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Enhancing Students' Mathematical Literacy through Ethnomathematics-Integrated Problem-Based Learning: A Study on Learning Independence

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Abstract: Enhancing Students' Mathematical Literacy through Ethnomathematics-Integrated Problem-Based Learning: A Study on Learning. This study addresses the issue of low mathematical literacy among junior high school students, particularly in relation to their learning independence. **Objective:** This study aims to (1) examine the effectiveness of the Problem-Based Learning (PBL) model integrated with an ethnomathematics approach in improving students' mathematical literacy, (2) analyze the relationship between mathematical literacy and learning independence, and (3) analyze their literacy levels based on the degree of learning independence. This combination is important to investigate because it not only contextualizes mathematics within students' cultural practices but also strengthens their learning independence, both of which are essential for the sustainable improvement of mathematical literacy. **Method:** A mixed-methods approach was employed using a sequential explanatory design. Quantitative analysis was conducted through a true experimental design with a posttest-only control group, while qualitative analysis was based on test results and interviews with students. **Findings:** The findings indicate that students in the experimental class using the ethnomathematics-based PBL model achieved higher mathematical literacy compared to those in the control class, which only used a Discovery Learning (DL) model. Additionally, learning independence has a positive effect on mathematical literacy. Students with high learning independence showed better fulfillment of literacy indicators, while those with medium and low learning independence showed varied levels of achievement in mathematical literacy. **Conclusion:** This study concludes that (1) the ethnomathematics-based PBL model is effective in improving mathematical literacy, (2) there is a relationship between mathematical literacy and learning independence, and (3) students with high, medium, and low learning independence have varying mathematical literacy. These findings highlight the importance of implementing a culturally integrated PBL model to enhance both cognitive and affective learning outcomes, while also emphasizing learning independence as an internal factor in supporting mathematical literacy development.

Keywords: mathematical literacy, learning independence, PBL, ethnomathematics.

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INTRODUCTION

Mathematical literacy is one of the essential skills that students must have in facing the challenges of the 21st century (Murtiyasa & Perwita, 2020). According to the OECD (OECD, 2018), mathematical literacy is the ability to formulate, use, and interpret mathematics in various real-life contexts. This ability involves the use of facts, concepts, procedures, and mathematical reasoning to solve contextual problems. However, various studies and international evaluation results, such as the Programme for International Student Assessment (PISA), indicate that student literacy in Indonesia remains at a low level (Annisavitri et al., 2020; Fitrianawati et al., 2020; Rusdi et al., 2020).

Based on the results of PISA (OECD, 2023), it can be seen that from 2000 to 2022, Indonesia's score remained below the internatinal average of 500, with a ranking that was relatively low compared to other participating countries. In the last year of PISA implementatin, namely 2022, Indonesia scored 359 with a ranking of 68 out of 80 participating countries. This global trend is also reflected at the local level, where junior high school students in Indonesia generally demonstrate low mathematical literacy. For example, in one of the junior high schools in Semarang City, interviews with teachers during the preliminary study revealed that students had difficulty in understanding and interpreting mathematical literacy-based questions.

These findings suggest that the low level of mathematical literacy is influenced not only by external factors, such as curriculum or learning resources, but also by internal student factors. One of the key internal factors is learning independence (Lestari et al., 2024; Maimun & Bahtiar, 2023). Classroom observations revealed that many students continue to rely heavily on their peers during learning activities, indicating that their learning independence is not yet well-developed. This finding is consistent with previous studies emphasizing that learning independence plays a critical role in supporting mathematical literacy (Gabriel et al., 2020; Ha et al., 2023; Kappassova et al., 2025; Zhidkikh et al., 2023). Students who lack independence often depend on teachers or peers to complete assignments. In contrast, students with higher learning independence tend to be more proactive in seeking information, developing learning strategies, and exercising better self-control when facing academic challenges (Ismail et al., 2021; Maslihah et al., 2021).

To overcome this problem, innovation is needed in learning models that can improve mathematical literacy while encouraging students' learning independence (Maslihah et al., 2021). One relevant model is Problem-Based Learning (PBL) (Maslihah et al., 2021). PBL is a learning model based on real problems that prioritizes student activities in identifying, analyzing, and finding solutions to complex problems (Smith et al., 2022; Zakaria et al., 2019). PBL not only improves cognitive abilities but also develops social and affective skills such as cooperation, communication, and learning independence. The integration of ethnomathematics into PBL offers a more contextual and meaningful approach (Batiibwe, 2024; Wulandari et al., 2024; Xu & Ball, 2025). Ethnomathematics, a concept introduced by D'Ambrosio, connects matematical concepts with local culture, making learning more relatable to students' daily experiences (Batiibwe, 2024; Rosa & Orey, 2011).

In recent years, the integration of ethnomathematics into contextual learning models has gained increasing attention due to its potential to enhance students' mathematical understanding and engagement. Ethnomathematics connects mathematical ideas with cultural practices, allowing students to explore mathematics through familiar contexts and daily life experiences.

From the perspective of cognitive learning theory, particularly Cognitive Load Theory (Barbieri & Rodrigues, 2025), the use of familiar cultural contexts can reduce extraneous cognitive load. By minimizing the mental effort required to understand unfamiliar contexts, students can allocate more cognitive resources to essential learning processes. In other words, ethnomathe matics helps direct students' working memory to core mathematical ideas rather than peripheral or unfamiliar aspects of the problem.

This approach not only supports cognitive development but also nurtures affective aspects such as motivation and identity in learning (Batiibwe, 2024; Radišiæ et al., 2024). Previous research has shown that ethnomathematics-based learning improves students' involvement, understanding, and mathematics learning outcomes (Kyeremeh et al., 2025; Putri et al., 2024). Several studies have also demonstrated that combining ethnomathematics with active learning models, such as PBL, can significantly enhance mathematical literacy. A meta-analysis by Pratama & Yelken (2024) confirmed that ethnomathematics-based learning positively influences mathematical literacy across diverse student populations. Furthermore, Prihatiningtyas & Buyung (2023) found that students who learned mathematics through PBL embedded with cultural elements achieved a 61% literacy improvement, which is significantly higher than the 29% improvement seen in conventional models. These findings affirm the value of integrating cultural knowledge into mathematics education to develop students' abilities to interpret, analyze, and solve contextual problems more meaningfully.

