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THE IMPLEMENTATION OF STEM-INTEGRATED PROBLEM-BASED LEARNING TO IMPROVE STUDENTS' MATHEMATICAL REASONING ABILITY

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Abstract: In the era of the industrial revolution 4.0, improving students' mathematical reasoning abilities is crucial. Student-centered, collaborative, contextual, and inclusive learning is key to facing this era. This study aimed to determine the improvement of the implementation of STEM-integrated problem-based learning on students' mathematical reasoning abilities. The population in this study were all VIII grade students of SMP Negeri 4 Bandar Lampung in the 2024/2025 academic year, which were distributed into 10 classes. The samples in this study were students of class VIII I as the experimental class and class VIII J as the control class, which were selected by a purposive random sampling technique. The research design used is the pretest-posttest control group design. Data on mathematical reasoning ability in quantitative data was collected through test instruments in the form of descriptions on the material of the system of linear equations of two variables. Data analysis used the Mann-Whitney U test. The test results indicate that the increase in mathematical reasoning abilities of students who participated in STEM-integrated problem-based learning was higher than that of students who took part in conventional learning. This study concludes that implementing learning with STEM-integrated, problem-based learning can improve students' mathematical reasoning abilities.
Keywords: mathematical reasoning ability; STEM-integrated problem-based learning

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Introduction

The industrial revolution 4.0 is an era that triggers innovation and new discoveries in various fields and drives rapid changes in multiple aspects of life rapidly (Adha, 2020). This change brings various consequences, one of which is the need for innovation and quality human resources (Zahra & Arifin, 2024). The development of technology in various fields has undergone transformations and developments that require individuals to have qualified and adaptive abilities (Irvan *et al*., 2025).

An individual's ability depends on the education they have received, so the role of education becomes very crucial. Education is a process of human efforts to build their potential, grow, and develop their innate potential both physically and spiritually in humans themselves (Adisaputro, 2020; Hariyanti *et al*., 2023). Education must be able to produce quality human resources so that they can face the rapid development of technology. Through education, humans are educated to have expertise and ability so that they become skilled, creative, innovative, and productive humans

In its implementation, education at each level contains a variety of lessons tailored to the applicable curriculum. One of the subjects taught at the primary and secondary education levels in accordance with the relevant curriculum in Indonesia is mathematics. As attached to Permendikbudristek No.7 of 2022 concerning Content Standards article 2, the lessons in the primary and secondary education curriculum, one of which is mathematics.

Mathematics is a very important subject because it has a very large role in shaping individuals who are intelligent, creative, and critical, which underlies the development of modern technology. This statement is in line with what was conveyed by Haejelia & Noer (2020), that learning mathematics is the first step in shaping science and technology in students. Mathematics is said to be the first step because mathematics is a conceptual tool that hones the thinking ability to solve problems in life

Under the Decree of the Head of the Education Standards, Curriculum and Assessment Agency of the Ministry of Education, Culture, Research and Technology Number 008/H/KR/2022, mathematics subjects have 6 objectives, namely, (1) mathematical understanding and procedural ability; (2) mathematical reasoning and proof); (3) mathematical problem solving; (4) mathematical communication and representation); (5) mathematical connections; and (6) mathematical disposition.

Based on the second point of the objectives of mathematics that have been set, mathematical reasoning is one of the important abilities that students must master. Mathematical reasoning is very important because this ability is the basis for developing a thinking process that is expected to support a person's ability to provide arguments from what is stated by connecting known facts (Srirahmawati, 2021). This statement is in line with Firdaus *et al.* (2021) that reasoning is needed in learning mathematics, because understanding mathematics requires reasoning ability.

It is known that mathematical reasoning ability is an important ability that students must master, but in reality, mathematical reasoning ability in Indonesia is still relatively low, as reflected in the low percentage of students' correct answers in the TIMSS international study, which contains aspects of knowledge, reasoning, and implementation (Mullis *et al.*, 2016). The problem that students' mathematical reasoning ability is still relatively lacking is also seen at SMPN 4 Bandar Lampung. Evidence supporting this statement is the results of the test conducted to determine the level of students' mathematical reasoning ability, which shows that students of SMPN 4 Bandar Lampung have low mathematical reasoning ability. The results of analyzing the answers of 32 students showed that only 11 students were able to answer the questions correctly (34.37%), while 21 other students (65.63%) were not able to answer correctly.

