

The effectiveness of problem-based learning assisted with the ethnomathematics-based Geocube e-module on problem-solving skills

Sumaji^{1*}, Evi Widianingrum¹, Savitri Wanabuliandari¹, Kasem Premprayoon²

¹Universitas Muria Kudus, Indonesia

²Thaksin University, Thailand

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ABSTRACT

Problem-solving skills are essential in improving the creative, critical, and logical thinking skills needed in mathematics learning and daily life. This study aims to examine the effectiveness of problem-based learning (PBL)-assisted ethnomathematics-based Geocube e-module on problem-solving skills. This quantitative research applied a quasi-experimental design. The specific design applied in this research is the non-equivalent pretest-posttest control group design. The research sample consisted of 32 participants, all of whom were students involved in this study. Research instruments included test questions. The researchers analysed the data using a two-sample t-test for independent samples and an N-gain test. The results showed that the application of the PBL learning model assisted by the Geocub e-module based on ethnomathematics effectively improved problem-solving skills. It can be seen that (1) the average mathematical problem-solving skills of students in the experimental class were better than the control class, (2) there is an increase in the average of students' mathematical problem-solving skills after being taught the PBL model assisted by the Geocub e-module based on ethnomathematics. The researchers concluded that the implementation of PBL, assisted with the ethnomathematics-based Geocub e-module, effectively improved the mathematics problem-solving skills of the students.

INTRODUCTION

Problem-solving skill is an important matter of mathematics learning to develop the students' confidence in solving mathematics problems and to master mathematics problem-solving skills (Schreiber, 2025; Schauer et al., 2024). Mathematics problem-solving skill refers to the efforts of students in applying skills and cognition to find solutions to mathematical problems (Akbari et al., 2025; Çibukçiu, 2025). Problem solving plays an important role in mathematics Education so that students can practice and integrate the concepts, theorems, and skills that have been learned (Tambunan, 2019). Research indicates that integrating local culture into mathematics learning is a crucial consideration for maximizing students' mathematics learning achievements (Simamora et al., 2018). Mathematics learning is a crucial aspect to consider in efforts to maximize student mathematics achievement.

Research indicates that students' problem-solving abilities in Indonesia, particularly in solving mathematical problems, remain low. Based on the results of the Trends International Mathematics Science Study (TIMSS) in 2015, Indonesia's position was ranked 45 out of 50 countries, with 2% at a high level, and 0% at an advanced level. Meanwhile, according to the results of the 2022 Programme for International Student Assessment (PISA) survey, Indonesia was ranked 70 out of 81 countries

*Corresponding author: sumaji@umk.ac.id

with an Indonesian mathematics score of 366. This score is below the international average score of 472. This shows that students' problem-solving abilities are still low (Fenanlampir et al., 2019).

Based on the problems above, efforts to improve students' mathematical problem-solving skills are problem-based learning models or Problem-Based Learning (PBL) (Orhan, 2024; Gilbert et al., 2024). Because, The Problem Based Learning (PBL) model is a learning model that involves students in learning activities and prioritizes existing problems in the school, home, or community environment to gain conceptual knowledge through problem-solving skills (Martínez-Gómez & Nicolalde, 2025). The Problem-Based Learning (PBL) model is a learning model that provides experiences that encourage students to learn actively, construct knowledge, and integrate learning contexts in schools and learning in real life scientifically. The syntax or steps of Problem-Based Learning (PBL) are: (1) Problem orientation; (2) Organizing students to study; (3) Guiding individuals and groups; (4) Developing and present works; and (5) Analyzing and evaluating the problem-solving process (Suharsono et al., 2025).

