinguishing Power	Decision
1	Valid	0.589 (Mid)	Easy	Fair	Retained
2	Valid		Moderate	Poor	Revised and Retained
3	Valid		Easy	Fair	Retained
4	Valid		Moderate	Poor	Revised and Retained
5	Valid		Moderate	Fair	Retained
6	Valid		Moderate	Fair	Retained

Based on the validity, reliability, difficulty level, and discrimination power analyses presented in Table 5, all items met the validity criteria and served as indicators of mathematical problem-solving ability. The instrument's reliability coefficient was categorized as moderate (0.589), indicating acceptable internal consistency for classroom-based research, although measurement error remained possible. Therefore, the results obtained in this study should be interpreted cautiously. Additional analysis using Cronbach's Alpha if Item Deleted showed that removing Item 2 reduced the reliability coefficient from 0.589 to 0.516, while removing Item 4 reduced it to 0.557. Furthermore, the simultaneous removal of Items 2 and 4 resulted in a further decrease in the reliability coefficient to 0.453. These findings indicate that deleting

Items 2 and 4 did not improve the instrument's internal consistency. Therefore, these items were revised for clarity of wording before the implementation stage and retained because they continued to contribute to the instrument's overall consistency and represented essential indicators of mathematical problem-solving ability.

Pretest result

At the first meeting, students were given a pretest consisting of six essay questions on comparative and scale materials. Pretest questions are questions that have been tested before. The pretest questions used contain indicators of mathematical problem-solving ability.

Learning stages

At the second meeting, students studied the sub-material of the concept of comparative and scale ratios. Furthermore, in the third meeting, the students studied the sub-material on inverse proportion and scales. One day before class time, the researcher provided soft files of teaching materials and student worksheets through the WhatsApp Group for students to study. This research was conducted using ethnomathematics in outdoor learning. The ethnomathematics used in this research involves playing traditional group games outside the classroom. Through real learning outside the classroom in groups, able to train their abilities in collecting and writing information that is in accordance with what is experienced, and increase the sense of cooperation among students in a group. During exploration activities outside the classroom, the researcher encourages students to ask questions when they encounter difficulties. In learning, students actively discuss problems with their groups on the student worksheets. After discussing, students enter the class to present the results of their discussion. Other students respond and ask questions of students presenting in front of the class. Researchers encourage students to express their opinions by asking questions about the answers of students who are less precise in solving problems. Then, at the end of the lesson, the researcher explains and corrects the answers based on students' submissions and guides students in concluding the material studied. Researchers also motivate students to maintain the spirit of learning during COVID-19 pandemic.

Posttest result

At the fourth meeting, the researcher administered a posttest to class VII G students consisting of six essay questions on comparative and scale material. The posttest questions assess mathematical problem-solving abilities and are of the same type as those previously tested. The pretest and posttest results were used to assess the increase in students' mathematical problem-solving abilities.

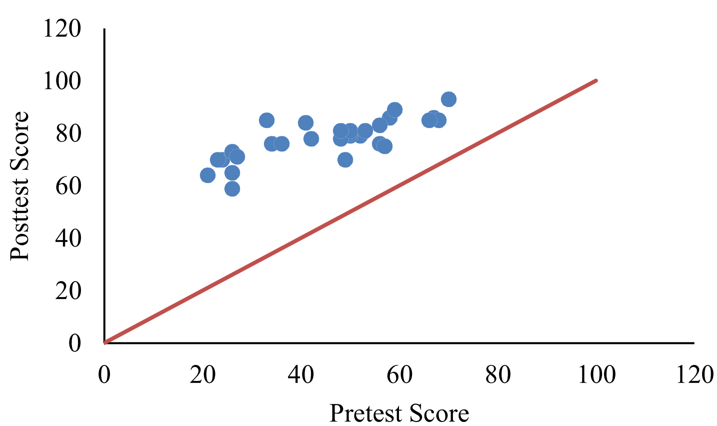


Figure 1. Scatter plot of pretest and posttest scores

Figure 1 presents the scatter plot of students' pretest and posttest scores. Most data points are above the diagonal, indicating that the majority of students obtained higher posttest scores than pretest scores. This finding suggests that students improved their mathematical problem-solving ability after using the developed teaching materials.

