

The Implementation of ChatGPT-Assisted Problem-Based Learning to Enhance Student Learning Outcomes in Electrical Fundamentals

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ABSTRACT

The integration of artificial intelligence (AI) tools into pedagogical models provides new opportunities to improve student learning, particularly in vocational education where practical competence is crucial. While AI applications such as ChatGPT are increasingly used in education, limited empirical evidence exists on their role in enhancing structured instructional models like Problem-Based Learning (PBL). This study addresses this gap by examining the effect of implementing PBL assisted by ChatGPT on student learning outcomes in the Basic Electricity course at SMK Negeri 5 Padang. A pre-experimental one-group pretest-posttest design was employed. The participants were 32 students of class X TITL 3 during the 2024/2025 academic year. Data were collected through pretests and posttests and analyzed using normalized gain scores and descriptive statistics to measure improvement and achievement levels. The results revealed a moderate increase in learning outcomes, with a normalized gain score of 0.39. Furthermore, 90% of students achieved the minimum competency criteria, while 10% had not yet reached the threshold. These findings demonstrate that PBL assisted by ChatGPT can effectively enhance students' conceptual understanding and academic achievement in vocational electrical engineering education. This study contributes to the literature on technology-enhanced learning by providing empirical evidence of the effectiveness of AI-assisted PBL. The implications underscore the potential of integrating AI tools to support student-centered learning designs, improve engagement, and strengthen both conceptual and practical mastery in vocational education.

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A. INTRODUCTION

Formal secondary education that equips students with specific expertise and skills to enter the industrial workforce is represented by Vocational High Schools (SMK) [1]. According to Law No. 20

of 2003 on the National Education System, the transformation of vocational education from a theoretical approach to practical experience provides a more promising direction for the development of skills, practical competencies, and graduates' work readiness. This transformation is reflected in various curriculum reforms, including the implementation of learning methods that emphasize hands-on practice, competency-based assessments focusing on mastery of real-world skills, and efforts to balance theoretical knowledge with practical application. In addition, the integration of digital technologies and the emphasis on core competencies aligned with industry demands are key aspects in ensuring graduates' competitiveness in the labor market. One of the vocational competencies offered at SMK is Electrical Power Installation Engineering (TITL), which requires an in-depth understanding of both theory and practice. However, classroom realities reveal that significant challenges remain in the learning process. Based on preliminary observations conducted at SMK Negeri 5 Padang in Class X TITL 3 for the Basic Electricity subject, the learning process has not yet met the expected instructional goals, as evidenced by a considerable number of students achieving scores below the Minimum Mastery Criteria (KKTP) [2].

One of the approaches that can improve student learning outcomes is the Problem-Based Learning (PBL) model. PBL emphasizes students' cognitive and behavioral engagement, as well as their ability to solve problems [3]. This learning model encourages students to face real-world problems with the aim of constructing their own knowledge, expanding investigative skills, fostering critical and independent thinking, and building self-confidence [4].

However, the effective implementation of PBL requires technological support as a source of information in the learning process. One such technology is ChatGPT, an AI-based tool that provides quick and efficient access to information and assists students in addressing various learning tasks and problem-solving cases [5]. ChatGPT is particularly promising because it has the potential to enhance students' learning motivation and independence. It can serve as a learning companion that is readily accessible anytime, thereby accelerating students' understanding of learning materials and supporting their efforts in generating solutions to problems encountered [6].

Previous studies have consistently shown that PBL can improve student engagement and learning outcomes, particularly in theoretical subjects such as Basic Electricity. By engaging students in active problem-solving, PBL not only prevents passive reception of knowledge but also promotes participation in decision-making and collaborative resolution of learning challenges. Building on this foundation, the present study investigates the integration of PBL assisted by ChatGPT in the Basic Electricity course, with the objective of examining its effectiveness in improving student learning outcomes.

B. METHOD

This study employed a pre-experimental approach with a one-group pretest–posttest design. This design was selected as it is relevant for the exploratory stage, aiming to evaluate the effectiveness of implementing Problem-Based Learning (PBL) assisted by ChatGPT in improving student learning outcomes. Within this design, measurements were conducted twice on the same group: (1) a pretest (O1) to measure initial competence prior to the intervention, (2) an intervention (X) in the form of PBL assisted by ChatGPT, and (3) a posttest (O2) to assess competence after the intervention. The choice of this design was based on the consideration that the research is still at an introductory and exploratory stage, thus not requiring a control group, while still allowing the identification of changes or improvements in learning outcomes. Accordingly, this design was deemed practical, efficient, and appropriate for examining the initial effectiveness of the proposed learning model.

The research subjects consisted of all students in Class X TITL 3 at SMK Negeri 5 Padang, totaling 21 individuals. The sampling technique employed was purposive sampling, chosen to maintain the internal validity of the study by ensuring that the sample possessed stable and relevant characteristics aligned with the research objectives. The inclusion criteria were: (1) students actively

enrolled in the Basic Electricity course, and (2) students with full attendance (no recorded absences) during the treatment period. These criteria were established to minimize potential confounding variables and to preserve the stability and reliability of the collected data. The research instrument consisted of a specially designed questionnaire to measure student learning outcomes before and after the intervention.