The application of PBL assisted by ethnomathematics makes learning more interesting. Ethnomathematics is a cultural study that identifies mathematical elements contained in a culture that can be applied in mathematics Education or learning. Ethnomathematics highlights cultural wisdom, motivating students to learn mathematics. (Mellawaty et al., 2025; Kobandaha et al., 2025; Dominikus et al., 2025; Yerizon et al., 2025). By integrating cultural values known to students in their learning, it can help students concretize abstract mathematical concepts, making them easier to understand (Nugraha & Nugraha, 2025; Lolkus, 2025; Näslund-hadley et al., 2025). This approach provides students with the opportunity to observe the applications and manifestations of mathematics in their daily lives, thereby enhancing their understanding and appreciation of the subject (Rodríguez-Nieto et al., 2025; Nasrum et al., 2025; Ilma et al., 2024). In learning mathematics, several abilities affect student learning achievement (Pratama & Yelken, 2024; Kusuma et al., 2024; Nurcahyo et al., 2024; Kabuye Batiibwe, 2024). Among these mathematical abilities is the ability to be mathematically literate. To ensure that the learning material delivered is more interactive, technology-based interactive media is required.

One of the interactive media based on technology is the Geocube E-Module. The Geocube E-Module is a type of media that contains text, images, graphics, animations, and videos, which can be accessed anywhere. (Dewi & Kuswanto, 2023; Wahyudi et al., 2025; Pantiwati et al., 2025). The Geocube E-Module is an electronic module that operates on a computer, featuring images, text, animations, and videos. (Yerizon et al., 2025; Ferdiani & Harianto, 2024; Wijayanto et al., 2023; Arnstein et al., 2023). The E-Module is a digital module that consists of text, images, or both, containing digital electronic material.

With the E-Module, students can foster motivation, teachers and students can identify which parts are not yet complete or have been completed, learning materials can be broken down to be more evenly distributed over one semester, and learning materials can be arranged according to academic level. (Lasala, 2023; Suryawati et al., 2024; Pamungkas et al., 2024). E-modules can be made more interactive and dynamic than printed modules, which tend to be more static. They can utilize video, audio, and animation to reduce the high verbal elements of printed modules. (Sedayu et al., 2024; Astalini et al., 2024; Asrizal et al., 2024; Alyusfitri et al., 2024).

This research is important because problem-solving skills are one of the essential competencies in mathematics learning in the 21st century. However, in reality, many students still struggle with solving contextual problem-solving questions. In addition, current learning is still centered on teachers and has not involved students, making it less meaningful. Therefore, an innovative learning approach is needed, such as Problem-Based Learning (PBL), which enables students to think critically and independently when dealing with problems. The use of the Geocube e-module is expected to increase students' motivation and independence in learning through its attractive and interactive visual displays. Furthermore, the integration of ethnomathematics elements in learning materials provides added value by linking mathematical concepts to the context of local culture, so that it not only improves students' understanding but also fosters a love of cultural heritage. By combining these three components, this research has the potential to make

Table 1
Each meeting learning topics

Meeting	Learning topics
1	Introduction to linear equations in two variables
2	Solving the concept of linear equations in two variables
3	How to draw a graph of a linear equation of two variables
4	System of linear equations in two variables
5	Elimination and substitution methods
6	Application of linear equations of two variables in everyday life

a significant contribution to developing an effective, contextual, and relevant mathematics learning model for students' current needs.

METHODS

This quantitative research applied a quasi-experimental design. The specific design applied in this research is the non-equivalent pretest-posttest control group design. The research population consisted of all eighth graders from a secondary public school in Kudu Regency. The sampling technique used was purposive sampling. The research samples consisted of eighth graders from the VIII A and VIII B classes. The experimental group was VIII A, comprising 32 students, who received PBL assisted with an ethnomathematics-based Geocub e-module, and the control group was VIII B, comprising three students, who received direct instruction. The material in this study is a linear equation of two variables. This study was conducted in 6 meetings in the experimental and control classes. The topics in each meeting are explained in the following Table 1.

The research instrument was two problem-solving tests to measure problem-solving abilities. The following test instruments were given to the experimental and control classes, as well as the pre-test and posttest.

