p-ISSN 2407-4489
e-ISSN 2528-7303

Improving Students' Mathematical Representation Skills through a STEM-Integrated Problem-Based Learning (PBL) Model on Inverse Proportionality Material

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Abstract

This study aims to determine the improvement of students' mathematical representation ability after the implementation of the STEM-integrated Problem Based Learning (PBL) model on inverse proportion material. This study employed a quantitative approach with a pre-experimental design using the One Group Pretest–Posttest Design. The research subjects consisted of 28 seventh-grade students of Amir Hamzah National Education Junior High School. The research instrument was a descriptive test of mathematical representation ability administered before and after the treatment. The data were analyzed using descriptive statistics, inferential statistics, and N-Gain analysis. The results showed that the average pretest score increased from 9.29 to 28.93 in the posttest after the implementation of the STEM-integrated PBL model. In addition, the average N-Gain score obtained was 0.28, which was categorized as low improvement. The results of the paired sample t-test also indicated a significant difference between students' pretest and posttest scores after the treatment ($p < 0.05$). These findings indicate that the STEM-integrated PBL model had a positive effect on students' mathematical representation ability. The improvement was reflected in students' ability to present mathematical ideas visually, symbolically, and verbally after participating in the learning process. In addition, the STEM-integrated PBL model encouraged students to be more active in discussions, collaboration, and solving contextual problems, making learning more meaningful. Therefore, the STEM-integrated PBL model can be used as an alternative mathematics learning model that is active and student-centered.

Keywords: Problem-Based Learning, STEM, mathematical representation, inverse relationships, mathematics education.

p-ISSN 2407-4489
e-ISSN 2528-7303

INTRODUCTION

Education is one of the important aspects in efforts to improve the quality of human resources. In the educational process, mathematics plays a crucial role as it can train students' logical, systematic, critical, and creative thinking skills. Therefore, mathematics learning is not only oriented towards calculation skills but also towards understanding concepts, solving problems, and communicating mathematical ideas in various forms of representation.

One of the important mathematical abilities that students should possess is the ability of mathematical representation. The ability of mathematical representation is the students' capability to present mathematical ideas or concepts in various forms, such as visual, symbolic, or verbal representations. This ability becomes one of the skills that are assessed in *Programme for International Student Assessment* (PISA). Santia (2018) in (A. D. Putri et al., 2025) states that the ability of mathematical representation is one of the indicators of students' mathematical literacy skills.

However, in reality, the ability of mathematical representation among students in Indonesia is still considered low. The results of the 2018 PISA study show that 71% of Indonesian students have not reached the minimum level of mathematical competence. In addition, the mathematical ability score of Indonesian students only reached 379, while the international average reached 490, placing Indonesia in 74th place out of 79 participating countries. Furthermore, based on the results of PISA in 2022, the mathematical ability score of Indonesian students only reached 366, while the international average reached 472 (OECD, 2019; OECD, 2023). This condition indicates that the ability of mathematical representation among Indonesian students still needs serious attention (Putri et al., 2025).

Based on the research results from (Fitrisyah et al., 2023; Khoerunnisa & Maryati, 2022; Ramadhana et al., 2022), it was found that the ability of mathematical representation among students in Indonesia is still considered low. The three studies found that students still face difficulties in transforming contextual problems into mathematical model forms, using symbols or mathematical equations accurately, and explaining the solution steps systematically. In general, students are more capable of using visual and verbal representations compared to symbolic representations or mathematical expressions. In addition, many students still do not have a good understanding of basic mathematics concepts, leading to errors in creating tables, graphs, images, and mathematical equations. The low ability in mathematical representation is also influenced by teaching that is still teacher-centered, a lack of real-context problem exercises, and a minimal opportunity for students to develop their own mathematical representations in the learning process.

Similar problems were also found in the material on direct and inverse proportions. The results of an initial study on seventh-grade students at SMP Negeri 2 Palopo showed that many students still experienced difficulties in understanding the concepts of direct and inverse proportions and performing calculations to solve problems. The errors made by students include pseudo construction, misconstruction, misanalogical construction, misconnection, and mislogical construction. These errors cause students to face obstacles in accurately constructing mathematical concepts (Angraerni et al., 2021).

