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DEEP LEARNING FOR ENHANCING MATHEMATICAL REASONING SKILLS IN VOCATIONAL HIGH SCHOOL STUDENTS

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ABSTRACT

Mathematical reasoning ability is an essential competence in mathematics learning, as it enables students to analyse patterns, formulate conjectures, construct logical arguments, and draw systematic conclusions. However, studies indicate that this ability, particularly among vocational high school (SMK) students, remains relatively low due to learning practices that emphasize procedures and formula memorization rather than deep conceptual understanding. Therefore, an appropriate learning approach is needed to promote critical and reflective thinking. This study aims to examine the effectiveness of the Deep Learning approach in improving the mathematical reasoning abilities of tenth-grade vocational high school students. A quantitative approach with an experimental method and a pretest–post-test control group design was employed. The subjects consisted of two classes selected through cluster random sampling: an experimental class receiving the Deep Learning approach and a control class receiving conventional instruction. The instrument was a mathematical reasoning test administered before and after learning. Data were analysed using descriptive statistics, followed by normality, homogeneity, and t-tests. The results showed that the experimental class achieved a higher average post-test score, with a significance value of 0.000 < 0.05, indicating a significant difference. Thus, the Deep Learning approach is effective in improving students' mathematical reasoning abilities.

Kemampuan penalaran matematis merupakan kompetensi penting dalam pembelajaran matematika karena membantu siswa menganalisis pola, membuat dugaan, menyusun argumen logis, serta menarik kesimpulan secara sistematis. Namun, berbagai penelitian menunjukkan bahwa kemampuan ini, khususnya pada tingkat Sekolah Menengah Kejuruan (SMK), masih tergolong rendah. Hal ini disebabkan oleh proses pembelajaran yang berfokus pada prosedur dan hafalan rumus tanpa pemahaman konsep secara mendalam. Oleh karena itu, diperlukan pendekatan pembelajaran yang mampu mendorong siswa untuk berpikir lebih kritis dan reflektif. Penelitian ini bertujuan untuk mengetahui efektivitas pendekatan *Deep Learning* dalam meningkatkan kemampuan penalaran matematis siswa kelas X SMK. Penelitian menggunakan pendekatan kuantitatif dengan metode eksperimen dan *pretest-posttest control group design*. Subjek penelitian terdiri dari dua kelas yang dipilih melalui teknik *cluster random sampling*, yaitu kelas eksperimen dengan pendekatan *Deep Learning* dan kelas kontrol dengan pembelajaran konvensional. Instrumen berupa tes kemampuan penalaran matematis yang diberikan sebelum pembelajaran dan setelah pembelajaran. Analisis data meliputi statistik deskriptif, uji normalitas, homogenitas, dan uji t. Hasil menunjukkan rata-rata nilai *post-test* kelas eksperimen lebih tinggi dibandingkan kelas kontrol, dengan nilai signifikansi sebesar 0,000 < 0,05. Dengan demikian, dapat disimpulkan bahwa pendekatan *Deep Learning* efektif meningkatkan kemampuan penalaran matematis siswa.

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INTRODUCTION

Mathematics is a very important subject in the world of education in Indonesia, because it can help students develop logical, critical and analytical thinking skills(Schoenfeld, 1992). Mathematics education plays a crucial role in developing students' logical, analytical, and systematic thinking skills. Understanding the fundamental principles of mathematics is important for developing rational thinking, reflecting the essential characteristics of mathematics, and permeating its generation, development, and application (Tang & Pereira, 2025). One crucial aspect of mathematics learning is mathematical reasoning. This ability helps students process information, draw conclusions, make generalizations, and solve problems logically and systematically (Wahyudi, 2025b).

According to the Ministry of National Education in Shadiq (2004) Mathematics and mathematical reasoning are closely related, as mathematical understanding is built through reasoning, and reasoning itself can be understood and practiced through mathematics learning. Mathematical reasoning is the cognitive process of articulating ideas, proving statements, solving problems, and drawing conclusions from the problem-solving process (Faridah & Marlina, 2025). Reasoning plays a crucial role in constructing mathematical knowledge. Furthermore, reasoning also plays a crucial role in the process of solving mathematical problems. Therefore, reasoning skills are crucial for students, both in the context of mathematics learning and in everyday life (Octriana et al., 2019).

According to the Education Unit Level Curriculum (Depdiknas, 2006), the objectives of mathematics learning in schools at the elementary and secondary levels are for students to be able to: 1) Understand mathematical concepts and apply them effectively in problem solving. 2) Use mathematical reasoning to make generalizations, construct proofs, and explain mathematical ideas. 3) Solve problems by being able to understand, design mathematical models, and interpret solutions. 4) Communicate mathematical ideas through symbols, tables, diagrams, or other media. 5) Develop positive attitudes toward mathematics, such as curiosity, perseverance, and confidence in problem solving. Thus, students are expected to be able to master mathematical concepts and develop critical, analytical, and creative thinking skills in solving problems (Riyanto, 2011).