Pre-Requisite Test Results

In this study, the prerequisite test conducted is the normality test, which is calculated using SPSS 25. The test used is the Kolmogorov-Smirnov test. The results of the normality test are presented in Table 6.

Table 6. Pretest and posttest normality test results

Test	Sig. Value
Pretest	0.076
Posttest	0.200

Based on Table 6, the significance value of the Kolmogorov-Smirnov test for the pretest is 0.076, greater than 0.05, and for the posttest is 0.200 > 0.05. Based on the test criteria, it is H_0 accepted. It can be concluded that the pre-test and post-test data are normally distributed.

Minor I hypothesis test results (learning completeness test)

The individual learning mastery test was used to determine whether the average posttest data for students' mathematical problem-solving abilities in the experimental class indicated individual learning mastery. The school-determined individual learning completeness is 70. The posttest results showed that students obtained a mean score of 77.70 with a standard deviation of 7.769. Based on the results of calculations using SPSS 25 software, obtained. $t_{count} = 5.429$ With = 5% = 0.05 and $df = 30 - 1 = 29$, obtained. $t_{table} = 1.69$ Because, $t_{count} = 5.429 > 1.69 = t_{table}$ it is H_0 rejected. Therefore, the average posttest score for students' mathematical problem-solving abilities has reached the Minimum Completeness Criteria of 70.

The classical learning mastery test was used to determine whether the percentage of posttest scores for students' mathematical problem-solving ability in the experimental class met classical mastery criteria. The completeness percentage set for mathematics is 75%. Based on the results of the calculation of the proportion test using SPSS 25, it is obtained $z_{\_count} = 1.96 \geq 1.64 = z_{\_table}$, it is H_0 rejected. So, the percentage of students who obtained posttest scores that met the classical learning completeness criterion was 90%.

Minor hypothesis test results II (paired T test)

This test aims to determine whether there is a difference between the average pretest and posttest scores of students' mathematical problem-solving abilities after the implementation of the developed teaching materials. Based on the calculations, obtained $t_{\_count} = 17.55$ with a standard error of the mean difference of 1.878, as well as $t_{1-\frac{1}{2}\alpha} = 2.034$ and $-t_{1-\frac{1}{2}\alpha} = -2.034$. Because, $t_{\_count} = 17.55$ which is not in the acceptance region of H_0 namely. $-2.034 < t < 2.034$ Then, H_0 was rejected. Therefore, there is a significant difference between the average scores of pre-test and post-test students' mathematical problem-solving abilities when applying comparative and scale teaching materials with ethnomathematical nuance.

Hypothesis III test results (N-Gain test results)

The N-gain test in this study was calculated as the average of the pretest and posttest scores. In the pretest stage, the average score was 44.63, and in the posttest stage, it was 77.70, as shown in Table 7.

Table 7. Recapitulation of N-Gain calculation test results

Pretest Score Average	Posttest Score Average	*N-Gain*	Criteria
44.63	77.70	0.66	Mid

Based on Table 7, the N-gain value is 0.66. This value indicates an increase of 0.66 in the average pre-test and post-test scores in the medium category. In addition, the N-gain test results for each indicator of mathematical problem-solving ability are presented in Table 8. The indicators of mathematical problem-solving ability presented in Table 8 were based on Pólya's mathematical problem-solving framework described in the method section.

Table 8. Recapitulation of calculation results of pretest, posttest, and n-gain test for each indicator of mathematical problem-solving ability

	Indicator A	Indicator B	Indicator C	Indicator D
Pretest	24.89	38.33	50.65	52.70
Posttest	75.00	73.33	79.83	79.17
N-Gain	0.67	0.57	0.59	0.56
Criteria	Mid	Mid	Mid	Mid

Based on Table 8, the N-gain test results for each problem-solving ability indicator (A to D) increased to the medium category. Indicators of the ability to identify elements that are known, asked, and skill-based describe students' ability to seek and find clear statements for each question. This teaching material contains learning activities that help students identify known or requested elements, as well as possible ones. Students try to find a clear statement of each question based on the illustrative examples provided, and they begin to get used to answering questions by first writing down what is known and what is asked. Indicators of ability to determine the appropriate approach and problem-solving method. This indicator was intended to help students determine formulas or other information that is not known in the questions, or use information already in the questions to develop new information or formulas to assist them in solving problems. This teaching material helps students analyze implied information in questions and compile new information before answering them. This teaching material provides an example of how to determine the implied information in the questions and to arrange new information properly and accurately. In addition, students can try to directly determine the implied information in the questions or compile new information from examples in the teaching materials. Learners are getting used to identifying implied information in questions and deriving new information from what is already known, which can help them solve problems.

