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APPLICATION OF THE PROBLEM BASED LEARNING MODEL TO IMPROVE VOCATIONAL SCHOOL STUDENTS' UNDERSTANDING OF MATHEMATICAL CONCEPTS ON MATRIX MATERIAL

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ABSTRACT

This study aims to evaluate the effectiveness of the Problem Based Learning (PBL) learning model in improving understanding of mathematical concepts among vocational high school students on matrix material. The method used in this study is quantitative with a quasi-experimental design, involving two groups, namely the experimental group that implemented the PBL model and the control group that used traditional learning methods. The research findings showed that there was a significant difference in the improvement of understanding of mathematical concepts between the two groups. The average Posttest score for the experimental group (7.57) was higher than the control group (4.72). The N-Gain analysis revealed that the improvement in understanding of mathematical concepts in the experimental group (0.62) was greater than the control group (0.38), although both groups were in the moderate improvement category. The results of the Independent Sample T-Test showed a p-Value = 0.000 < 0.05, which indicated that the improvement between the two groups was statistically significant.

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Penelitian ini bertujuan untuk mengevaluasi keefektifan model pembelajaran *Problem Based Learning* (PBL) dalam memperbaiki pemahaman tentang konsep matematika di kalangan murid SMK pada materi matriks. Metode yang digunakan dalam penelitian ini adalah kuantitatif dengan desain eksperimen kuasi, melibatkan dua kelompok, yaitu kelompok eksperimen yang menerapkan model PBL dan kelompok kontrol yang menggunakan metode pembelajaran tradisional. Temuan penelitian menunjukkan bahwa terjadi perbedaan yang signifikan dalam peningkatan pemahaman konsep matematika di antara kedua kelompok tersebut. Rata-rata nilai Posttest untuk kelompok eksperimen (7,57) lebih tinggi dibanding kelompok kontrol (4,72). Analisis *N-Gain* mengungkapkan bahwa peningkatan pemahaman konsep matematika di kelompok eksperimen (0,62) lebih besar daripada kelompok kontrol (0,38), meskipun kedua kelompok dalam kategori peningkatan sedang. Hasil dari uji *Independent Sample T-Test* menunjukkan nilai *p-Value* = 0,000 < 0,05, yang mengindikasikan bahwa peningkatan di antara kedua kelompok itu signifikan secara statistik.

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INTRODUCTION

The learning process is an activity that requires dynamic interaction between students, teachers, and teaching materials in an environment that facilitates. In its implementation, responsible teachers must put in maximum effort to create a supportive learning environment so that students can optimize their abilities (Dwikoranto et al., 2021). Through an effective learning environment, students are encouraged to be proactively involved in gaining significant learning experiences and are able to create mutually beneficial interactions. Success in learning is largely determined by the teacher's skill in managing the educational process, selecting appropriate teaching methods, and creating situations that enable students to think actively and critically. By implementing appropriate learning strategies, students are expected to become not only recipients of information but also direct participants in exploring understanding and connecting content to daily activities (Samadun & Dwikoranto, 2022).

Mathematics as a field of study contribute greatly to building the ability to think systematically, logically and critically among students. Mathematical thinking skills not only support academic success but also play a role in developing students' character and skills in various fields (Rafianti et al., 2020). Therefore, mathematics learning is seen as an effective means of optimizing students' potential in the educational process. In mathematics learning, students are expected to master several basic skills that support a comprehensive understanding of the material. These skills include the ability to understand mathematical concepts, reason logically, solve contextual problems, represent mathematical ideas, and recognize the benefits of applying mathematics in everyday life (Ulva et al., 2024) . However, in practice, students' ability to understand mathematical concepts remains low because they do not actively participate in the learning process. This situation aligns with research findings Putri et al., (2023), which indicates that minimal student participation has an impact on their lack of ability to understand concepts, think critically, and solve mathematical problems.

One teaching method that can increase student active engagement and is relevant for various subjects, including mathematics, is Problem-Based Learning (PBL). This model utilizes real-life situations as a backdrop to help students hone their critical thinking skills and challenge-solving skills. Through the application of PBL, students are not only guided to find solutions but also to deeply understand the concepts underlying the problems (Rahma & Kurniawati, 2024). This learning model places students at the center of learning activities and requires them to apply their existing knowledge to find solutions. Meanwhile, the teacher serves as a liaison in the learning process. Therefore, the learning process becomes more meaningful and encourages students to build conceptual understanding independently. Research conducted by Kurniawati & Ummah, (2023) also proves that the use of the PBL model in the mathematics learning process has proven successful in increasing student participation and achieving learning targets.

One topic in mathematics teaching that contains many concrete and applicable concepts is matrices. This material requires students to understand basic matrix operations and their application in solving contextual problems. Knowledge competencies in matrix materials include the ability to apply matrix operations to solve relevant problems, while skill competencies emphasize the appropriate application of concepts in various contexts. In this study, efforts to improve student competency in matrix materials were implemented by implementing a problem-based learning approach designed to suit the vocational backgrounds of students at vocational high schools (Santi et al., 2022).