1. *Joko bought some mangosteens and oranges. If he purchased four mangosteens and three oranges, they had to pay Rp21,000. However, when he bought three mangosteens and five oranges, they paid Rp24,000. However, when he got home, Joko realised the seller had given him the wrong price: the price of 1 orange should have increased by Rp1,000, and the cost of 1 mangosteen should have decreased by Rp500 from the price he paid. What is the correct price of 1 mangosteen and one orange?*
2. *Fani bought two cakes and three glasses of juice for a total of Rp27,000. Riko bought three cakes and two glasses of juice for a total of Rp28,000. They wanted to know: Who paid more for one cake and one glass of juice?*

On the other hand, the control group received direct learning. After that, the researchers administered the posttest to both groups to measure the students' mathematics problem-solving skills at the final step. This test was functional to determine the development of the students' mathematics problem-solving skills. In this study, researchers used a test to assess students' mathematical problem-solving skills with two-variable linear equation material. Researchers used descriptive tests with the aim of obtaining data on problem-solving abilities between the experimental class and the control class. Problem-solving indicators include: (1) understanding the problem, (2) preparing a solution plan, (3) implementing the plan, and (4) checking the results.

The next step in this study is to collect initial data for testing. Furthermore, after obtaining the research data, data analysis was carried out which included (1) normality and homogeneity tests as prerequisite tests, (2) hypothesis 1 test with Paired Samples T Test, (2) hypothesis 2 test with Independent Samples T Test and (3) hypothesis 3 test by comparing N- Gain Score, then Independent Samples T Test. The data analysis technique in this study at the initial stage was a prerequisite test of the initial data, namely the normative and homogeneity tests. Furthermore, test questions were given to the experimental class and the control class. The stages in compiling test questions include: analysing core competencies and basic competencies, determining question indicators, compiling questions according to indicators, and compiling assessment rubrics. The assessment rubric is in Table 2.

Table 2
Assessment rubric

Score	Assessment criteria
4	Analyze known information, write down the solution steps correctly, and provide the right answer.
3	Analyze known information, write down the correct solution steps, and provide incorrect answers.
2	Analysing known information, writing down solution steps incorrectly, and providing incorrect answers.
1	Breaking down the known information in the question, not writing down the solution steps, and not providing an answer.
0	Unable to do any analysis at all or provide an answer.

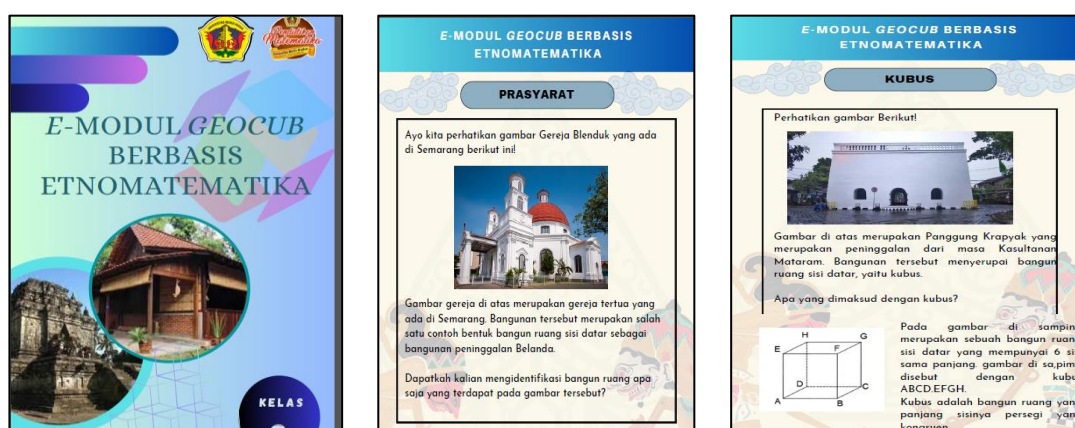


Figure 1. Geocube based ethnomathematics

After the test was given, a hypothesis test was carried out which included: (1) the independent samples t-test which was used to test which average learning outcomes were better between the experimental and control classes and, (2) the N-gain score test to test the improvement between the pre-test and posttest.