Students' errors in constructing mathematical concepts need to be addressed because they can affect the understanding of concepts in subsequent material. Therefore, a learning approach is needed that can help students build their own knowledge through investigation and problem-solving processes. Mathematics learning should be directed as an activity that can actively develop students' thinking skills. In constructivist learning, students are encouraged to construct their own knowledge so that their understanding of concepts becomes more meaningful (Mutiah et al., 2023; Wahyuni et al., 2024).

One of the learning models that can be used to help students develop mathematical representation skills is Problem Based Learning (PBL). The PBL model is a learning model that uses contextual

p-ISSN 2407-4489
e-ISSN 2528-7303

problems as the basis for learning, encouraging students to investigate, discuss, think critically, and find solutions

to the given problems (Putri et al., 2025). Through problem-based learning, students can be more active in constructing mathematical concepts and connecting them to real-life situations.

In addition to the use of appropriate learning models, mathematics learning also needs to adapt to the demands of 21st-century learning. 21st-century learning is characterized by student-centered learning and focuses on enhancing 21st-century skills. In the 21st century, learners are required to master the skills needed in the society 5.0 era. The skills that need to be developed are the 4C skills (Communication, Collaboration, Critical Thinking, and Creative Thinking) (Yuliana & Irawan, 2024). Therefore, an approach to learning is needed that can integrate various disciplines in the mathematics learning process.

One suitable approach is the STEM approach (Science, Technology, Engineering, and Mathematics). Learning with the STEM approach is identified as learning that combines four disciplines, namely science, technology, engineering, and mathematics, by focusing on a learning process that explores two or more fields involving students actively in the context of problem-solving in the real world (Pandiangan & Lubis, 2024). Thus, the STEM approach can help students solve everyday problems by involving critical, creative, and collaborative thinking processes.

The STEM approach can also be integrated with various learning models, one of which is Problem Based Learning (PBL). The integration of PBL and STEM in mathematics learning is expected to create a more meaningful learning process because students not only understand mathematical concepts theoretically but also can apply them in solving real problems.

Although several previous studies have discussed the implementation of Problem Based Learning (PBL) and STEM approaches in mathematics learning, most studies focused on problem-solving skills, critical thinking, or general mathematical achievement. Research specifically investigating students' mathematical representation ability on inverse proportionality material through the integration of STEM and PBL is still limited, particularly at the junior high school level. In addition, previous studies rarely emphasized how STEM-integrated PBL can support students in constructing visual, symbolic, and verbal mathematical representations simultaneously.

The topic of inverse proportionality is chosen in this research because it is closely related to everyday life, such as the relationship between the number of workers and the time to complete a job, the number of water pumps and the time for irrigating fields, as well as the number of machines and the duration of the production process. In solving problems related to the material of inverse value comparison, students are required to be able to represent the problems in the form of tables, mathematical models, symbols, or verbal explanations.

Therefore, this study offers novelty by integrating the STEM approach with the Problem Based Learning model specifically on inverse proportionality material to improve students' mathematical representation abilities. This study also focuses on the three indicators of mathematical representation ability, namely visual, symbolic, and verbal representations, which are essential competencies in mathematics learning and 21st-century education.

METHOD

This research uses a quantitative approach with a type of pre-experimental research pre-experimental design). The research design used is One Group Pretest– Posttest Design, which involves one group of subjects with a pretest given before the treatment and a post- test after the treatment. The research design is illustrated as follows:

p-ISSN 2407-4489
e-ISSN 2528-7303

Table 1. One Group Pretest–Posttest Design

Pretest	Treatment	Post-test
O_1	X	O_2

Keterangan:
O_1 : Mathematical representation ability pretest;
X : Learning using the STEM-integrated PBL model assisted by student worksheet;
O_2 : Mathematical representation ability posttest. (Simbolon et al., 2025)

The research was conducted at Amir Hamzah National Education Junior High School in the second semester of the 2025/2026 academic year. The subjects of the research were 28 seventh-grade students selected using purposive sampling techniques according to the research needs. The research instrument was a mathematical representation ability test in the form of essay questions, where each instrument consisted of 5 questions given during the pretest and posttest. The instruments were developed based on indicators of mathematical representation ability, including visual representation, symbolic representation, and verbal representation.