Although many studies have examined the effectiveness of PBL and ethnomathematics separately, few have integrated both in a single comprehensive learning model. For example, a study by Atikasari et al. (2024) demonstrated that ethnomathematics-based PBL could enhance students' creative mathematical thinking abilities, while Nuraini et al. (2022) reported its potential to improve mathematical literacy in transformation geometry. Similarly, a recent meta-analysis by Pratama & Yelken (2024) confirmed the positive impact of ethnomathematics on mathematical literacy across various contexts.

Furthermore, no research has been found that systematically analyzes the relationship between the application of the ethnomathematics-based PBL model and internal aspects of students, such as learning independence, in relation to mathematical literacy. Therefore, this study is relevant and important to carry out, as it aims to fill this gap by offering an integrated approach that combines the PBL model, ethnomathematics nuances, and analysis based on the level of learning independence, thereby improving the mathematical literacy of junior high school students. Based on this description, the researcher aims to investigate the effectiveness of the ethnomathematics-based PBL model in enhancing students' mathematical literacy, explore the relationship between mathematical literacy and learning independence, and analyze mathematical literacy in relation to students' learning independence.

METHOD

Participants

The sample in this study was selected from the population of all ninth-grade students at a public junior high school in Semarang, consisting of six classes. Using a random sampling technique, two sample classes were selected: class IX E as the experimental class and class IX F as the control class, with each class comprising 32 students. The subjects of this study were determined using purposive sampling, consisting of two students from the experimental class for each category of learning independence: high, medium, and low.

Prior to the intervention, preliminary data in the form of students' daily test scores, which were collected before the research began, were analyzed to ensure the equivalence of the two sample classes. The analysis included a normality test, a homogeneity test, and an independent samples t-test to compare the means. The results indicated that both classes had normally distributed data, were homogeneous, and showed no significant difference in their average scores, suggesting that both classes had the same initial conditions.

Research Design and Procedures

This study employed a mixed-method approach using a sequential explanatory design, in which the quantitative method was conducted first, followed by the qualitative method (Sukestiyarno, 2021). The stages of mixed-method with sequential explanatory design can be seen in Figure 1.

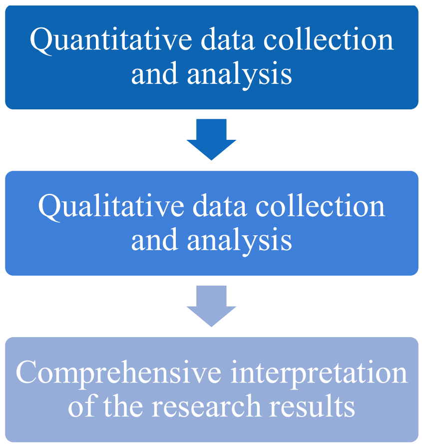


Figure 1. Stages of mixed-method with sequential explanatory

This approach was selected to ensure that the results of this research deliver not only statistical proof of the learning model's effectiveness but also a richer understanding of students' experiences and thought processes. The quantitative method employed a true experimental design, specifically a posttest-only control group design (Sugiyono, 2019). In this design, there were two groups: an experimental group and a control group. The experimental group was taught using the ethnomathematics-based Problem-Based Learning (PBL) model (X), whereas the control group received instruction through the Discovery Learning (DL) model (Y). After the treatment, both groups were given a posttest (O_1 and O_2) to determine whether the treatment influenced students' mathematical literacy. The quantitative method is also used to examine the relationship between mathematical literacy and learning independence.

Meanwhile, the qualitative method was employed to describe the mathematical literacy of students with varying levels of learning independence within the ethnomathematics-based PBL learning process.

This study was conducted at the junior high school level located in Semarang City, Indonesia. The procedure consisted of three main stages. First, in the preparation stage, researchers developed and validated instruments, determined research samples, and prepared lesson plans for both experimental and control groups. Second, during the implementation stage, the experimental group participated in PBL integrated with ethnomathematics, while the control group received instruction using the DL model. The intervention was conducted over four sessions, each lasting approximately 80 minutes, with the learning topic of transformational reflection for both classes. In the experimental class, each session followed the stages of an ethnomathematics-based PBL, as outlined in Table 1.

Table 1. Stages of PBL-ethnomathematics learning model

Stage	Activity
Orienting Students to the Problem	Students were introduced to a contextual problem related to cultural elements and asked to identify both known and unknown information within the problem.
Organizing Students for Learning	Students were assigned to small groups, provided with ethnomathematics-based worksheets, and encouraged to gather information from books, learning materials, or the internet to support problem-solving.
Guiding Individual and Group Investigation	The teacher facilitated students as they worked individually or in groups to investigate and solve the problem using the provided worksheets.
Developing and Presenting the Work	Students compiled their findings into a group product and presented it to the class. Other groups acted as the audience and were encouraged to ask questions or provide feedback.

Analyzing and Evaluating the Problem-Solving Process	Students and the teacher analyzed and reflected on the problem-solving process and the solutions presented. Students also provided feedback on the results of other groups.

Meanwhile, the control class followed the stages of the DL model, including stimulation, problem statement, data collection, data processing, verification, and generalization (Hardi et al., 2021). To provide a clearer overview, the detailed session-based topics for both classes are presented in the following diagram (Figure 2).