Mathematical reasoning encompasses more than just calculation and analytical skills. It involves various important processes, such as gathering evidence, analyzing data, making conjectures, constructing strong arguments, drawing logical conclusions, and definitively proving the truth of a statement. Furthermore, mathematical reasoning also involves developing, proving, and applying mathematical generalizations that connect various concepts in mathematics. Thus, mathematical reasoning relies on existing knowledge and rules in mathematics to build a deeper understanding (Susilowati, 2016).

In this era of globalization and the Industrial Revolution 4.0, higher-order thinking skills such as mathematical reasoning are increasingly necessary, including for students at vocational education levels such as Vocational High Schools (SMK). Mathematical reasoning enables students not only to use mathematical techniques routinely, but also to understand concepts, draw general conclusions, and demonstrate logical arguments. Research shows that students' mathematical reasoning abilities in vocational high schools are still lacking, for example, they tend to use imitative reasoning more often than creative reasoning (Fatimah, 2021).

Amidst technological advances and the demands of 21st-century skills, mathematics education in vocational secondary schools (SMK) faces the challenge of developing reasoning skills that not only support understanding of basic concepts but also practical application in students' fields of expertise. Mathematical reasoning is a crucial foundation for Year 10 SMK students, as this ability enables them to connect mathematical concepts with vocational subjects such as mechanical engineering, accounting, or information technology. However, reality shows that many SMK students still experience difficulties in developing deep mathematical reasoning, partly due to a learning approach that still focuses on memorization and procedures without paying attention to conceptual (Afifah et al., 2023).

Mathematical reasoning is a crucial skill in learning mathematics and other sciences. It enables students to analyze, evaluate, and solve mathematical problems more efficiently (Shafira et al., 2023). However, many students in high school and vocational high schools still struggle to develop their mathematical reasoning skills. One factor affecting students' mathematical reasoning abilities is the learning approach used. This approach, which generally involves lectures and practice problems, is less effective in improving students' mathematical reasoning abilities (Rohmah, 2021). Mathematical reasoning is crucial for high school students to possess, as it aligns with the vision of mathematics to prepare students for future needs. According to Sumarmo (2010) in (Hendriana et al., 2021) mathematics learning aims to develop awareness of the benefits of mathematics and foster self-confidence through an objective attitude in facing changing times. Therefore, a more innovative and effective learning approach is needed to improve students' mathematical reasoning abilities.

Deep learning is an effective and efficient learning approach because it aims to create high-quality and meaningful learning. Assessment in deep learning is conducted comprehensively, from planning to completion, to monitor student progress. This approach aligns with the development of 21st-century skills, which emphasize the ability to analyze, evaluate, and create. Thus, deep learning can optimize students' competencies in understanding and applying the knowledge they have learned (Nugraha & Hasanah, 2021). Deep learning is a learning approach that can be used to improve students' mathematical reasoning skills. It focuses on a deeper and more complex understanding of concepts and the ability to apply those concepts to broader situations (Swawikanti, 2024). By using a deep learning approach, students can understand mathematical concepts better and can improve their mathematical reasoning abilities.

Deep learning is a learning approach that encourages students to think deeply and meaningfully. Rather than simply memorizing information, students who use this approach strive to understand concepts conceptually, connect new ideas with prior knowledge, and apply the knowledge gained to new situations or everyday life. According to (Biggs & Tang, 2011) and (Marton & Saljo, 1976) Deep learning involves higher-order thinking processes such as searching for meaning, using evidence and logic, and reflecting on one's own thinking processes. Thus, deep learning can foster critical thinking, problem-solving, creativity, and reasoning skills (Suryadi, 2025).

Deep learning is a learning method that uses multiple layers of representation to understand data. Each layer transforms the data into a more abstract and complex representation, allowing for the learning of highly complex functions. In classification tasks, higher layers enhance important features and eliminate irrelevant information. For example, in image recognition, the first layer might detect edges, the second detect patterns, and the third recognize objects as combinations of these patterns. What is unique about deep learning is that these features are not designed by humans but are instead learned from data using general learning algorithms. Thus, deep learning can discover complex patterns in data without the need for human intervention (LeCun et al., 2015).