The results of various previous studies show that implementing the PBL model can have a positive effect on learning achievement. A study conducted by Henniwati, (2021) and Nasrina, (2021) showed that student learning outcomes improved beyond the minimum completion criteria, indicating the effectiveness of the PBL model in mathematics learning. However, research on the application of the PBL model that focuses on improving mathematical concept understanding, especially in matrix material, is still limited. Therefore, this study was designed to implement a problem-focused learning approach to deepen vocational high school students' understanding of mathematical concepts in the topic of matrices.

METHOD

In this study, the researchers adopted a quantitative method using a quasi-experimental design. This study involved two groups: an experimental group of 10 TKJ 1 students and a control group of 10 TKJ 2 students. In the first session, a pre-test was conducted, while in the final session, a post-test was conducted. The design implemented in this study refers to the ideas expressed by Russeffendi (Sumartini, 2016) :

$$\begin{array}{ccc} \mathbf{O} & \mathbf{X} & \mathbf{O} \\ \mathbf{O} & & \mathbf{O} \end{array}$$

With the description O as a measure of students' mathematical concept understanding ability, 10 refers to problem-focused learning, and indicates that the sampling was carried out randomly. The group that was researched included all TKJ students in the 10th grade who attended SMK Putra Indonesia. The sample employed for this particular research was split into two distinct categories, specifically the experimental group from 10th grade TKJ 1 and the control group from 10th grade TKJ 2. The tool used in this study was a written test, which was intended to assess the mastery of mathematical concepts, consisting of 5 questions. Information was gathered using an assessment tool, after which it underwent analysis with IBM SPSS. software edition 25. Data analysis involved the N-Gain assessment was implemented to check if the data exhibited a normal distribution pattern. If the data was confirmed to follow a normal distribution, the next step was to carry out a homogeneity test and a t-test, however, the Mann-Whitney method was employed if the data deviated from a typical distribution pattern.

RESULTS AND DISCUSSION

Result

To measure students' initial understanding of mathematical concepts, a test was conducted by giving them questions. Based on the pretest results obtained, the level of understanding of mathematical concepts of class X TKJ students was:

Table 1. Pretest Result Data

Statistik	Experiment	Control
N	30	30
X	3,68	1,53
S	1,22	4,88

The average scores obtained by the two groups reveal a discrepancy, as can be seen in the table presented previously. The group undergoing experimentation began with a score of 3.68 on the initial assessment, contrasting with the control group's starting score of 1.53. This suggests the experimental group had a better average score than the control group. Consequently, we can

say that the two groups differed in their foundational capacity to understand mathematical ideas. To verify the collected data follows a normal distribution, the normality test findings are shown below:

Table 2. Normality Test Results

Shapiro-wilk

	Statistik	df	Sig.
Experiment Class	.963	30	.365
Control Class	.949	30	.157

Based on information from the Shapiro-Wilk analysis results table, the significance level (Sig.) for the experimental group was recorded at 0.365, while for the control group it was recorded at 0.157. Since both significance levels are higher than 0.05 (Sig. > 0.05), it can be stated that the data from the two groups follow a normal distribution. To further assess the improvement in students' understanding of mathematical ideas following the introduction of the problem-centered learning strategy, a final test was given to both groups upon completion of the learning activities. The subsequent table displays the post-test results gathered from both the experimental and control groups:

Table 3. Posttest Result Data

Statistik	Experiment	Control
N	30	30
X	7,57	4,72
S	1,35	3,72

The table above shows that the average scores achieved by both groups varied. Following the assessment, the experimental group attained a grade of 7.57, in contrast to the control group's grade of 4.72. This indicates that students engaged in problem-focused learning had a superior understanding of mathematical concepts. Here's a restatement of the normality test findings to confirm the data obtained followed a normal distribution.:

Table 4. Normality Test Results

Shapiro-wilk

	Statistik	df	Sig.
Experiment Class	.975	30	.687
Control Class	.984	30	.913

Based on the Shapiro-Wilk normality test analysis, the significance for the experimental group was recorded at 0.687, while for the control group it was recorded at 0.913. Considering that both values exceed 0.05 (Sig. > 0.05), it can be concluded that the data after the intervention has a normal distribution. Thus, to determine the extent of the increase in students' understanding of mathematical concepts after receiving treatment, an N-Gain calculation was carried out, as follows:

Table 5. N-Gain Result Data

Statistik	Experiment	Control
N	30	30
N-Gain	.62	.38
Interpretation	Currently	Currently

From the table presented, it can be concluded that the development of mathematical concept understanding in both classes is in the moderate category. However, the experimental group's N-Gain value surpasses that of the control group, suggesting that employing Problem-Based Learning yields a greater beneficial influence on enhancing students' grasp of mathematical concepts. An Independent Sample T-Test was performed to assess if a notable difference existed between the pair of groups. The outcomes obtained are detailed below:

Table 6. Independent Sample T-Test

Statistik	Mark
T-Statistik	3,944
p-Value	0,000

The p-value, which was determined to be 0.000 through the application of the Independent Sample T-Test, is demonstrably less than the threshold of 0.05, This suggests a noteworthy disparity in the growth of comprehension regarding mathematical ideas when comparing the group undergoing experimentation with the group not undergoing such experimentation. Thus, it can be concluded that the PBL learning method is much more successful than the method used in the control class.