To overcome this problem, an effort is needed that can improve students' mathematical reasoning ability in the era of the industrial revolution 4.0. The characteristics of learning approaches that are by the era of the industrial revolution 4.0 include having learning materials that are associated with problems faced in everyday life, and facilitating student involvement in the social environment (Sinaga, 2023). In addition, to improve students' mathematical reasoning, a learning approach is also needed that makes students independent and active in learning, varies, and emphasizes the process so that students can draw conclusions based on valid proof (Mandasari, 2021). Based on these characteristics, learning with the STEM (science, technology, engineering, and mathematics) approach can be used as an alternative learning approach that facilitates the ability needs of the industrial revolution 4.0 era.

The STEM approach is one alternative approach when implementing mathematics learning that can be implemented to facilitate mathematical reasoning ability (Putri & Juandi, 2023). Through the STEM approach, education that upholds the quality of learning ability can be realized, namely critical thinking, creative, innovative, and the ability to communicate and collaborate (Rahmadhani *et al*., 2023). STEM integration is carried out in every discipline involving aspects of science, technology, engineering, and mathematics (Rohendi *et al*., 2023).

As a learning approach, STEM requires a model in its implementation. (Mulyani, 2019; Syazali, 2022) state that STEM-based learning can be integrated with several learning models, including

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cooperative, PBL, PjBL, and other learning models. The PBL model facilitates students in developing their mathematical reasoning ability. According to Ni'mah *et al*. (2024) & Sari *et al*. (2022), PBL makes it easy for students to develop their mindset and ability to solve problems and facilitates students as active and independent learners. The PBL model can stimulate students' mathematical reasoning ability because the PBL model provides a stimulus for students to think at a high level to solve real problems, so that students will use their mathematical reasoning ability (Kotto *et al*., 2022).

In implementing the PBL model, the teacher, as a facilitator, will provide several problems that trigger students to use their reasoning ability to solve the problems given (Marthaliakirana *et al*., 2022; Puspita & Purbo, 2024; Wardani, 2023). So, further and extensive studies are needed regarding the implementation of STEM-integrated problem-based learning to improve students' mathematical reasoning ability. This study aims to present quantitative data of research regarding STEM-integrated with problem-based learning.

Method

This research was conducted from October 14 to November 8, 2024, during the odd semester of the 2024/2025 school year at SMPN 4 Bandar Lampung. The population in this study were all VIII grade students of SMPN 4 Bandar Lampung as many as 285 which were distributed in 10 classes, namely classes VIII A - VIII J. Sampling was carried out by purposive random sampling and VIII I class was selected as many as 33 students as the experimental class and VIII J class as many as 32 students as the control class.

This research is a quasi-experimental study involving one independent variable, namely the learning approach, and one dependent variable, namely students' mathematical reasoning. Data collection techniques using test techniques. The design used is a pretest-posttest control group design. This research design is designed to produce normalized improvement data (N-gain). The test is in the form of description questions that are prepared based on mathematical reasoning indicators with the material of the Two-Variable Linear Equation System.

In its implementation, this research was organized into three stages. The first stage is the preparation stage. At this stage, observations were made to determine the characteristics of the population under study and then determine the material to be used. In addition, at this stage, the preparation of devices and instruments was also carried out, which were then communicated with the supervisor and mathematics teacher at school. The second stage is the implementation stage. At this stage, the pretest was given on the first meeting, then the treatment was given as a learning process, and the learning process was closed by giving the posttest on the last meeting. The treatment given to class VIII I as the experimental class is learning using problem-based learning integrated with STEM. In contrast, class VIII J as the control class is given treatment in the form of learning with a scientific approach using the PBL model. The last stage is the final stage. At this stage, the data from the pretest and posttest results are processed and analyzed.

Before analyzing the data, a prerequisite test was carried out, namely the normality test. After conducting the normality test, it is known that the sample comes from a population that is not normally distributed. Because the sample comes from a population that is not normally distributed, the non-parametric test, the Mann-Whitney U Test, is used in hypothesis testing.

Results and Discussion

Results

1. **Pre-test Data of Students' Mathematical Reasoning Ability**

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The analysis was conducted on the initial data of students' mathematical reasoning ability in the experimental class and control class obtained from the *pretest* score. Based on the data collection results, the initial data of students' mathematical reasoning ability are obtained as presented in Table 1.