Although the application of Deep Learning in education has been widely researched at the elementary education level (Barokah & Mahmudah, 2025) and general high school students, studies specifically exploring the mathematical reasoning process of vocational high school students in deep learning-based learning are still limited. Mathematics learning at the vocational high school (SMK) level requires not only procedural mastery but also strong mathematical reasoning skills so that vocational high school graduates can apply mathematical concepts in real vocational contexts. Mathematical reasoning skills include aspects that are important indicators in assessing the depth of mathematical understanding in vocational high school students, such as the ability to formulate, connect concepts, prove, and validate mathematical arguments (Adiputra & Putri, 2022). Descriptive research in the context of vocational schools shows variations in reasoning abilities between groups of students and identifies the need for learning strategies that can foster these mathematical reasoning abilities (Gultom et al., 2022).

Several studies have shown that active student involvement in the learning process directly impacts improved mathematical reasoning skills. Modeling the learning process that focuses on reflection, conceptual understanding, and critical thinking skills can help students develop stronger mathematical arguments (Khardita & Agoestanto, 2023). In recent years, a pedagogical approach called deep learning (not in the sense of artificial intelligence techniques, but rather as an approach to in-depth learning such as mindful, meaningful, and joyful) has received attention in educational research in Indonesia because it has the potential to increase engagement, conceptual understanding, and critical thinking skills in students. (Mutmainnah et al., 2025). The implementation of a deep learning approach in mathematics classrooms has been reported to improve conceptual understanding and critical thinking skills at various levels. While most studies have focused on general elementary and secondary education, this opens up an opportunity to explore how deep learning principles can be translated into the context of vocationally oriented vocational schools (Rosiyati et al., 2025).

However, empirical evidence directly linking vocational high school students' mathematical reasoning processes to learning practices based on deep learning principles remains limited. Most previous studies have focused on describing the level of reasoning achievement or assessing the effectiveness of traditional learning models, such as problem-based learning and discovery learning, on reasoning outcomes (Ariati & Juandi, 2022). Without a detailed analysis of cognitive, metacognitive strategies, and social interactions in the reasoning process when a deep learning approach is implemented, this gap leaves important questions about how vocational high school students' mathematical reasoning processes occur during mathematics learning that applies deep learning principles, and which aspects are most effective in stimulating students' mathematical thinking through this approach (Sudarmono et al., 2025).

In response to the demands of 21st-century learning, deep learning has been adopted as a pedagogical approach that emphasizes in-depth understanding of material through active student engagement, metacognitive reflection, and complex problem-solving. In the educational context, deep learning refers not only to artificial intelligence technology, but rather to a learning strategy that encourages students' cognitive and affective engagement with the concepts being studied, resulting in meaningful and sustainable internalization of knowledge. This approach encompasses the principles of meaningful learning, mindful learning, and joyful learning, designed to deepen students' understanding of the subject matter (Dewi et al., 2025). Several empirical studies have demonstrated the effectiveness of applying deep learning in mathematics. For example, the deep learning approach has been shown to improve students' mathematical reasoning skills compared to conventional learning and other learning models. (Dahroni et al., 2025). These findings indicate that students who are guided through learning with deep learning principles tend to show significant improvements in reflective thinking and complex problem solving (Wahyudi, 2025).

In previous research conducted by Senad Orhani, he revealed that immersive learning has proven to have significant potential to transform students' learning styles, enhance their learning experiences, and enhance their math skills. However, this utilization must be carried out carefully and appropriately, including assessing the needs and challenges of each learning context (senad Orhani, 2024). Research conducted by Dahroni et al ., (2025) stated that Deep Learning-based learning is proven to be significantly more effective than differentiated learning in improving students' mathematical reasoning problem-solving abilities. Using a deep learning approach allows students to understand mathematical concepts better and can improve their mathematical reasoning abilities.

Various previous studies have shown that the application of deep learning in education contributes positively to the personalization of learning and improved learning outcomes. A study by Naseer et al., (2024) developed a deep learning-based adaptive learning platform in higher education and demonstrated significant improvements in student academic achievement, engagement, and learning satisfaction. This research emphasizes the power of deep learning in analyzing learning performance data to tailor individual learning pathways, but its primary focus remains on the context of higher education and general cognitive achievement, rather than specific mathematical reasoning abilities.

In line with this, research on deep learning-based adaptive e-modules for vocational students focuses more on aspects of media design, visual effectiveness, and improving general conceptual understanding (Feriyadi et al., 2025). This approach has been shown to support independent learning and adapt to students' learning styles, but has not explicitly measured or analyzed the processes and indicators of mathematical reasoning ability as the main goal of learning (Pamungkas et al., 2024). Other research examining personalized learning using machine learning and deep learning also confirms that adapting content to students' characteristics and learning styles can improve motivation and learning outcomes. However, most of these studies focus on the technical aspects of adaptive systems, personalized learning pathways, or global academic performance, and many are conducted in higher education or cross-disciplinary learning contexts, rather than mathematics learning in vocational schools (Villegas et al., 2024).