FINDINGS

The use of ethnomathematics-based e-modules is designed to bring local cultural context into the learning process, so that students can understand mathematical concepts through experiences that are close to everyday life. By integrating the PBL approach and local cultural richness in an interactive digital format, students are encouraged to be more active in exploring problems, formulating solution strategies, and conveying solutions logically. The results of the study showed that this approach was able to significantly improve students' problem-solving skills, both in terms of conceptual understanding, critical thinking processes, and the ability to apply mathematics contextually. Figure 1 shows the example of the module.

This research was conducted as an effort to answer the problem formulation and test the hypothesis that has been formulated previously. The presentation of research data includes analysis requirements tests (normality and homogeneity tests), as well as effectiveness tests with independent t-tests, sample t-tests, and N-Gain.

Hypothesis prerequisite test

Before examining the hypotheses with a statistical test, the researchers analyzed the data with a normality test. The researchers used the Kolmogorov-Smirnov test to assess the normality of the data, assisted by SPSS 26. Then, the researchers examined the data homogeneity. The results of the preliminary step consisted of normality, homogeneity, and mean similarity tests. Value of the experimental group is $0,077, \geq 0,05$, indicating normal distribution of the data. On the other hand,

Table 3

The Kolmogorov Smirnov normality test of the pre-test		
Class	<i>Sig.</i>	α
Experiment	0,077	0,05
Control	0,200	

Table 4

The homogeneity test of the pre-test		
	<i>CapSig.</i>	α
The value of the students	0,650	0,05

Table 5

The mean similarity of independent sample t-test of the pre-test		
	<i>Sig. (2 – Tailed)</i>	α
	0,540	0,05

Table 6

The Kolmogorov Smirnov normality test of the post-test		
Groups	<i>Sig.</i>	α
Experiment	0,194	0,05
Control	0,200	

Table 7

The homogeneity test of the post-test		
	<i>CapSig.</i>	α
The scores of the students	0,792	0,05

the value of the control group is $0,200 \geq 0,05$, indicating normal data distribution. Thus, the researchers concluded the data were normally distributed. Table 3 presents the results of the normality test. Then, the researchers examined the data homogeneity for both groups. The researchers obtained a sig-value of $0,650 \geq 0,05$, indicating homogeneous data. Table 4 shows the homogeneity test results.

Testing the effectiveness of the module

The researchers examined the mean similarity of both groups. The obtained value is $0,540 \geq 0,05$, indicating no differences in terms of mathematics problem-solving skills between the two groups. Table 5 shows the t-test of two independent samples.

The researchers applied the two-sample t-test for independent samples. The test examined the means of the students' mathematics problem-solving skills taught by PBL assisted with an ethnomathematics-based Geocub e-module and those taught with direct learning. Initially, the researchers examined the normality and homogeneity of the posttest data from both groups.

The value of the experimental group is $0,194 \geq 0,05$, indicating a normal data distribution. On the other hand, the value of the control group is $0,200 \geq 0,05$, indicating normal data distribution. Thus, the researchers concluded the data were normally distributed. Table 6 presents the results of the normality test.

Then, the researchers examined the homogeneity of the preliminary data from both groups. The obtained value is $0,792 \geq 0,05$ indicating homogeneous data. Table 7 shows the homogeneity test results.

Table 8

The independent sample t-test	
<i>Sig. (2 – Tailed)</i>	α
0,000	0,05

Table 9

The N-gain score		
Class	N-Gain Score	Interpretation
Experiment	0,63	Currently
Control	0,47	Currently

Table 10

The N-gain score of the Kolmogorov Smirnov normality test		
Class	<i>Sig.</i>	α
Experiment	0,200	0,05
Control	0,200	

Table 11

The N-gain score of homogeneity test		
	<i>Sig.</i>	α
Student Scores	0,336	0,05

Table 12

The Independent Sample T-Test for the N-Gain Test	
<i>Sig. (2 – Tailed)</i>	α
0,000	0,05

Based on the analysis, the obtained $\text{sig. (2 – tailed)} = 0,000$. In this test, the applied test is the right-sided test. Thus, the obtained value is $p\text{-value} = \frac{1}{2} \times \text{sig. (2 – tailed)}$ or $\frac{1}{2} \times 0,000 = 0$. Here are the criteria of the hypothesis test $\frac{1}{2} \times \alpha$ or $\frac{1}{2} \times 0,05 = 0,025$ since $0 < 0,025$. So the conclusion is the mathematics problem-solving skills with the problem-based learning model assisted with ethnomathematics-based Geocub e-module was higher than those with direct learning. Table 8 shows the t-test results of two independent samples.