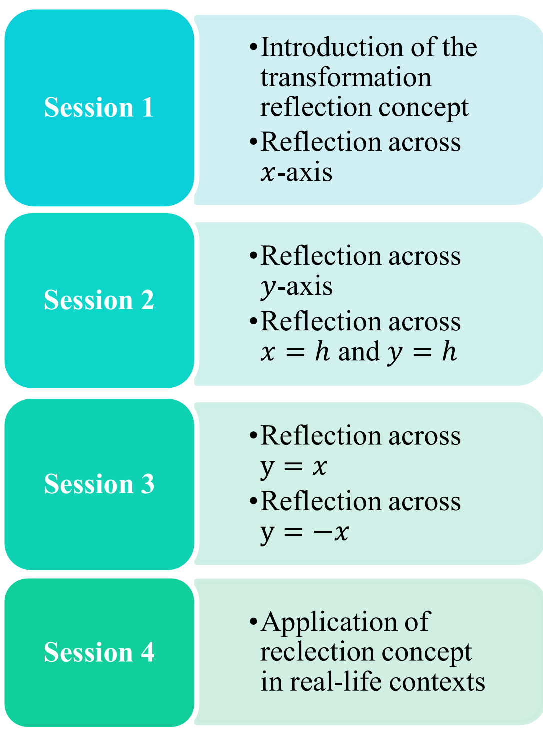


Figure 2. Learning topics for each session

After the lessons, a posttest was given to both groups. Third, in the follow-up stage, students in the experimental group completed a learning independence questionnaire, and selected students were interviewed to gain deeper insights into their mathematical literacy.

Research Instruments

Data were collected using three techniques: tests, questionnaires, and interviews. The test technique involved the use of written test instruments to gather data on the mathematical literacy levels of students in both classes after the treatment was administered. The test consisted of five essay-type questions developed based on the mathematical literacy indicators used in this study, namely: (1) communication; (2) using mathematical tools; and (3) evaluate. The test instruments underwent validity tests (with an average validity of 0.855), reliability tests (0.898), a discriminatory power analysis, and a difficulty level analysis.

The questionnaire served as a tool to gather data on the level of learning independence among students in the experimental class. The learning independence questionnaire used is an adaptation of previous research that has been tested for validity, reliability, and trials. The results obtained indicate that the Learning Independence Questionnaire is valid and suitable for use in research. The learning independence indicators used in this study were: (1) independence from others; (2) having self-confidence; (3) behaving in a disciplined manner; (4) having a sense of responsibility; (5) behaving on one's own initiative; and (6) being able to exercise self-control.

Interviews were conducted using an interview guideline sheet to gather more in-depth information about the mathematical literacy of students with high, medium, and low learning independence in the experimental class. To ensure the credibility of the data, the member checking technique was applied by presenting the interpreted interview results back to the participants for validation and confirmation.

Data Analysis Techniques

The posttest scores on mathematical literacy were analyzed both quantitatively and qualitatively. Quantitative analysis was conducted using: (1) mean completeness test, classical completeness tests, two-mean difference test, and N-gain test to examine the effectiveness of the ethnomathematics-based PBL model; (2) simple regression analysis to examine the relationship between students' mathematical literacy and learning independence. Qualitative analysis was conducted in three stages, as outlined by Sugiyono (2016) and Sukestiyarno (2021), namely data reduction, data display, and drawing conclusions.

To analyze students' mathematical literacy skills, a scoring rubric with a 0-3 scale was developed and applied to three indicators of mathematical literacy. The criteria for each score are presented in Table 2.

Table 2. Scoring rubric for mathematical literacy indicators

Score	Ability Level	Description
3	Able	The student's answer is complete, correct, and follows the appropriate procedures.
2	Quite able	The student provides a mostly correct answer with minor errors.
1	Less able	The student's answer shows several conceptual or procedural mistakes.
0	Not able	The student is unable to answer or gives an irrelevant answer.

This rubric was applied to quantify the qualitative findings from students' written work, ensuring consistent and objective analysis.

Integration of Ethnomathematics in the PBL Model

In this study, the ethnomathematics context used in the PBL model comes from Cetho Temple, a Hindu cultural heritage site located in Karanganyar Regency, Central Java. This temple features mathematical elements that are evident in its architectural structure, spatial layout, and symmetrical patterns, making it a valuable source for linking mathematical concepts, particularly the topic of reflection transformation, with local culture. The application of the Cetho Temple context to mathematical literacy questions is presented in Table 3.

Table 3. Application of cetho temple context to mathematical literacy questions

Question Number	Question
1	Cetho Temple is a historical relic located in Karanganyar Regency. The Cetho Temple features a gate, which is also an iconic symbol of the temple. The gate consists of two parts: the upper and lower parts. The lower surface of the gate forms a square. If the surface of Cetho Temple is represented by the coordinates of points $A(1.1)$, $B(4.1)$, $C(4.5)$, and $D(1,5)$ reflected across the line $y = -x$, then the shadows of points $A, B, C,$ and D are….
2	Cetho Temple is a relic of a past kingdom. It is located on the slopes of Mount Lawu, precisely in Cetho Hamlet, Gumung Village, Jenawi District, Karanganyar Regency, Central Java. Cetho Temple is one of the cultural heritage sites designated since March 26, 2007. Cetho Temple is a group of buildings with 11 terraced buildings that stretch from east to west. On the eighth terrace is a pavilion used for prayer. The roof of the pavilion forms a trapezoid. If the surface is presented in Cartesian coordinates with coordinate

	points $A(1.1)$, $B(5.1)$, $C(4.4)$, and $D(2,4)$, then the image of each coordinate point when reflected against $y = x$ is....
3	The Cetho Temple gate is one of the distinctive ornaments at the Cetho Temple tourist attraction. This gate itself consists of several levels. Each level displays its own splendor to visitors. If the bottom and top of the gate form the coordinates of the image points $A'(-2.3)$ and $B'(-2.10)$ after being reflected against $y = 2$, then they are reflected back against the line $y = -x$, then determine the ratio of the starting point of the gate and the resulting reflection to the line $y = -x$!
4	One of the ornaments that characterizes the Cetho Temple is the Surya Majapahit, which depicts the sun. If the initial coordinate of the Surya Majapahit's diameter is $K(-1,2)$ and the resulting $K'(a, b)$ is reflected over the x-axis, what is the multiplication result of a and b?
5	Look at the picture below!  The image is a statue of Prabu Banyuwangi at Cetho Temple. The statue of Prabu Banyuwangi is an object of worship or prayer for Hindus. If the main point of the statue of Prabu Banyuwangi is at a positive unit on the x-axis and b positive unit on the y-axis. Points a and b produce $(3.-4)$ after being reflected at $y = -x$. Then the image is reflected back on the x-axis which produces $(c.d)$. Determine the sum of a, b, c, and d!