The improvement in students' ability to implement problem-solving strategies may have been influenced by the structured problem-solving activities provided in the teaching materials. Students were guided to identify relevant information, determine appropriate strategies, and apply mathematical procedures systematically through contextual problems related to Semarang culture and daily life. The integration of ethnomathematics contexts and outdoor learning activities enabled students to experience mathematics in concrete situations, which may have helped them better understand abstract mathematical concepts. Furthermore, collaborative discussions during Problem-Based Learning (PBL) activities helped students exchange ideas and develop solution strategies together.

The improvement in students' ability to interpret problem-solving results may have occurred because the developed teaching materials provided structured activities that guided students to recheck their answers and verify the accuracy of each step in the solution. Through contextual ethnomathematical problems, students were encouraged to connect mathematical concepts with real-life situations, thereby supporting meaningful learning experiences. In addition, the PBL approach facilitated students' discussion, explanation, and justification of their answers during group activities. These learning activities may have helped students interpret and communicate their solution processes more effectively, consistent with constructivist learning theory, which emphasizes active knowledge construction through social interaction and meaningful learning experiences (Vygotsky, 1978).

Based on the findings, the developed teaching materials were categorized as valid and practical. They showed the potential to improve students' mathematical problem-solving abilities through Problem-Based Learning and outdoor learning activities. However, because this study employed a one-group pretest-posttest design without a control group, the findings should be interpreted cautiously. Nuryadi et al. (2023) reported that ethnomathematics-based teaching materials are valid, practical, and effective, helping students learn and understand mathematics and the culture of their environment. Learning experiences conducted in authentic environments can enhance students' engagement and support meaningful learning by connecting academic concepts with real-world situations (Rickinson et al., 2004). Similarly, Gembong et al. (2023) state that learning using ethnomathematics-based mathematics teaching materials makes students enthusiastic and motivated in learning; this is because, in addition to learning about Javanese culture, they are also trained to solve mathematical problems regarding the local wisdom of the surrounding community so that they are accustomed to solving problems with the right problem-solving path. They are required to find and build their own knowledge by conducting experiments using concrete objects. In addition, PBL encourages students to investigate problems, construct their own understanding, and develop systematic problem-solving skills through collaborative learning activities (Hmelo-Silver, 2004). These findings are supported by Asmara et al. (2018), who yielded an N-gain value of 0.50, indicating an increase in students' mathematical problem-solving ability in the moderate category through outdoor learning. They are required to discover and build their own knowledge by conducting experiments using concrete objects.

CONCLUSION

The conclusions of this research is the development process of comparative teaching materials with an ethnomathematics nuance on scale topics was carried out using a modified 4D model, limited to the develop stage. The resulting teaching materials, which integrate a Problem-Based Learning (PBL) model into outdoor learning settings, were found to be feasible, with an overall feasibility percentage of 87.6%. This feasibility was reflected in three aspects: content feasibility (88.25%), presentation feasibility (87.05%), and language feasibility (87.50%). Furthermore, the teaching materials were considered practical based on the results of a readability questionnaire administered to 30 students, with an average understanding score of 96.67% across 10 statements. In addition, the comparative teaching materials with an ethnomathematical scale approach in outdoor learning were proven effective in improving students' mathematical problem-solving skills.

This effectiveness was supported by the results of the individual and classical learning mastery tests, paired t-test, and N-gain test, which indicated a medium improvement category with an N-gain score of 0.66.

■ DECLARATION OF GENERATIVE AI USAGE IN THE WRITING PROCESS

During the preparation of this manuscript, the authors used generative AI tools to assist with language refinement, paraphrasing, readability improvement, and literature exploration. All research data, analyses, interpretations, and conclusions were produced solely by the authors. The authors reviewed and edited all AI-assisted outputs and take full responsibility for the content of the published article.

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