Table 1. Research Design

<i>Pretest</i>	<i>Treatment</i>	<i>Posttest</i>
O ₁	X	O ₂

Description of Research Design Notation :

- O₁ = Pretest score, measured prior to the implementation of the Problem-Based Learning (PBL) model assisted by ChatGPT.
- O₂ = Posttest score, measured after the implementation of the PBL model assisted by ChatGPT.
- X = Learning intervention using the Problem-Based Learning (PBL) model assisted by ChatGPT.

2.1. Research Instruments

The primary data collection instrument employed in this study was a test. The instrument was designed to assess students' mastery of the subject matter by administering a series of questions. The test was conducted in the form of pretest and posttest essay questions aligned with the learning objectives of the Basic Electricity subject. Prior to implementation, the instrument was pilot-tested, and its feasibility was examined through prerequisite tests, including validity and reliability analysis.

2.1.1 Test (*Pretest dan Posttest*)

2.1.1.1 Validity Test

An item is considered valid if it is capable of measuring the intended construct and demonstrates a strong correlation with the total score. In this study, the validity of the test items was examined using the Pearson Product Moment correlation formula, as proposed by Suharsimi Arikunto [14], which is expressed as follows:

$$r_{\{xy\}} = \frac{\{n \sum xy - (\sum x)(\sum y)\}}{\left\{ \sqrt{[n \sum x^2 - (\sum x)^2][n \sum y^2 - (\sum y)^2]} \right\}}$$

where :

- rx_y = correlation coefficient between item score (X) and total score (Y)
- n = number of respondents
- x = item score
- y = total score

After performing the calculations, the obtained correlation coefficient r_{hitung} was compared with the critical value of the correlation table r_{tabel} at a 5% significance level. An item is considered valid if $r_{hitung} > r_{tabel}$ the item is deemed invalid [7]. Based on the validity analysis of the trial test items, all items were found to be valid. Specifically, five items were validated for the pretest and five items for the posttest.

2.1.1.2 Reliability Test

The reliability test was conducted to ensure that the research instrument produced consistent and stable data when applied under similar conditions. In educational research, measurement

consistency is essential, as students' learning outcomes, attitudes, and perceptions may be influenced by subjective and situational factors. One of the most widely used techniques is Cronbach's Alpha, which measures the internal consistency of an instrument, particularly questionnaires or tests employing Likert scales. The value of Cronbach's Alpha ranges from 0 to 1, with higher values indicating greater reliability. Generally, a coefficient of ≥ 0.70 is considered acceptable for social and educational research, while a coefficient of ≥ 0.60 may still be tolerated in exploratory studies, as suggested by Suharsimi Arikunto [14].:

$$r_{11} = \left(\frac{k}{k-1} \right) \left(1 - \frac{\sum Si}{St} \right)$$

Where :

r_{11} = Instrument reliability

k = Number of items

$\sum Si$ = Sum of the variances of each item

St = Total test variance

The decision criteria for reliability testing are as follows: If Cronbach's Alpha > 0.60 , the test instrument is considered reliable. If Cronbach's Alpha < 0.60 , the test instrument is considered unreliable [7].

Table 2. Reliability Test Criteria

No.	Coefficient Range	Category
1.	0,80-1,00	Very High
2.	0,60-0,80	High
3.	0,40-0,60	Moderate
4.	0,20-0,40	Low
5.	0,00-0,20	Very Low

Source : Suharsami Arikunto[14]

Based on the reliability analysis of the trial test items, the pretest obtained a reliability coefficient of 0.61, which falls into the High category, while the posttest achieved a reliability coefficient of 0.85, which is categorized as Very High. Therefore, the research instrument was declared reliable, with the pretest categorized as high reliability and the posttest as very high reliability.

2.2. Data Analysis Technique

2.2.1. N-Gain Test

The normalized gain score ($\langle g \rangle$) was employed to measure the improvement in students' learning outcomes before and after the implementation of the learning intervention. According to Hake [15], the normalized gain score can be calculated using the following formula:

$$\langle g \rangle = \frac{Sf - Si}{100 - Si}$$

Description:

$\langle g \rangle$ = Normalized gain score

Si = Pretest score

Sf = Posttest score

100 = Maximum score

Table 3. Criteria for Normalized Gain Score

Normalized Gain Score (g)	Category
$g > 0,7$	High
$0,3 \leq g \leq 0,7$	Moderate
$g < 0,3$	Low

Source : Hake [15]

2.2.2 Classical Mastery Test

Following the implementation of the Problem Based Learning (PBL) model, the level of classical mastery is determined by calculating the percentage of students who achieved the minimum mastery criteria. Classical mastery is considered achieved if the percentage of students who meet the criteria is $\geq 85\%$. The calculation can be expressed using the following formula.

$$\text{Ketuntasan Klasikal} = \frac{\text{Jumlah Peserta Didik yang Tuntas}}{\text{Jumlah Peserta Didik}} \times 100\%$$

C. RESULT AND DISCUSSION

3.1. Research Findings

After conducting the experiment with 21 students of class X TITL 3 at SMK Negeri 5 Padang, the implementation of the Problem Based Learning (PBL) model assisted by ChatGPT produced data on students' learning outcomes. Learning achievement was measured using pretest and posttest instruments. The pretest was administered to assess students' initial abilities, while the posttest was used to measure the learning improvement after treatment with the PBL model assisted by ChatGPT.