RESULT AND DISCUSSION

Effectiveness of Ethnomathematics-Based PBL

The first stage of this research involved collecting quantitative data on the posttest results of students' mathematical literacy in the experimental class and the control class. The data were then analyzed using the t-statistic test for the mean completeness test and the two-sample difference test, as well as the z-statistic test for the classical completeness test. Based on the analysis of quantitative data, the results are presented in Table 4 below.

From the results of the three analyses, it is known that H_0 is rejected and H_1 is accepted. So it can be concluded that: (1) students'

Table 4. Statistical test of learning effectiveness

Statistical Test	Value of t_{table} or z_{table}	Value of t_{count} or z_{count}	H_1 accepted if	Result
Mean completeness test	$t_{table} = 1.69$	$t_{count} = 2.79$	$t_{table} < t_{count}$	
Classical completeness test	$z_{table} = 1.64$	$z_{count} = 1.77$	$z_{table} < z_{count}$	H_1 accepted
Two-mean difference test	$t_{table} = 1.69$	$t_{count} = 4.34$	$t_{table} < t_{count}$	

mathematical literacy in the ethnomathematics-based PBL class meets the minimum completion criteria (MCC); (2) students' mathematical literacy in the ethnomathematics-based PBL class achieves classical learning completion, with the proportion of students reaching completion being more than or equal to 70%; and (3) the average mathematical literacy score of students in the ethnomathematics-based PBL class is higher than that in the DL class. The results of the N-gain analysis showed that the experimental class achieved higher improvements in all mathematical literacy indicators than the control class. The greatest improvement occurred in the communication indicator, which was in the high category, followed by the using mathematics tools indicator and the evaluating indicator, which were in the medium category. Conversely, in the control class, the N-gain was in the medium category for communication, using math tools, and evaluating indicators. Overall, the average N-gain of the experimental class (65.3%) was better than that of the control class (47.3%). The average N-gain score for each mathematical literacy indicator is shown in Figure 3.

Based on the research results described, it was found that the ethnomathematics-based PBL model is effective in enhancing students' mathematical literacy. These results are supported by research by Maslihah et al. (2021), which states that the PBL model can improve mathematical literacy. This is because PBL provides opportunities for students to build their own knowledge through solving real-world problems, thereby improving critical thinking skills and essential application skills in mathematical literacy (Junianto & Wijaya, 2019).

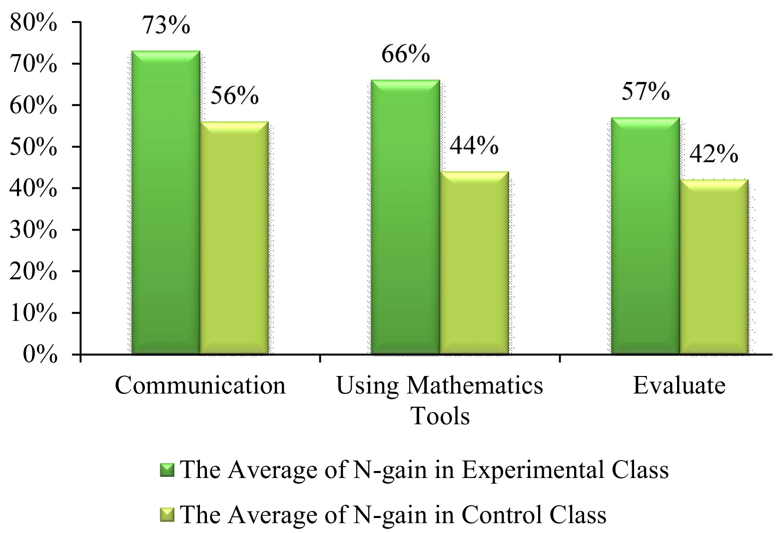


Figure 3. The average of N-gain score in each mathematical literacy indicator

The effectiveness of ethnomathematics-based PBL can be attributed to its specific mechanisms, which contextualize mathematical concepts within students' cultural backgrounds, making abstract ideas more relatable and meaningful. According to Buyung et al. (2020), integrating ethnomathematics into PBL allows students to engage with culturally relevant problems, encouraging them to apply mathematical reasoning in authentic contexts. Furthermore, the problem-solving process in PBL fosters inquiry, collaboration, and critical thinking, all of which are essential components of mathematical literacy (Boye & Agyei, 2023; OECD, 2023). This combination not only enhances conceptual understanding but also promotes students' learning independence and confidence in applying mathematics in real-life situations.

However, different from the previous ones who applied PBL in general, this study added an ethnomathematics approach that links learning with local culture. Similar results were found in research by Pratama & Yelken (2024), which revealed that ethnomathematics-based learning has a strong positive effect on mathematical literacy and is more effective than conventional learning. This is because ethnomathematics learning not only improves understanding of mathematical concepts but also increases learning motivation and makes it easier for students to understand mathematical material by linking the subject matter to their culture and daily life (Pratama & Yelken, 2024; Prihatiningtyas & Buyung, 2023).

The PBL model integrated with ethnomathematics has proven effective in improving mathematical literacy, as revealed by research by Prihatiningtyas & Buyung (2023), which showed a 61% increase in mathematical literacy in the experimental class compared to the control class, which was only 29%. This substantial difference suggests that embedding cultural contexts through ethnomathematics makes mathematical concepts more accessible and engaging for students, thereby facilitating deeper understanding. However, it is important to consider the role of teacher facilitation and students' prior familiarity with cultural contexts, which may influence the effectiveness of the model. Moreover, while the quantitative improvement is impressive, further qualitative research could explore how students internalize and transfer these skills beyond the classroom setting.