Based on this review, a clear research gap exists: the limited number of empirical studies specifically testing the effectiveness of deep learning on mathematical reasoning skills, particularly in 10th-grade vocational high school students, who have different learning characteristics and vocational needs than high school and college students. Previous research has not deeply linked the adaptive mechanisms of deep learning to mathematical reasoning indicators such as making conjectures, developing arguments, and drawing logical conclusions.

Therefore, this study positions itself as a development and strengthening of previous studies by focusing on: (1) the context of secondary vocational education, (2) specific mathematics learning, and (3) measuring mathematical reasoning ability as the main variable. Thus, this study is expected to provide more specific theoretical and empirical contributions regarding the role of deep learning in improving the quality of mathematical thinking of vocational high school students.

METHOD

This research used a quantitative approach with experimental methods. The research design used was a pretest-posttest control group design. The study involved two groups an experimental class that received instruction using the Deep Learning approach and a control class that received conventional instruction (Sugiyono, 2016). The research subjects were 10th-grade vocational high school students selected using cluster random sampling. The research instrument used was a mathematical reasoning ability test administered before and after learning (pretest) and after learning (posttest). The reasoning indicators used, as seen in the following table:

Table 1. Mathematical Reasoning Ability Question Grid

Question Number	Mathematical Reasoning Indicators
1	Analyze patterns and relationships between terms in a sequence.
2	Using mathematical models to check the truth of a statement and draw logical conclusions based on the results of calculation evaluations.
3	Construct mathematical models of contextual situations, use deductive reasoning to find solutions, and generalize results to similar cases,

Source: (Sumarmo, 2013)

The research data were analyzed using descriptive statistics to determine the students' mathematical reasoning abilities. Subsequently, prerequisite tests namely normality and homogeneity tests, were conducted. A t-test was used to determine the differences in mathematical reasoning abilities between the experimental and control classes.

RESULTS AND DISCUSSION

Result

Data on pupils' mathematical reasoning skills were obtained through pre-tests and post-tests administered to the experimental and control classes. The results of the descriptive statistical analysis are presented in the table below.

Table 2. Descriptive Statistics for Pre-test and Post-test score

	N	Minimum	Maximum	Mean	Std. Deviation
Pre Test Experiment	30	60	70	65.00	2.877
Post Test Experiment	30	73	83	78.00	2.877
Pre Test Control	30	59	69	64.00	2.877
Post Test Control	30	65	74	69.77	2.582
Valid N (listwise)	30				

Table 2 shows that the average pre-test score for the experimental class was 65.00 and for the control class 64.00 This indicates that the initial abilities of the two classes were relatively similar. After the learning intervention, the average post-test score in the experimental class increased to 78.00, whilst that of the control class was 69.77 Thus, the improvement in mathematical reasoning ability among students in the experimental class was greater than that in the control class. A normality test was conducted to determine whether the research data are normally distributed. The normality test utilized the Kolmogorov–Smirnov test with the aid of statistical software. The results of the normality test are presented in Table 3.

Table 3. Tests of Normality

		Kolmogorov-Smirnov[a]			**Shapiro-Wilk**		
	Class	**Statistic**	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Student Learning Achievement	Pre Test Experiment	.103	30	.200*	.961	30	.330
	Post Test Experiment	.103	30	.200*	.961	30	.330
	Pre Test Control	.103	30	.200*	.961	30	.330
	Post Test Control	.150	30	.082	.944	30	.114

Table 3 shows that the normality test results using the Kolmogorov Smirnov and Shapiro Wilk tests show that all data, both pre-test and post-test scores in the experimental and control classes are normally distributed. This is indicated by all significance (Sig.) values being greater than 0.05, meaning that the null hypothesis of normal distribution is accepted. The fulfillment of this assumption indicates that the data are suitable for further analysis using parametric statistical tests. Therefore, the analysis can be continued to the next stage, namely testing the homogeneity of variances between the two groups. A homogeneity test was conducted to determine whether the variances of the two groups were equal or not. The results of the homogeneity test are presented in Table 4.

Table 4. Test of Homogeneity of Variance

		Levene Statistic	**df1**	**df2**	**Sig.**
Student Learning Achievement	Based on Mean	.308	1	58	.581
	Based on Median	.390	1	58	.535
	Based on Median and with adjusted df	.390	1	57.339	.535
	Based on trimmed mean	.329	1	58	.568

The homogeneity of variances was tested using Levene's test, with the criterion that if the significance level (Sig.) is greater than 0.05, the variances between groups are homogeneous. All significance levels were greater than 0.05, indicating that the variances in students' learning outcomes between groups are homogeneous. A hypothesis test was conducted using an independent samples t-test to determine whether there was a significant difference between the mathematical reasoning abilities of students in the experimental class and the control class. The results of the t-test are presented in Table 5.