Discussion

Based on the results of the pretest analysis, there was a difference in the level of initial understanding of mathematical concepts between the experimental group and the control group. This indicates that before receiving the treatment, students in the experimental group demonstrated a greater level of conceptual understanding than their peers in the control group. However, this difference was still within normal limits and did not affect the validity of the treatment. This finding aligns with a study conducted by Rahmaeda & Setyawan, (2020) which showed that the use of a problem-based teaching model can significantly improve students' understanding of mathematical concepts. Overall, these findings support the view that problem-focused learning can help students connect mathematical concepts to their learning experiences, resulting in a more comprehensive and meaningful understanding of the concepts.

To ensure that the data obtained conforms to the normality assumption, normality testing was carried out using the Shapiro–Wilk method. According to the analysis results, the pretest data from the two classes showed a normal distribution pattern, thus meeting the criteria for proceeding to the next step of statistical analysis. This indicates that the basic abilities of students in both classes have a fairly even distribution of scores, so the comparison results can be considered objective and valid.

After implementing the PBL learning method in the experimental class, there was a clear improvement in students' mastery of mathematical ideas. This information shows that students who learned with PBL managed to understand concepts better than those who used conventional learning methods. These results are in line with a study conducted by Anggraini & Sumardi, (2025) and also show a significant difference between the group using the PBL approach and those who learned with traditional methods. Overall, this improvement confirms that the use of the PBL method encourages students to be more involved, think critically, and construct their own understanding, resulting in optimal learning outcomes.

Based on the test results using the Shapiro–Wilk method, the data from both classes showed a normal distribution, thus fulfilling the requirements for parametric statistical analysis. This

indicates that the post-test results had a homogeneous and proportional distribution of values, allowing for more accurate and reliable interpretation.

To evaluate the improvement in understanding of mathematical concepts after utilizing the learning method, an analysis was conducted using the N-Gain approach. The results of the analysis showed that the experimental group showed an increase in conceptual understanding from the medium category to the high category, while the control group remained in the medium category. This indicates that the implementation of the PBL model not only provides better learning outcomes but also deepens students' understanding of the relationships between mathematical concepts. Thus, PBL encourages students to connect mathematical ideas in more meaningful ways, thus strengthening their conceptual understanding and sustaining it.

To determine whether there is variation in the improvement of understanding of mathematical concepts between two classes, an evaluation was conducted using the Independent Sample T-test. The research findings showed a significant difference in development between the experimental group and the control group.. This indicates that PBL-based learning methods are more effective in helping students understand mathematical concepts than conventional learning methods. This finding further supports previous research showing that problem-based approaches can provide more meaningful learning experiences, because students participate directly in the thinking and problem-solving process.

The results of this study show that the PBL learning approach is much more successful in improving students' increase students' mastery of mathematical concepts when compared with traditional methods. This finding is consistent with the study by Megawati et al., (2024) which confirmed the significant impact of PBL on students' understanding of mathematical concepts in grade VIII. This is also in line with the results of a study conducted by Harmaen et al., (2024) which showed a significant influence of the application of PBL on conceptual understanding in grade 5 at the elementary school level.

CONCLUSION

This study aims to assess the extent to which problem-based learning models can support vocational school students better understand material related to mathematical concepts, particularly matrices. From the analysis and discussion conducted, it can be concluded that using the PBL model is more effective than conventional learning methods. By implementing PBL, students become more involved in problem-solving efforts, develop critical thinking, and are able to connect mathematical concepts with real-world situations. Therefore, PBL helps students construct their knowledge independently, which leads to a significantly improved understanding of mathematical concepts. Theoretically, the results of this study support the constructivist idea of emphasizing the importance of students' active involvement in developing knowledge through learning experiences. Practically, these findings suggest that the PBL model can be an effective teaching method for mathematics teachers in vocational schools, especially for materials requiring analytical skills and the application of concepts. Based on the findings of this study, it is recommended that mathematics teachers use the PBL model more frequently when teaching to improve critical thinking skills and conceptual understanding among students.. Furthermore, educational institutions are expected to provide support in the form of training and provide adequate learning facilities to implement problem-based learning optimally. For future researchers, it is recommended to consider applying PBL to other mathematics materials or combining it with other innovative learning methods to assess its broader impact on students' higher-order thinking skills.

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