Compared to the study of Prihatiningtyas & Buyung (2023), which only emphasized a particular local culture, this study shows that the flexibility of implementing relevant cultural contexts still produces similar positive impacts. This shows that the success of ethnomathematics-based PBL does not only depend on the type of culture raised, but also on how students are given space to learn independently through contextual problem solving. Ethnomathematics-based PBL also plays a role in maximizing student activity and creativity in learning, as well as providing learning experiences that always be remembered by students (Perdana & Isrokatun, 2019).

Compared to the DL model implemented in control classes, DL tends to provide minimal guidance, which can lead to confusion and misconceptions, especially among students who lack a strong foundational knowledge (Setiawati et al., 2021). In contrast, ethnomathematics-PBL combines local cultural context with structured problem-solving, making learning more meaningful and relevant, and significantly improving students' critical thinking skills (Perdana & Isrokatun, 2019). By providing targeted guidance and a real-world context, ethnomathematics-PBL successfully overcomes the main weaknesses of DL and produces better mathematics learning outcomes.

Relationship between Mathematical Literacy and Learning Independence

The next stage of this research was to examine the relationship between students' mathematical literacy and learning independence. The data obtained from the posttest results and the learning independence score of the experimental class were further analyzed using simple linear regression. Prior to conducting the regression analysis, a series of classical assumption tests were performed to ensure the validity of the model.

Classical Assumption Test Results

Classical assumption tests include normality tests, linearity tests, and assisted heteroscedasticty tests. The results of the normality tests can be seen in Figure 4 below.

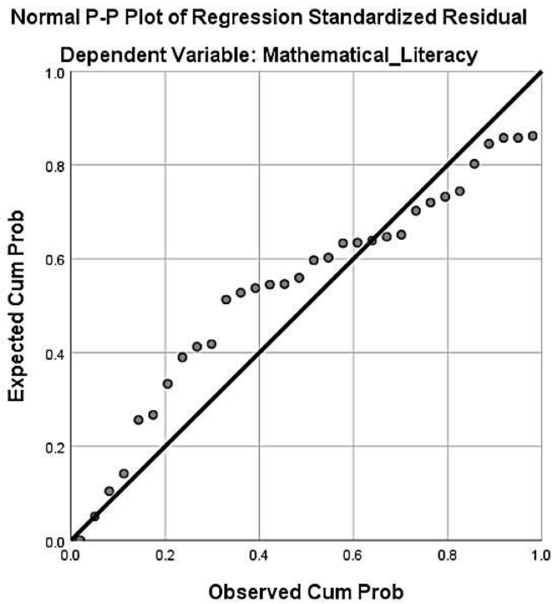


Figure 4. Result of normality test

The P-P Plot output shows that the plotting points always approach the normal line (diagonal line) of the P-P Plot of Regression Standardized Residual, so the residual values can be assumed to be normally distributed.

The linearity test output obtained a value of Sig. < 0.05, and the heteroscedasticity test output obtained a value of Sig. > 0.05. It can be concluded that there is a relationship between mathematical literacy and learning independence, and there are no symptoms of heteroscedasticity, meaning the regression model is considered good and can be continued with simple linear regression analysis.

Simple Linear Regression Analysis Results

The results of the regression analysis are presented in Table 5. Based on the results of the regression coefficient test output, the value Sig. = 0.000 < 0.05. Therefore, it can be concluded that learning independence has a significant effect on mathematical literacy.

Table 5. Result of simple regression analysis

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	61.840	20.744		2.981	.006
	Learning_Independence	.244	.344	.129	.711	.482
a. Dependent Variable: Mathematical_Literacy						

Figure 5 shows that the value of $\propto = 61{,}840$ and the value of $\beta = 0{,}244$. If the regression coefficient (β) is positive, then there is a positive effect of the independent variable on the dependent variable, and vice versa. Therefore, it can be concluded that learning independence has a positive effect on mathematical literacy.

Students' Mathematical Literacy in Terms of Learning Independence

The second stage of this study involved collecting qualitative data on the mathematical literacy of students with varying levels of learning independence in the experimental class, categorized as high, medium, and low. In this study, six research subjects were selected comprising two students with high learning independence, two students with medium learning independence, and two students with low learning independence, as determined through purposive sampling techniques based on the results of the student learning independence questionnaire. These specific subjects were chosen because they represented typical characteristics of each category and demonstrated consistency in their responses, making them suitable to provide in-depth insights into the relationship between learning independence and mathematical literacy within the ethnomathematics-based problem-based learning framework. The posttest mathematical literacy and learning independence scores for each subject are presented in Table 6 below.

Test Results of the Subject with High Learning Independence

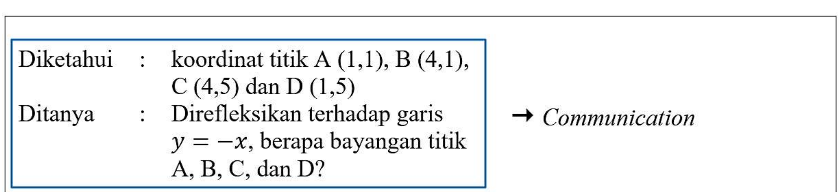
Based on the test results of subjects KE-21 and KE-23, students with high learning independence have mastery of the following mathematical literacy indicators: (1) describing the information known and asked from questions with a score of 3; (2) using mathematical techniques according to the applicable flow and concepts to help the problem-solving process with a score of 3; and (3) presenting the results obtained through a conclusion with a score of 2. The results of the analysis are an accumulation of the test results of subjects KE-21 and KE-23, as shown in Table 7 below. Figures 5 and 6 present the test results for subjects KE-21 and KE-23, which support the data in Table 7.