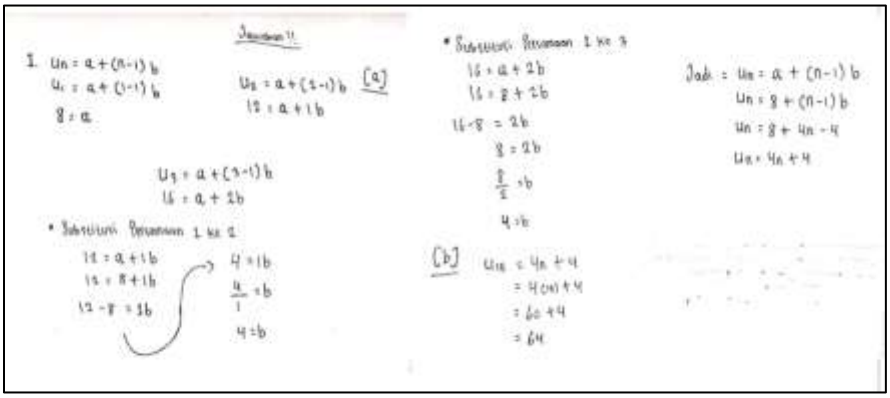
Table 5. Results of the Independent Samples t-test

	t-test for Equality of Means						
	t	**Df**	**Sig. (2-tailed)**	**Mean Difference**	**Std. Error Difference**	**95% Confidence Interval of the Difference Lower**	**Upper**

Student Learning Achievement	Equal variances assumed	11.666	58	.000	8.233	.706	6.821	9.646
	Equal variances not assumed	11.666	57.336	.000	8.233	.706	6.820	9.646

From the test results, the Sig. (2-tailed) value = 0.000 < 0.05, so H_o is rejected and H_a is accepted. Consequently, there was a significant difference in student learning outcomes between the two groups under study, with one group achieving a higher average score than the other. This means that the Deep Learning approach yields significantly higher student learning outcomes than the conventional approach.

The following are the post-test results for students using the deep learning and conventional learning methods. The post-test results were similar for both the deep learning and conventional learning methods. Both used the same arithmetic sequence formulas: $un = a + (n-1)b$ dan $S_n = \frac{2}{n}(2a + (n-1)b)$.



Translate:
Answer!!

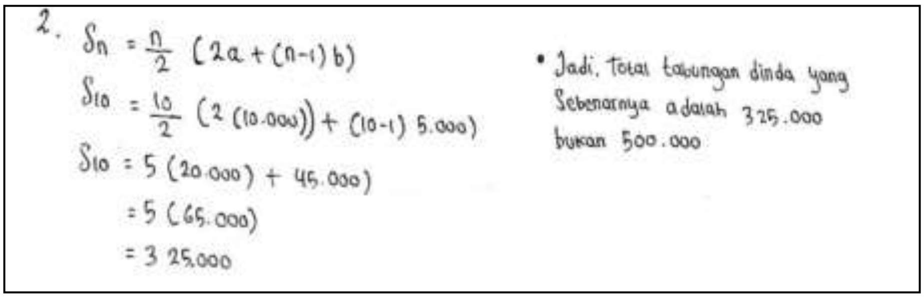
Substitute equation (1) into equation (2).

Substitute equation (1) into equation (3).

Therefore,

Figure 1. Student Post-Test Answer Results

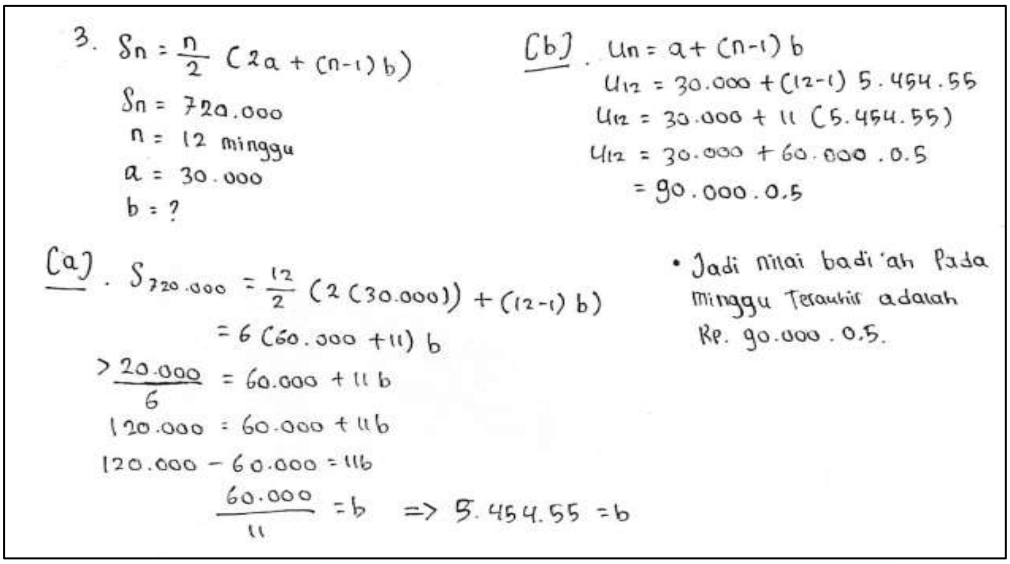
Based on the analysis of the answers, students were able to recognize sequence patterns, use mathematical models appropriately to verify calculations, and construct general sequence formulas. However, deductive reasoning and pattern explanations were not yet demonstrated in depth. Overall, students' mathematical reasoning skills were good, but they still needed improvement in generalization and logical explanation.