Table 1. Pre-test Data of Students' Mathematical Reasoning Ability

Class	Students	Lowest Score	Highest Score	Average	Std. Deviation
Experimental	33	0	17	9,76	4,29
Control	32	1	16	5,31	3,44

Ideal maximum score = 35

The data in Table 1. shows there is a difference in the average initial data of mathematical reasoning ability in experimental and control class students. In the experimental class, the average initial mathematical reasoning ability of students tends to be higher than in the control class. Furthermore, it can also be observed that the standard deviation in the experimental class is higher than the control class. This shows that the initial data of students' mathematical reasoning ability in the experimental class is more diverse than the control class students.

2. Post-test Data of Students' Mathematical Reasoning Ability

The final data of students' mathematical reasoning ability in the experimental and control classes were obtained from the post-test scores. Based on the data collection results, the final data of students' mathematical reasoning ability are presented in Table 2.

Table 2. Post-test Data of Students' Mathematical Reasoning Ability

Class	Students	Lowest Score	Highest Score	Average	Std. Deviation
Experimental	33	9	33	23,24	6,63
Control	32	8	30	17,66	5,56

Ideal maximum score = 35

The data in Table 2 shows the difference in the average final mathematical reasoning ability between experimental and control class students, with the experimental class average being higher. In addition, the experimental class data also showed greater variation (higher standard deviation) than the control class.

3. Gain Data of Students' Mathematical Reasoning Ability

Data on students' mathematical reasoning ability gain were obtained from the pretest and posttest scores. The data was used to determine the improvement of students' mathematical reasoning ability in experimental and control classes. The recapitulation of students' mathematical reasoning ability gain data is presented in Table 3.

Table 3. Gain Data of Students' Mathematical Reasoning Ability

Class	Students	Lowest Gain	Highest Gain	Average	Std. Deviation
Experimental	33	0,19	0,91	0,55	0,21
Control	32	0,05	0,84	0,41	0,20

Ideal maximum gain = 1.00

Based on Table 3, the average gain in mathematical reasoning ability of experimental class students is higher than the control class, indicating a greater improvement. The standard deviation is

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also higher in the experimental class, indicating a more diverse variation in ability improvement compared to the control class.

4. Research Hypothesis Test Results

Based on the results of the normality test, it was found that the gain data of students' mathematical reasoning ability in the experimental class who participated in STEM-integrated problem-based learning and the control class who participated in conventional learning came from a population that was not normally distributed. Therefore, the hypothesis test was conducted using a non-parametric statistical test, namely the *Mann-Whitney U* test as referred to in Table 4.

Table 4. Hypothesis Test Results of Students' Mathematical Reasoning Ability Gain Data

Research Data	Students	z_{count}	$-z_{tabel}$	Test Decision
Gain Data of Students' Mathematical Reasoning Ability	65	$-2{,}55$	$-1{,}65$	H_0 rejected

Based on the results of the calculations that have been carried out, it is obtained that $z_{count} = -2.55$ and $-z_{table} = -1.65$, because $z_{count} < -z_{table}$ then H_0 is rejected. Thus, the median *gain* data of students' mathematical reasoning ability between students who participated in STEM-integrated problem-based learning is higher than that of students who participated in conventional learning (scientific approach). This shows that the increase in students' mathematical reasoning ability in the class that participated in STEM-integrated problem-based learning is higher than that of students who participated in learning with a scientific approach.

The results of hypothesis testing are also supported by the results of the analysis of the achievement of indicators of students' mathematical reasoning ability. The analysis aims to determine student achievement on each indicator. Each indicator was analyzed on the *pretest* and *posttest* score data. The results of the analysis of the achievement of each indicator of students' mathematical reasoning ability are presented in Table 5.

Table 5. Analysis of Achievement of Students' Mathematical Reasoning Ability Indicators

Indicator	Experiment Class		Control Class	
	Initial	End	Initial	End
Conjecturing	50%	84,85%	10,16%	74,22%
Performing mathematical manipulation	8,59%	61,62%	11,46%	38,54%
Expressing mathematical statements orally	42,42%	79,55%	36,72%	64,06%
Providing evidence for a truth	28,96%	70,37%	17,71%	51,04%
Checking the truth of a statement	35,35%	68,69%	10,42%	48,44%
Summarizing a statement	15,15%	39,39%	8,33%	37,50%

Based on Table 5, the achievement of each indicator of students' mathematical reasoning ability in experimental and control classes has increased. The increase in indicators of students' mathematical reasoning ability in the experimental class tends to be higher than the control class on several indicators. However, in the last indicator, namely concluding a statement, the achievement percentage of the final indicator from both classes tends to be the same. This is because PBL with a STEM approach and PBL with a scientific approach provide opportunities for students to practice concluding. In the STEM approach, this activity occurs at the society stage, while in the scientific approach, this activity takes place at the communicating stage.