Table 6. Learning independence and mathematical literacy scores

Subject Code	Category of Learning Independence	Score of Learning Independence	Score of Mathematical Literacy
KE-21	High	70	86
KE-23	High	69	90
KE-04	Medium	60	90
KE-17	Medium	59	84
KE-30	Low	48	74
KE-01	Low	45	78

Table 7. Recapitulation of mathematical literacy subject KE-21 and KE-23

Subject Code	Mathematical Literacy Indicators		
	Communication	Using Mathematics Tools	Evaluate
KE-21	Able to describe the information known and ask questions *(Score: 3)*	Able to use mathematical techniques according to the applicable flow and concepts to help the problem-solving process *(Score: 3)*	Able to present the results obtained through a conclusion *(Score: 3)*
KE-23	Able to describe the information known and ask questions *(Score: 3)*	Able to use mathematical techniques according to the applicable flow and concepts to help the problem-solving process *(Score: 3)*	Less able to present the results obtained through a conclusion *(Score: 1)*



Jawab :

$A(1,1)\ R_{y=-x} \rightarrow A'(-y,-x)$
$A'(-1,-1)$
$B(4,1)\ R_{y=-x} \rightarrow B'(-y,-x)$
$B'(-1,-4)$
$C(4,5)\ R_{y=-x} \rightarrow C'(-y,-x)$
$C'(-5,-4)$
$D(1,5)\ R_{y=-x} \rightarrow D'(-y,-x)$
$D'(-5,-1)$

→ *Using mathematics tools*

Jadi, bayangan titik koordinat $A'(-1,-1)$, $B'(-1,-4)$, $C'(-5,-4)$ dan $D'(-5,-1)$.

→ *Evaluate*

Figure 5. Subject KE-21's answer

Diketahui : A (1,1), B (5,1), C (4,4) dan D (2,4)
Ditanya : refleksikan terhadap $y = x$

→ *Communication*

Jawab :

$A(1,1) \rightarrow y = x \rightarrow A'(y,x)$
$A'(1,1)$
$B(5,1) \rightarrow y = x \rightarrow B'(y,x)$
$B'(1,5)$
$C(4,4) \rightarrow y = x \rightarrow C'(y,x)$
$C'(4,4)$
$D(4,5) \rightarrow y = x \rightarrow D'(y,x)$
$D'(5,4)$

→ *Using mathematics tools*

Figure 6. Answer of subject KE-23

Based on the test results, subject KE-21 has fulfilled indicators 1, 2, and 3 because they were able to describe the information known and asked for in questions, use mathematical techniques according to the applicable flow and concepts to aid the problem-solving process, and present the results obtained through a conclusion. Meanwhile, subject KE-23 has fulfilled indicators 1 and 2, but has not fulfilled indicator 3 because it was unable to present the results obtained through a conclusion.

During the interview, subject KE-21 demonstrated a good understanding and was able to explain the information known and the questions asked in a coherent manner. Subject KE-21 looked confident and did not hesitate when answering questions. The subject was also able to explain the concept of reflection and the steps involved in solving the problem. Below is an interview excerpt with subject KE-21.

P : What do you understand from the question?
KE-21 : I understand what is given and what the question wants. Its about reflection
P : What kind of reflection is it?
KE-21 : It reflects across the x-axis, so I use the formula (x,-y).
P : Are you sure about solution?
KE-21 : Yes Sir, because I followed the step I learned before and the result makes sense.
P : Can you explain how you got the final result?
KE-21 : First I identified the origin point, then applied the reflection formula. After

that, I checked the coordinates and concluded the answer correctly.

Meanwhile, subject KE-23 showed a good understanding of the problem. Subject KE-23 was able to convey the information that was known and asked clearly. In addition, the subject was able to explain the steps of the solution, mention the formula used, but did not conclude the final result. Below is an interview excerpt with subject KE-23.

P : Can you explain what information is given in this question?
KE-23 : It gives two points and a line for the reflection, so we have to find the image of the points.
P : What is being asked?
KE-23 : It asks for the result of reflecting those points over the given line.
P : Do you know how to solve it?
KE-23 : Yes, first I use the reflection formula according to the line, then I calculate the coordinates of the image.
P : What about the final result?
KE-23 : After calculating, I found the reflected points, and I made a conclusion from that.

The results showed that students with high learning independence were able to meet all indicators of mathematical literacy, including presenting information, using mathematical tools, and drawing conclusions. This finding is in line with study by Fitriani et al. (2024), which states that students with good learning independence tend to solve problems independently and systematically.

Test Results of Subject with Medium Learning Independence

Based on the test results of subjects KE-04 and KE-17, students with medium learning independence have mastery of the following mathematical literacy indicators: (1) describing the information known and asked from questions with a score of 2; (2) using mathematical techniques according to the applicable flow and concepts to help the problem-solving process with a score of 2; and (3) presenting the results obtained through a conclusion with a score of 1. The results of the analysis are an accumulation of the test results of subjects KE-04 and KE-17, as shown in Table 8 below. Figures 7 and 8 present the test results for subjects KE-04 and KE-14, which support the data in Table 8.

Table 8. Recapitulation of mathematical literacy subject KE-04 and KE-17

Subject Code	Mathematical Literacy Indicators		
	Communication	**Using Mathematics Tools**	**Evaluate**
KE-04	Quite able to describe the information known and answer questions *(Score: 2)*	Able to use mathematical techniques according to the applicable flow and concepts to help the problem-solving process *(Score: 3)*	Less able to present the results obtained through a conclusion *(Score: 1)*
KE-17	Quite able to describe the information known and answer questions *(Score: 2)*	Less able to use mathematical techniques according to the applicable flow and concepts to help the problem-solving process *(Score: 1)*	Less able to present the results obtained through a conclusion *(Score: 1)*