Based on the second objective, the researchers used the N-gain with the independent t-test of the right-side party. The test was useful to examine the mean improvement of the students' mathematics problem-solving skills from both groups. The first step was analyzing the data with the N-gain test.

The N-gain mean of the students' mathematics problem-solving skills taught by the PBL model is 0.63 higher than those taught with direct learning, 0.47. Both groups have moderate N-gain scores. The researchers differentiated the experimental group from the control group based on three findings. The researchers found nine students from the experimental group had high interpretation, 22 students with moderate interpretation, and one learner with low interpretation. On the other hand, from the control group, the researchers found a learner with high interpretation, 28 students with moderate interpretation, and three students with low interpretation. Table 9 shows the N-gain scores from both groups.

Before the implementation of the independent sample t-test for the N-test purposes, the researchers examined the normality and homogeneity of the data. The value of the experimental group is $0,200 \geq 0,05$ indicating normal data distribution. On the other hand, the value. of the control group is $0,200 \geq 0,05$ indicating normal data distribution. Thus, the researchers concluded the data were normally distributed. Table 10 shows the normality test results.

Then, the researchers examined the homogeneity of the preliminary data from both groups. The obtained value is $0,336 \geq 0,05$ indicating two data variants are homogeneous. Table 11 shows the homogeneity test results.