The data collection technique in this study was carried out through several stages to obtain accurate data in accordance with the research objectives. The first stage began with administering a pretest to students before the learning process was implemented. The pretest aimed to determine the students' initial abilities related to the material to be studied, allowing the researchers to compare students' abilities before and after the treatment. After the pretest was completed, the learning activities were conducted by implementing the Problem Based Learning (PBL) model integrated with the STEM approach and supported by the use of Student Worksheets. During the learning process, students were encouraged to actively solve problems, engage in discussions, and develop their critical thinking and mathematical representation abilities. Furthermore, a post-test was administered to the students. The post-test aimed to determine the improvement in students' abilities after participating in learning activities using the STEM-integrated PBL model assisted by Student Worksheets. The results of the pretest and post-test were then analyzed to identify the improvement in students' mathematical representation abilities after the implementation of the model.

Before being administered to the research subjects, the instrument was validated by mathematics education experts to ensure its content validity and its alignment with the indicators of mathematical representation ability. The instrument was also tested on students to determine its reliability. Based on the results of the reliability test, the instrument met the reliable criteria and was considered appropriate for use in this study.

The research data were analyzed using descriptive and inferential statistics. Descriptive analysis was used to determine the mean, maximum value, minimum value, and standard deviation of the students' pretest and posttest results. Furthermore, a normality test was conducted to determine the data distribution. The normality test was performed using the Shapiro-Wilk test because the sample size was less than 50.

Next, hypothesis testing was conducted to determine the improvement in students' mathematical representation skills after the integrated Problem Based Learning (PBL) model with STEM was applied. The research hypothesis used is:
H_0: There is no improvement in students' mathematical representation skills after the model is applied Integrated STEM PBL.
H_1: There is an improvement in students' mathematical representation skills after the integrated STEM PBL model is applied.

p-ISSN 2407-4489
e-ISSN 2528-7303

If the data is normally distributed, hypothesis testing is conducted using the paired sample t-test. However, if the data is not normally distributed, the Wilcoxon signed rank test is used at a significance level of 5% ($\alpha = 0.05$).

The improvement of students' mathematical representation skills is analyzed using Gain scores, which are the difference between post-test scores and pre-test scores obtained by students after participating in learning using the integrated STEM Problem Based Learning (PBL) model.

$$Gain = Skor\ posttest - Skor\ pretest$$

This study has several limitations. The research only involved one class with a relatively small sample size and did not use a control group. Therefore, the findings cannot be generalized broadly to all student populations. However, the results of this study can provide an initial overview regarding the effectiveness of STEM-integrated PBL in improving students' mathematical representation abilities.

RESULTS AND DISCUSSION

Based on the results of the research conducted, data on students' mathematical representation ability before and after the implementation of the integrated Problem Based Learning (PBL) model in the material of inverse proportion was obtained. This data was obtained through the administration of a pretest before the learning process and a posttest after the learning process was completed. The results of the pretest and posttest were used to observe the improvement in students' mathematical representation ability after the integrated STEM PBL learning model was applied. The data from the pretest and posttest results of students' mathematical representation ability can be seen in the Table 2.

Based on the Table 2 of pretest and posttest scores of students' mathematical representation abilities, it can be seen that there was an improvement in learning outcomes after the implementation of the Problem Based Learning (PBL) model integrated with STEM on the material of inverse proportion. At the time of the pretest, most students received low scores. Out of 28 students, many scored below average due to difficulties in understanding the questions and presenting problem-solving in the form of mathematical representation. The total pretest score obtained by the students was 260, with an average of 9.29.

After being treated using the Problem Based Learning (PBL) model integrated with STEM, the students' posttest results showed a significant improvement. The total posttest score of the students increased to 810, with an average of 28.93. Almost all students experienced an increase in scores compared to the pretest. Students who previously received low scores began to solve problems with more systematic and structured steps.

The increase in value indicates that learning using the STEM-integrated PBL model has a positive impact on students' mathematical representation skills. Students are beginning to understand the relationships between variables in the material of inverse value comparisons and are able to present problem-solving in the form of visual, symbolic, and verbal representations. In addition, students also appear more capable of explaining the problem-solving process using their own language.