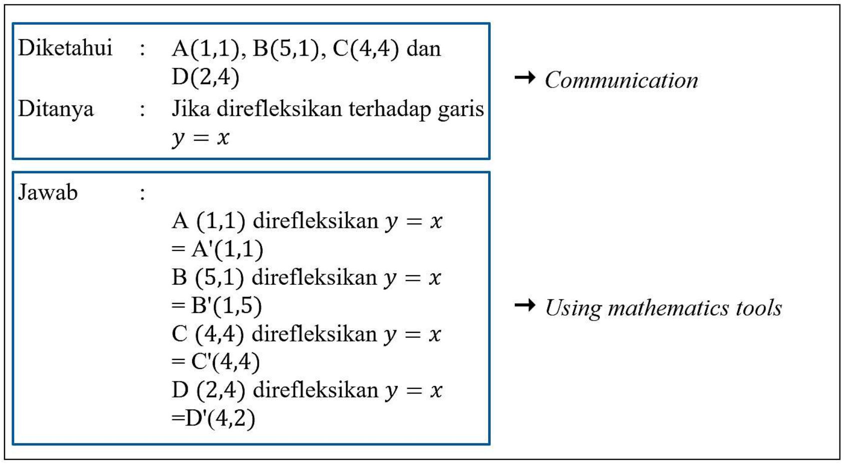


Figure 7. Answer of subject KE-04

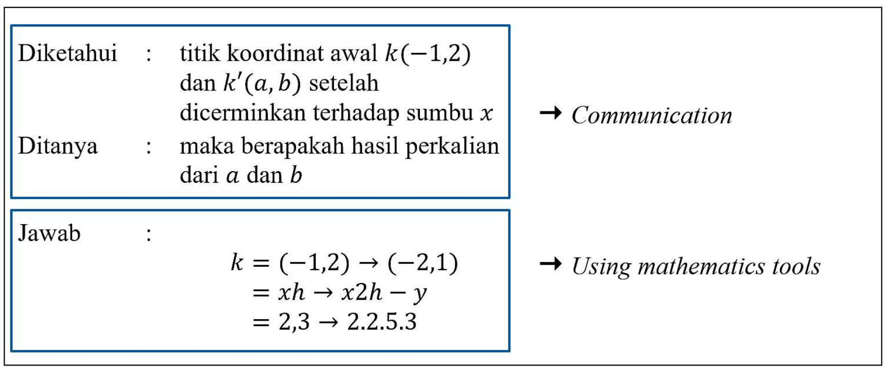


Figure 8. Answer of subject KE-17

Based on the test results, subjects KE-04 and KE-17 have fulfilled indicator one because they were able to describe the information known and answer the questions asked. Then, subject KE-04 also fulfilled indicator two because it was able to use mathematical techniques according to the applicable flow and concepts to help in the problem-solving process. However, subject KE-17 is still unable to fulfill that indicator. In addition, neither subject was able to fulfill indicator three because they were not able to present the results obtained through a conclusion.

During the interview, subject KE-04 showed an understanding of the information given in the problem and was able to convey what was asked. Subject KE-04 was also able to explain the steps of the solution and conclude the final result using the subject's own language with the correct mathematical terms. Below is an interview excerpt with subject KE-04.

P : Can you tell me what you understood from this question?
KE-04 : The question gave two points and a line to reflect over.
P : Then, what was the question asking?
KE-04 : It asked for the reflected result of those two points.
P : So how did you solve it?
KE-04 : I used the reflection formula, then calculated the image points. After that, I wrote the conclusion.
P : Can you explain the final result again?

KE-04: Yes, Sir, the reflected points change position, so I obtained the new coordinates as a result.

Meanwhile, subject KE-17 showed limited understanding of the content of the questions. Although the subject was able to mention the information that was known and requested, they did not understand how to solve the questions and were unaware of the formula that should be used. Below is an interview excerpt with subject KE-17.

P : Can you explain how you solved this problem?
KE-17 : I couldn't it. I think I didn't finish it.
P : Do you know what formula should be used?
KE-17 : I don't know, Sir.

Students with medium learning independence demonstrated partial fulfillment of indicators, particularly in the areas of communication and the use of mathematical tools, but remained weak in drawing conclusions. This condition illustrates that they have the initiative to learn, but are not yet fully able to manage the learning process independently. This is supported by Sipayung et al. (2022), which states that students with medium independence still need social stimulus or guidance in understanding the material. In contrast to students with high independence who are able to take their own initiative, the medium group tends to be active only in social contexts, such as group work, but is less brave in making decisions when working independently. This strengthens the results of the study, Hasibuan et al. (2019), which stated that students with medium learning independence tend to still be influenced by the work of others.

Test Results of Subject with Low Learning Independence

Based on the test results of subjects KE-30 and KE-01, students with low learning independence have mastery of the following mathematical literacy indicators: (1) describing the information known and asked from questions with a score of 1; (2) using mathematical techniques according to the applicable flow and concepts to help the problem-solving process with a score of 1; and (3) presenting the results obtained through a conclusion with a score of 0. The results of the analysis are an accumulation of the test results of subjects KE-30 and KE-01, as shown in Table 9 below. Figures 9 and 10 present the test results for subjects KE-30 and KE-01, which support the data in Table 9.

Table 9. Recapitulation of mathematical literacy subject KE-30 and KE-01

Subject Code	Mathematical Literacy Indicators		
	Communication	**Using Mathematics Tools**	**Evaluate**
KE-30	Quite able to describe the information known and answer questions *(Score: 2)*	Quite able to use mathematical techniques according to the applicable flow and concepts to help the problem-solving process *(Score: 2)*	Less able to present the results obtained through a conclusion *(Score: 1)*
KE-01	Less able to describe the information known and asked questions *(Score: 1)*	Less able to use mathematical techniques according to the applicable flow and concepts to help the problem-solving process *(Score: 1)*	Not able to present the results obtained through a conclusion *(Score: 0)*

Diketahui : titik koordinat A(1,1), B(4,1), C(4,5), D(1,5)		→ *Communication*
Jawab : $A(1,1) \rightarrow y = -x \rightarrow$ A'(-1, -1) $B(4,1) \rightarrow y = -x \rightarrow$ B'(-1, -4) $C(4,5) \rightarrow y = -x \rightarrow$ C'(-5, -1) $D(1,5) \rightarrow y = -x \rightarrow$ D'(-5, -1)		→ *Using mathematics tools*