Translate:
Therefore, Dinda's actual total savings amount to Rp325,000, not Rp500,000.

Figure 2. Student Post-Test Answer Results

The student was able to correctly determine Dinda's savings using the arithmetic sequence formula. He was able to identify the value of the first term, a = 10,000, and the difference, b = 5,000. And the number of weeks n = 10. By applying the formula $S_n = \frac{n}{2}(2a + (n-1)b)$. And the student obtained a total savings of Rp 325,000 and concluded that Dinda's claim of a total of Rp 500,000 was wrong. Although the calculation was correct, the student did not show the process of checking the pattern of each term and immediately used the formula without verifying the suitability of the model. However, overall, the student's answer was correct and his reasoning was quite good in using mathematical models to evaluate a statement.

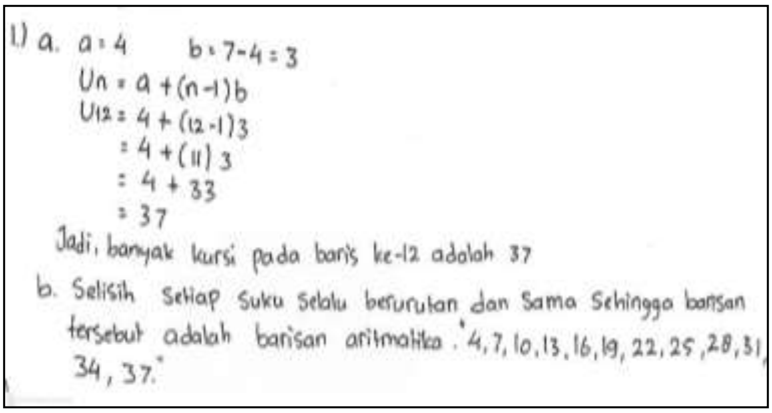


Translate: *Therefore, the value of badi'ah in the final week is Rp90,000.05.*

Figure 3. Student Post-Test Answer Results

The student was able to build a mathematical model of a contextual situation quite well. He recognized that the prize value that increases each week forms an arithmetic sequence. By using the formula for the sum of the sequence: $S_n = \frac{n}{2}(2a + (n-1)b)$. To find the amount of the prize increase per week b, using the total budget information of Rp720,000. and the student successfully determined the values of a = 30,000, n = 12, S12 = 720,000. and then obtained the correct value of b through substitution and algebraic manipulation.

Furthermore, the student also successfully determined the prize value in the 12th week using the formula for the nth term: $U_n = a + (n-1)b$. Although there were some parts that were written less neatly or a little confusing, the student's main steps were precise and logical. This shows that the student is able to perform deductive reasoning, build models, solve problems and draw conclusions correctly. The following are the results of the pre-test answers of students who used the deep learning and conventional learning methods. Both pre-test results did not differ much from those who used the deep learning and conventional learning methods. Both used the same arithmetic sequence formula, namely $un = a + (n-1)b$ and $S_n = \frac{2}{n}(2a + (n-1)b)$.



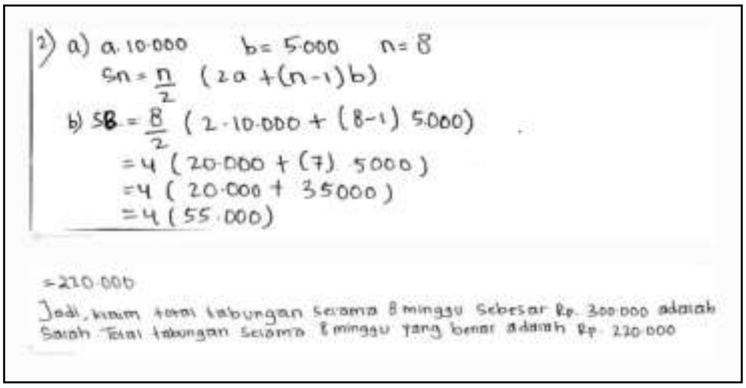
1) a. a = 4 b = 7 − 4 = 3
Un = a + (n−1)b
U12 = 4 + (12−1)3
= 4 + (11) 3
= 4 + 33
= 37
Jadi, banyak kursi pada baris ke-12 adalah 37
b. Selisih setiap suku selalu berurutan dan sama sehingga barisan tersebut adalah barisan aritmatika. "4, 7, 10, 13, 16, 19, 22, 25, 28, 31, 34, 37."