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Discussion

Based on the results of the analysis of the data from the research that has been done, it is found that the improvement of the mathematical reasoning ability of students who participated in learning with the STEM approach is higher than students who participated in conventional learning. Technological assistance in STEM, such as Geogebra and Canva used in this study, was able to support the improvement of students' mathematical reasoning ability. The results of this analysis are in line with the findings in the research of Putri & Juandi (2023) that the use of implementation technology or STEM-based *software* can help students understand the material and improve students' mathematical reasoning ability, so that the mathematical reasoning ability of students who learn with learning with the STEM approach are better than students who learn with conventional learning. Thus, it can be concluded that learning with the STEM approach can improve students' mathematical reasoning ability.

In terms of the overall achievement of students' mathematical reasoning ability indicators, the percentage of indicator achievement of students who participated in STEM-integrated problem-based learning was higher than students who participated in conventional learning. Of the five indicators studied, the highest indicator achievement was the conjecture indicator. Students who participated in STEM-integrated problem-based learning are able to formulate possible solutions according to their initial abilities better than students who participated in conventional learning. This is because students who participated in STEM-integrated problem-based learning are motivated to observe the real problems given in the LKPD and then describe the things that will be done to solve the problem. Thus, students are accustomed to analyzing information and making conjectures as solutions. This statement is reinforced by Jannah *et al*. (2020), that the ability to make conjectures can be strengthened by giving problems that train students to estimate the solution.

Through the stages in learning with problem-based learning integrated with STEM, students are given the opportunity to be able to make conjectures, be able to perform mathematical manipulations, be able to express mathematical statements orally, in writing, pictures, or diagrams, be able to provide reasons or evidence for a truth, be able to check the truth of a statement, and be able to conclude a statement. Thus, students are passive recipients of information and active actors in building their knowledge. Through STEM learning that is relevant to real life, students can see how mathematical concepts are applied in various contexts, thus increasing learning motivation and learning relevance (Dare *et al*., 2021; Sadea, 2024). This encourages students to develop a deeper understanding of mathematical concepts and improve their reasoning ability. Based on this explanation, it is expected that students' mathematical reasoning ability can develop significantly with the implementation of the STEM approach.

The STEM approach, although it has many advantages, also has weaknesses that need to be considered. One of the main challenges in implementing STEM-integrated problem-based learning is the complexity of integrating the entire PBL syntax in one meeting. This is due to the complexity of STEM stages that often require more time for exploration and investigation. In this study, the entire syntax of STEM-integrated problem-based learning can only be fully implemented in meetings after students have a better understanding of the basic concepts and experimental procedures. This time limitation can be an obstacle, especially in the context of a tight curriculum.

Several other obstacles are faced during the implementation of STEM-integrated problem-based learning, including some students still having difficulty using implementations that support learning. This is because the use of technology in learning is still unfamiliar to students, so teachers play an important role in introducing the implementations used to students. The use of the Canva implementation on smartphones was chosen to encourage students to improve their ability to work together and share ideas through the collaboration features provided by (Sihombing *et al*., 2024).

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The treatment given to the control class was conventional learning. The conventional learning in question is learning using the PBL model with a scientific approach. Mathematics learning using the PBL model with a scientific approach has a lower effect on mathematical reasoning ability than learning with STEM-integrated problem-based learning because during the learning process, students are passive in several stages of the PBL-Scientific model.

The results of the analysis of the achievement of indicators of students' mathematical reasoning ability support the results of hypothesis testing. The percentage of achievement of mathematical reasoning ability indicators showed a higher increase in STEM-integrated problem-based learning compared to conventional learning (scientific approach). This is the effect of each stage of the STEM-integrated problem-based learning model (Putri & Juandi, 2023). All stages of problem-based learning integrated with STEM require students to be active gradually and continuously to find solutions to problems related to STEM. Thus, students can develop their logic and reasoning ability.

Conclusion

Based on the results of research and discussion, the improvement of the mathematical reasoning ability of students who participated in STEM-integrated problem-based learning is higher than the improvement of the mathematical reasoning ability of students who participated in conventional learning. Thus, the implementation of STEM-integrated problem-based learning can improve the mathematical reasoning ability of students in grade VIII of SMP Negeri 4 Bandar Lampung in the 2024/2025 academic year.

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