Based on the N-Gain analysis, the average N-Gain obtained is 0.282571. This value indicates that the improvement in students' mathematical representation skills after the implementation of the STEM-integrated Problem Based Learning (PBL) model is in the low category. Nevertheless, the results still show an improvement in students' abilities compared to before the learning was conducted. This improvement occurs because students are actively involved in the learning process, discussing in groups, and are given the opportunity to solve contextual problems related to everyday life.

p-ISSN 2407-4489
e-ISSN 2528-7303

Table 2. Pre-Test and Post-Test Scores of Students

No	Student Name	Pre-Test Score	Post-Test Score	N-Gain
1	Abidzar	8	35	0,375
2	Ghaisan	8	32	0,333
3	Luis	8	45	0,514
4	Caisar	12	52	0,588
5	Dafa	18	51	0,532
6	Angelina	14	27	0,197
7	Andaz	5	18	0,173
8	M. Fahri	0	12	0,15
9	Elyana	4	21	0,224
10	Pedro	8	20	0,166
11	Daniel	8	20	0,166
12	Stanley	4	15	0,115
13	Imanuel	18	30	0,193
14	Laura	20	52	0,533
15	Elisa	16	44	0,437
16	Audrey	13	41	0,418
17	Christian	16	32	0,25
18	Evelyn	16	30	0,219
19	Gledys	8	23	0,208
20	Shafira	4	18	0,182
21	Tsania	8	26	0,25
22	Aqilla	6	26	0,27
23	Yesa	8	22	0,194
24	Wardaful	0	12	0,15
25	Tesalonika	0	10	0,125
26	Abigel	10	28	0,257
27	Gresia	8	24	0,222
28	Fauzi	12	44	0,471
TOTAL:		**260**	**810**	**7,912**
AVERAGE:		**9,29**	**28,93**	**0,282571**

Although the average N-Gain score was categorized as low, several factors may have influenced the limited improvement. First, students were still adapting to the STEM-integrated PBL learning process because they were not accustomed to student-centered learning activities. Second, some students still had difficulties in understanding basic mathematical concepts and transforming contextual problems into mathematical representations. Third, the limited duration of the treatment may not have been sufficient to significantly improve students' representation abilities. Nevertheless, the learning process showed positive changes in students' participation, collaboration, and confidence during classroom discussions.

The results of the normality test using Shapiro–Wilk showed that the pretest and posttest data were normally distributed, so hypothesis testing could be conducted using a paired sample t-test. Based on the results of the hypothesis testing, it was found that there was a difference between the students' pretest and posttest scores after the implementation of the STEM-integrated Problem Based Learning (PBL) model. This indicates that the applied learning model encourages the improvement of students' mathematical representation abilities.

During the learning process, students appeared more active in discussing and collaborating in groups to solve the given problems. The learning began with the provision of contextual problems related to the material of inverse value comparison, making it easier for students to understand the mathematical concepts being studied. Students were trained to understand the problems, determine solution strategies, construct mathematical models, and present the results of group discussions.

p-ISSN 2407-4489
e-ISSN 2528-7303

The integration of STEM in learning also helps students connect mathematical concepts with real life. In the aspect of science, students understand the relationships between variables in everyday life. In the aspect of technology, students utilize worksheets and learning media as tools to understand concepts. In the aspect of engineering, students are trained to develop systematic problem-solving strategies. Meanwhile, in the aspect of mathematics, students use mathematical concepts and operations to obtain accurate solutions. This learning process helps students gradually improve their mathematical representation skills.

The results of this study are in line with the research of Muhammad Rifqi Azizi et al., which states that the average mathematical representation skills of junior high school students in the PBL learning model are better compared to the expository learning model. This research shows that the application of Problem Based Learning has a strong influence on students' mathematical representation skills. Mathematical representation skills refer to students' ability to convey mathematical ideas in visual, symbolic, or verbal forms to solve mathematical problems (Azizi et al., 2024).

The results of this study are in line with the research of Magdalena Siahaan et al. which states that the Problem Based Learning model is effective in enhancing students' representation skills because students are encouraged to actively solve problems, develop a mindset, and apply their own ideas in solving mathematical problems. Learning that actively involves students can help them understand mathematical concepts more deeply and improve their ability to convey mathematical ideas through various forms of representation (Siahaan et al., 2023).