Translate:

a. *Therefore, the number of chairs in the 12th row is 37.*
b. *The difference between each term is constant, indicating that the sequence is an arithmetic sequence: 4,*

Figure 4. Student Pre-Test Answer Results

The student was able to identify that the difference between the terms is always constant, namely 3, and concluded that this is an arithmetic sequence. This demonstrates an understanding of the pattern in the sequence. However, the student incorrectly identified the first term, namely a = 4. The first term of the given sequence is 4. Therefore, the student has the ability to analyze the pattern, but is less thorough in identifying the basic elements of the sequence.



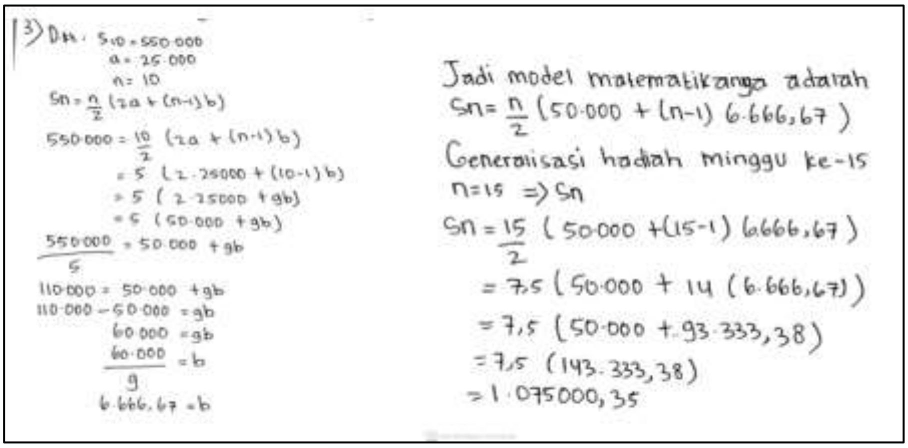
2) a) a 10.000 b = 5.000 n = 8
Sn = n/2 (2a + (n−1)b)
b) S8 = 8/2 (2·10.000 + (8−1) 5.000)
= 4 (20.000 + (7) 5000)
= 4 (20.000 + 35000)
= 4 (55.000)
= 220.000
Jadi, klaim total tabungan selama 8 minggu sebesar Rp. 300.000 adalah salah. Total tabungan selama 8 minggu yang benar adalah Rp. 220.000

Translate:

Therefore, the claim that the total savings over 8 weeks amount to Rp300,000 is incorrect. The correct total savings over 8 weeks are Rp220,000.

Figure 5. Student Pre-Test Answer Results

Students demonstrate strong mathematical reasoning skills in the context of the sum of terms in an arithmetic sequence. They understand the concept of patterns, are able to select and use appropriate formulas, perform calculations correctly, and are able to construct mathematical models from contextual situations.



3) Dik. S10 = 550.000
a = 25.000
n = 10
Sn = n/2 (2a + (n−1)b)
550.000 = 10/2 (2a + (n−1)b)
= 5 (2·25000 + (10−1)b)
= 5 (2·25000 + 9b)
= 5 (50.000 + 9b)
550.000/5 = 50.000 + 9b
110.000 = 50.000 + 9b
110.000 − 50.000 = 9b
60.000 = 9b
60.000/9 = b
6.666,67 = b
Jadi model matematikanya adalah
Sn = n/2 (50.000 + (n−1) 6.666,67)
Generalisasi hadiah minggu ke-15
n = 15 ⇒ Sn
Sn = 15/2 (50.000 + (15−1) 6.666,67)
= 7,5 (50.000 + 14 (6.666,67))
= 7,5 (50.000 + 93.333,38)
= 7,5 (143.333,38)
= 1.075000,35

Translate:

Therefore, the mathematical model is.

Generalization of the reward in the 15th week.

Figure 6. Student Pre-Test Answer Results

Students have fairly good mathematical reasoning skills in the context of the sum of terms in an arithmetic sequence. They understand the concept of patterns, are able to select and use appropriate formulas, and are able to construct mathematical models from contextual situations. The main weakness lies in their lack of thoroughness in substitution of values and calculations.

Discussion

The research findings indicate that the implementation of a deep learning approach has a significant impact on improving the mathematical reasoning skills of Year 10 vocational school students. This is evident from the higher average post-test scores in the experimental class compared to the control class, as well as the results of the hypothesis test, which indicate a significant difference between the two groups.