Figure 9. Answer of subject KE-30

Diketahui : titik koordinat awal $k(-1,2)$ dan $k'(a,b)$ setelah dicerminkan terhadap sumbu x Ditanya : Maka berapakah hasil perkalian dari a dan b?	→ *Communication*
Jawab : $k = (-1,2) \rightarrow (-2,1)$ $= xh \rightarrow x2h - y$ $= 2,3 \rightarrow 2.2.5.3$	→ *Using mathematics tools*

Figure 10. Answer of subject KE-01

Based on the test results, subject KE-30 has not fulfilled indicator one optimally because they only describe the information known, but have not written down what is asked in the question. But subject KE-30 has fulfilled indicator two because able to use mathematical techniques according to the applicable flow and concepts to help the problem-solving process, although there are still a few errors. For indicator 3, subject KE-30 has not fulfilled because not able to present the results obtained through a conclusion. Meanwhile, subject KE-01 has not fulfilled the three indicators.

During the interview, subject KE-30 showed the ability to understand the information given in the question, but was unable to determine what was asked in the question. The subject was also able to explain the solution steps and state the formula used in the subject's own language. This shows that the subject is able to meet the communication indicators and use mathematical tools in mathematical literacy. Below is an interview excerpt with subject KE-30.

P : Can you tell me what you understood from the question?
KE-30 : I know what is given in the question.
P : Then, how do you solve it?
KE-30 : I tried to solve it based on what I understood, using the formula I remembered.
P : What formula did you use?
KE-30 : I used the formula that suited the question, although I explained it in my own way.
P : Do you understand the concept used in this question?
KE-30 : Yes, Sir. I understand.

Meanwhile, subject KE-01 showed the ability to mention the information given in the problem and what was asked. However, when asked about how to solve the problem, the subject did not understand the steps needed to find the solution. Below is an interview excerpt with subject KE-01.

P : Can you tell me what information is given in the question?
KE-01 : It gives some points and asks about reflection.
P : What is being asked in the problem?
KE-01 : We have to find the values of a, b, and c, then add them together.
P : Do you understand how to solve the question?
KE-01 : No, I don't. I forgot all the formulas and concepts about reflection.
P : So you didn't reach the final result?
KE-01 : No, Sir. I couldn't finish it because I didn't know how.

Students with low learning independence show difficulty in understanding and solving mathematical literacy problems, especially in developing solution strategies and drawing conclusions. This finding is in line with Forbes-McKay et al. (2023), who stated that students with low levels of independence have difficulty in organizing learning strategies and are very dependent on external assistance. In addition, Hasibuan et al. (2019) also revealed that students with low learning independence tend not to consistently solve problems correctly and carefully, and are easily influenced by the work of others, resulting in less-than-optimal mathematical literacy achievements.

Students with low independence also consistently fail in the indicator evaluate, because they are less accustomed to reflecting and drawing conclusions from the problem-solving process. They tend to focus solely on procedural steps without understanding the ultimate meaning of the solutions obtained. An ethnomathematics approach helps address this by presenting a cultural context close to students' lives, making it easier for them to understand, relate, and draw meaningful conclusions. A study by Pratama & Yelken (2024) showed that ethnomathematics can enhance students engagement and conceptual understanding relevant and familiar contexts.

The results of this study have important implications for the development of instructional strategies that are relevant to students' sociocultural contexts. The implementation of ethnomathematics-based PBL contributes not only to the achievement of cognitive goals in mathematics learning but also fosters the development of students' learning independence. Teachers can utilize local cultural elements as contextual tools that are close to students' daily lives, creating more meaningful learning experiences and enhancing intrinsic motivation. This approach also aligns with the spirit of the Merdeka Curriculum, which emphasizes differentiation, contextualization, and character building. For example, by integrating local cultural practices into math problems through Ethnomathematics-PBL, students in coastal regions might explore geometry through traditional boat designs. In contrast, students in agricultural areas analyze statistics based on rice harvest cycles. This not only makes learning more relevant to students' real-life contexts but also fosters a stronger sense of identity and character.

However, this study has several limitations. First, the study was conducted in a school with a small number of students, so the results may not be applicable to other schools. Future research should utilize a larger sample from multiple schools to obtain more reliable and generalizable results. Second, this study focused on only one local culture in the field of ethnomathematics. To better understand the impact across Indonesia, future studies should compare different local cultures by applying the same method in various regions. Third, the PBL was only carried out for a short time, which might not show its full effect on students' learning independence. Longer studies that follow students over several months or a full school year would help see how well the method works in the long run.

CONCLUSION

The results of this study revealed that the application of the ethnomathematics-based PBL model has proven effective in enhancing mathematical literacy. This is evidenced by the mathematical literacy of students in the ethnomathematics-based PBL class reaching the minimum completion criteria (MCC), with the proportion of students who have completed it being greater than or equal to 70%.. The analysis results also showed that learning independence has a positive effect on mathematical literacy. Moreover, the average mathematical literacy of students in the ethnomathematics-based PBL class is higher than that of students in the DL class, indicating a statistically and practically significant impact.

In addition to improving achievement, the ethnomathematics-based PBL model also encouraged students to engage more meaningfully with mathematical concepts by situating problems within familiar cultural contexts. This allowed students to better understand abstract concepts through real-life and culturally relevant experiences. The integration of cultural elements within PBL not only deepens conceptual understanding but also fosters critical thinking, communication, and reasoning, which are the key components of mathematical literacy. Therefore, this model should be positioned not merely as an alternative but as a strategic instructional approach that ought to be systematically adopted in mathematics education. Its implementation can strengthen the realization of the Merdeka Curriculum by ensuring that mathematical learning remains contextually grounded, culturally responsive, and capable of equipping students with the competencies needed for future challenges. This study also offers a methodological contribution by providing a systematic design for embedding ethnomathematics into PBL and assessing its effectiveness.

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