This study is also supported by the research of Farich Akbar, which shows that the PBL model with a STEAM approach can improve students' mathematical representation skills. According to Nurfitriyanti (2020), as cited in (Akbar et al., 2023), the PBL model has a significant impact on students' mathematical representation skills because students are trained to understand problems, devise solution strategies, and communicate their mathematical ideas through various forms of representation.

The implementation of STEM in mathematics learning also contributes to the improvement of students' mathematical abilities. The STEM approach helps students develop critical thinking, creativity, and problem-solving skills as they are trained to solve problems through activities integrated with everyday life (Rahmawati et al., 2022). This is also in line with the research of Veni Saputri and Tatang Herman, which states that the integration of STEM in mathematics learning can enhance 21st-century mathematical competencies, especially in critical thinking, communication, collaboration, creativity, and mathematical problem-solving skills (Saputri & Herman, 2022). This aligns with the results of this study, where the application of the Problem Based Learning (PBL) model integrated with STEM makes students more active in understanding. Students discuss in groups, formulate problem-solving strategies, and present answers in the form of visual, symbolic, and verbal representations, thereby enhancing their mathematical representation skills.

According to (Sumaji, 2019, as cited in Rahmawati & Juandi, 2022), through the STEM approach, students' mathematical abilities can be developed so that they can solve problems logically and systematically, as well as communicate and collaborate effectively. This is consistent with research findings where students become more active in discussions, expressing opinions, and explaining problem-solving steps during the learning process.

Learning using the PBL model integrated with STEM also creates a more engaging and less monotonous learning atmosphere. Students become more enthusiastic about participating in lessons because the problems presented are directly related to everyday life. Group discussion activities make students more confident in expressing their opinions and help them understand mathematical concepts through interaction with their peers. Additionally, student-centered learning encourages students to be more active in seeking information and finding solutions to the problems given by the teacher.

p-ISSN 2407-4489
e-ISSN 2528-7303

Thus, it can be concluded that the application of the Problem Based Learning (PBL) integrated with STEM can enhance students' mathematical representation skills on the topic of inverse proportionality. This improvement is evident from the results of the students' pretest and posttest, the gain scores obtained, and the changes in students' abilities to present mathematical ideas through visual, symbolic, and verbal representations. Problem-based learning combined with the STEM approach provides a more active, contextual, and meaningful learning experience, thereby helping students to better understand mathematical concepts.

The findings of this study have practical implications for mathematics learning in schools. Teachers can use the STEM-integrated PBL model as an alternative learning strategy to create more active and contextual learning environments. Through contextual problems and collaborative activities, students are encouraged to express mathematical ideas using visual, symbolic, and verbal representations. In addition, the integration of STEM can help students connect mathematical concepts with real-life situations and develop 21st-century skills such as collaboration, critical thinking, and creativity.

CONCLUSIONS

Based on the results of the research conducted, it can be concluded that the application of the STEM-integrated Problem Based Learning (PBL) model has a positive effect on students' mathematical representation abilities on inverse proportionality material. The improvement in students' abilities can be seen from the increase in the average pretest score from 9.29 to 28.93 in the posttest, although the average N-Gain score of 0.28 was still categorized as low. The implementation of the STEM-integrated PBL model encouraged students to become more active in discussions, collaboration, and contextual problem-solving activities. Students also showed improvement in presenting mathematical ideas through visual, symbolic, and verbal representations. Learning activities connected to real-life situations made mathematics learning more meaningful and student-centered.

However, this study still has limitations, particularly the absence of a control group and the relatively small sample size. Therefore, future researchers are recommended to conduct studies using experimental designs with larger samples and longer treatment durations to obtain more comprehensive findings regarding the effectiveness of STEM-integrated PBL. For mathematics teachers and educational practitioners, the STEM-integrated PBL model can be considered an alternative learning approach to improve students' mathematical representation abilities and support the development of 21st-century skills in classroom learning.

ACKNOWLEDGMENT

The authors would like to express their gratitude to Amir Hamzah National Education Junior High School for granting permission and providing support in the implementation of this research. The authors also thank the mathematics teacher and the seventh-grade students who participated in and supported the research process. Furthermore, the authors express their appreciation to all parties who provided assistance, support, and contributions that made this research possible. The authors also gratefully acknowledge those who supported the funding of this research publication.

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