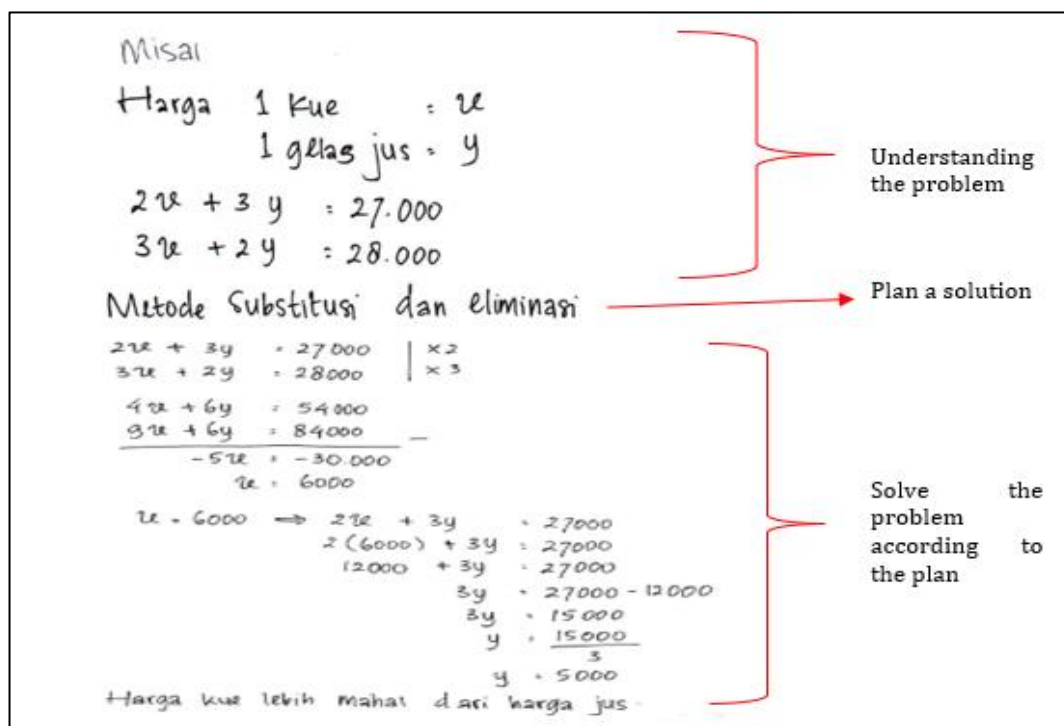


Figure 2. Example of experimental class student work

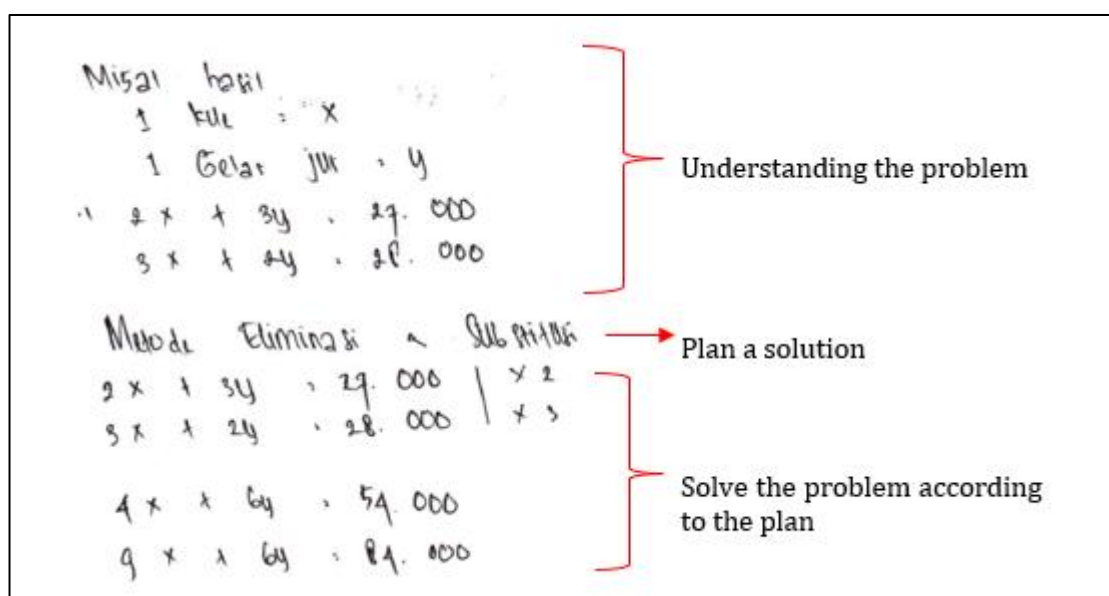


Figure 3. Example of control class student work

The analysis obtained $\text{sig. (2-tailed)} = 0,000$. In this test, the applied test is the right-side test. Thus, the obtained value is $P\text{-value} = \frac{1}{2} \times \text{sig. (2-tailed)}$ or $\frac{1}{2} \times 0,000 = 0$. Here are the criteria of the hypothesis test: $\frac{1}{2} \times \alpha$ or $\frac{1}{2} \times 0,05 = 0,025$. Since, $0 < 0,025$, the result indicates the differences in improved mean scores of students' mathematics problem-solving skills from both groups. Table 12 shows the independent sample t-test data.

The differences of student's problem-solving skills also can be seen in the example of the student's work between experimental and control classes as shown in Figure 2 and 3. Figure 2 shows that, in the first indicator, the student denotes the price of a cake and a glass of juice with the x and y variables and makes a mathematical model: $2x + 3y = 27000$ and $3x + 2y = 28000$. In the second indicator, the student plans the solution with substitution and elimination methods. At the stage of

solving the problem, the student has already completed the problem with the solution $x=6000$ and $y=5000$. The conclusion is that the price of a cake is pricier than the price of a glass of juice. Therefore, it can be concluded that the student in the experimental class has met all indicators of the problem-solving skills correctly.