The improvement in the mathematical reasoning skills of students in the experimental class occurred because the Deep Learning approach encouraged students to understand mathematical concepts in greater depth. In this approach, students do not merely focus on mastering procedures or formulas, but also on understanding concepts and the relationships between mathematical concepts (S. Orhani, 2024). Theoretically, deep learning emphasizes in-depth conceptual understanding, the development of higher-order thinking skills, and the interconnectedness of concepts and real-world contexts. This aligns with the philosophical study of deep learning in mathematics education, which emphasizes students' active cognitive engagement with the concepts being studied, rather than mere memorization or mechanical procedures (Dahroni et al., 2025a). This approach is supported by learning pillars that encourage reflective thinking, complex thinking, and the formation of deep meaning in the learning material.

Furthermore, the Deep Learning approach provides students with opportunities to actively participate in the learning process through exploration activities, group discussions, and problem-solving. These activities enable students to develop critical and analytical thinking skills in solving mathematical problems (Siregar et al., 2025). This aligns with research by Widodo & Kartika, (2022), which found that deep learning-oriented learning can improve students' higher-order thinking skills, including mathematical reasoning.

Mathematical reasoning skills are crucial in mathematics learning because they relate to students' ability to make predictions, construct arguments, and draw logical conclusions. According to the National Council of Teachers of Mathematics (NCTM), mathematical reasoning skills are one of the process standards that must be developed in mathematics learning. Research by Bernard & Nurhayati, (2021) also shows that students' mathematical reasoning skills can improve if they are given opportunities to explore concepts and are actively involved in the learning process.

The application of the Deep Learning approach also allows students to connect mathematical concepts to real-world situations, making learning more meaningful. When students can deeply understand concepts, they will find it easier to apply those concepts to solve various mathematical problems. This is supported by research by Zulkardi et al. (2021), which states that mathematics learning that emphasizes conceptual understanding can improve students' reasoning and problem-solving skills.

Furthermore, the Deep Learning approach encourages students to reflect on their thinking processes when solving a problem. This reflection process helps students evaluate the strategies they use and correct errors that occur during the problem-solving process. According to research by Hattie (2017), learning that encourages reflection and deep understanding has a significant impact on improving the quality of learning and developing students' thinking skills.

Findings from other literature suggest that deep learning can be more effective in improving mathematical reasoning and problem-solving skills than conventional approaches, particularly when students are given the opportunity to actively construct concepts and engage in reflective discussions. Study Dahroni et al. (2025) showed that classes taught using the deep learning model experienced a greater increase in mathematical reasoning abilities compared to the conventional differential learning approach.

In addition, other empirical evidence shows that the implementation of deep learning principles in mathematics learning can increase student engagement and their conceptual understanding of mathematics, especially when learning is designed to be student-centered and facilitates higher-order thinking activities (Anggraini et al., 2025). Some related research provides an initial glimpse into the potential of this approach, a 2025 study of high school students showed that Deep Learning was perceived as a tool that helped visualize concepts and provide instant feedback, despite concerns regarding the risk of technology dependency (Slamet et al., 2025). In addition, research in vocational schools throughout West Jakarta in 2025 also indicated that the implementation of Deep Learning can improve learning outcomes, although it has not yet thoroughly analyzed the reasoning process that occurs (Ardiansyah & Nugraha, 2025). On the other hand, research on multiplicative reasoning errors of vocational high school students in the current year shows that students tend to use previous experience or knowledge in solving problems, which is an important basis for designing Deep Learning-based learning that suits the characteristics of vocational high school students (Andriani & Hataningrum, 2024).

Thus, the results of this study indicate that the Deep Learning approach can be an effective alternative learning strategy for improving students' mathematical reasoning skills. This approach provides students with the opportunity to understand concepts more deeply, develop critical thinking skills, and connect mathematical concepts to real-world situations, thus making learning more meaningful.

CONCLUSION

The findings of this study demonstrate that the Deep Learning approach is effective in improving the mathematical reasoning skills of tenth-grade vocational high school students. This is supported by the significant difference in post-test results between the experimental and control classes, where students who experienced Deep Learning achieved higher scores. The statistical analysis confirms that this improvement is significant, indicating that the approach has a real impact on enhancing students' ability to analyse patterns, construct arguments, and draw logical conclusions.

This effectiveness is closely related to the characteristics of the Deep Learning approach, which emphasizes meaningful understanding, active student involvement, and the development of higher-order thinking skills. Through reflective activities, problem-solving, and concept exploration, students are better able to connect ideas and apply mathematical concepts in various contexts. Therefore, the Deep Learning approach can be considered a suitable and effective alternative for improving mathematical reasoning skills, especially in vocational high school settings.

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