Figure 3 shows that students in the control class can solve three problem-solving indicators, although they do so incorrectly. In the first indicator, students represent the price of a cake and a glass of juice with x and y and make a mathematical model $2x + 3y = 27000$ and $3x + 2y = 28000$. In the second indicator, the student plans the solution with substitution and elimination. However, despite the student having already found a solution during the problem-solving stage, that answer is incorrect.

DISCUSSION

The results of the study showed that in the experimental class, the average mathematical problem-solving skills of students taught using the PBL model, assisted by the Geocub e-module based on ethnomathematics, were higher than those of the control class taught through direct learning. This is because the experimental class, taught using the PB model and assisted by the Geocub e-module based on ethnomathematics, was more engaging, making students happier and more interested in learning (Martínez-Gómez & Nicolalde, 2025). The PBL learning model offers an excellent opportunity for students to actively participate in learning, such as solving problems, gaining experience, acquiring knowledge, and developing the ability to solve problems independently (Short-Meyerson et al., 2025). The application of problem-based learning can increase the average score of mathematical problem-solving skills. The problem-solving skills of students taught using problem-based learning, assisted by learning media, are higher than those of students taught using the direct learning model (Akbar et al., 2022).

The second hypothesis test shows that there is an increase in the average of students' mathematical problem-solving skills after being taught the PBL model assisted by the Geocub e-module based on ethnomathematics. This can be seen from the average N-Gain, students who were taught an average posttest score of 0.63 higher than the pre-test 0.47, which indicates an increase in the moderate to high category. This increase indicates that the application of the PBL model combined with the ethnomathematics approach has a positive impact on students' conceptual mastery and critical thinking skills in solving mathematical problems. The PBL model encourages active student involvement through group discussions, independent investigations, and presentations of results, so that students are more involved in the learning process. In addition, the integration of local cultural elements in the e-module makes learning more contextual and meaningful for students, which is in accordance with the constructivist approach in education. The use of visual and interactive learning media through Geocube also helps students understand concepts more concretely (Short-Meyerson et al., 2025).

The researchers found that the improved mathematics problem-solving skills of the students were due to the implementation of PBL, which assisted with the ethnomathematics-based Geocub e-module, and could improve the students' enthusiasm. The applied e-module was accessible from every learner's smartphone. Additionally, students had the opportunity to solve problems and answer question items from the ethnomathematics-based Geocub e-module. Also, teaching materials with valid integrated problems of ethnomathematics could improve the students' mathematics problem-solving skills. The implementation of an ethnomathematics-based module could improve students' mathematics problem-solving skills. The application of problem-based learning assisted by e-modules is efficacious in improving students' mathematical problem-solving abilities. The researchers found differences in mathematics problem-solving skills before and after the implementation of the model and learning. Arfiani et al. (2020) found the mathematics problem-solving skill differences between those receiving the applied learning model and the mathematics learning media.

CONCLUSION

The implementation of the PBL learning model assisted by the Geocub e-module based on ethnomathematics effectively improves problem-solving skills. Improvement in students' mathematical problem-solving skills can be seen in the following criteria: (1) the average mathematical problem-solving skills of students in the experimental class are better than the control class; (2) there is an increase in the average of students' mathematical problem-solving skills after being taught the PBL model assisted by the Geocub e-module based on ethnomathematics. This study was limited to junior high school students and the material of two-variable linear equations. Therefore, further research can be developed for different levels of Education and materials.

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AUTHOR'S DECLARATION

Authors' contributions

S: Finding research ideas, compiling learning instruments, and data analysis including the N-Gain test and the Independent Samples T-Test, EW: Creating theoretical frameworks, interpreting data, and assisting in the development of learning media, SW: Collecting data, managing learning implementation, and data analysis. KP: Conducting a review of the research report and providing input to improve the research findings.

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Availability of data and materials

In this study, all data used support the research findings. All data are available and can be obtained from the corresponding author

Competing interests

This article has never been published and is not currently under review in any journal. All data submitted is the sole responsibility of the authors. There is no conflict of interest in this research.

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