3.1.1 Data Description

3.1.1.1 Pretest Data

The results of the pretest indicated that students' initial abilities were relatively low. Out of 21 students, only 43% achieved scores within the higher range, while the majority scored below the minimum mastery criterion (KKTP = 75). Statistical analysis yielded a mean score of 75.90 with a standard deviation of 11.14. The frequency distribution is presented in Table 4.

Table 4. Data Frekuensi Pretest

No.	Score Interval	Frequency
1	93-100	2
2	85-92	3
3	75-84	4
4	≤ 75	12

The data show that most students (57%) scored below the mastery criterion, demonstrating that learning outcomes prior to the intervention were not satisfactory. This reflects the necessity of implementing a more engaging and effective learning model.

3.1.1.2 Posttest Data

The posttest results revealed a significant improvement in student performance after the implementation of the PBL model assisted by ChatGPT. Out of 21 students, 19 students scored within the higher range, while only 2 students scored below the mastery criterion. The statistical analysis showed a mean score of 85.24 with a standard deviation of 7.67. The frequency distribution is summarized in Table 5.

Table 5. Frekuensi Data Posttest

No.	Score Interval	Frequency
1	93-100	3
2	85-92	11
3	75-84	5
4	≤ 75	2

The findings indicate that the majority of students (90%) exceeded the minimum mastery criterion, suggesting that the application of the PBL model assisted by ChatGPT had a positive effect on learning outcomes.

3.1.1.3. Data Analysis

3.1.1.3.1. Learning Outcomes Improvement

The comparison between pretest and posttest scores of 21 students showed a positive trend in learning outcomes. Based on the N-Gain Score analysis, the normalized gain value was 0.39, which falls into the moderate category. This finding indicates that the implementation of the Problem Based Learning (PBL) model assisted by ChatGPT in the subject of Fundamentals of Electricity was able to moderately improve students' learning achievements in class X TITL 3 at SMK Negeri 5 Padang.

3.1.1.3.2. Classical Mastery

The analysis of mastery learning showed that prior to the intervention (pretest), only 43% of students (9 students) achieved the minimum mastery criteria. After applying the PBL model assisted by ChatGPT, the posttest results demonstrated a significant improvement, with 90% of students (19 students) achieving mastery of the learning objectives. This comparison highlights the effectiveness of integrating PBL with ChatGPT in enhancing students' attainment of learning outcomes.

3.2. Discussion

The N-Gain analysis confirmed that the application of the PBL model assisted by ChatGPT improved student learning outcomes with a moderate gain category. This result aligns with previous studies [8–11], which also found that PBL models tend to improve student knowledge acquisition with moderate levels of effectiveness. In terms of classical mastery, the findings showed a notable increase: from 43% before treatment to 90% after treatment. This demonstrates that the use of PBL assisted by ChatGPT can substantially enhance students' achievement levels, consistent with other findings in vocational education contexts [12]. However, it is important to note that 10% of students still failed to reach the mastery criteria. Several potential factors may explain this result, including:

- Variations in students' learning styles that were not fully accommodated by the learning model.
- Limited adaptation time to effectively use ChatGPT as a learning companion.
- Differences in students' prior knowledge of the subject matter [12].

The success of PBL with ChatGPT integration cannot be separated from the role of technology as an interactive learning medium. The technology facilitated time-efficient access to information, structured content delivery, and user-friendly interaction, all of which contributed to the improvement of learning outcomes [6]. Nevertheless, to address the remaining learning gaps, remedial approaches—such as differentiated instruction and intensive mentoring—are recommended [13].

Overall, the findings suggest that the PBL model assisted by ChatGPT represents a promising strategy for improving learning outcomes in vocational education, particularly in technical subjects such as Fundamentals of Electricity. This model not only enhances knowledge acquisition but also supports students' abstract reasoning skills. It is therefore recommended for wider implementation in vocational schools, accompanied by continuous evaluation and innovation. Future research may focus on integrating differentiated learning strategies within the PBL-ChatGPT framework to better accommodate diverse student learning needs and achieve more comprehensive mastery [6, 9].

D. CONCLUSION

The implementation of the Problem-Based Learning (PBL) model assisted by ChatGPT, particularly in the domain of knowledge acquisition, demonstrated its effectiveness in the Fundamentals of Electricity course at SMK Negeri 5 Padang. The analysis revealed a moderate improvement in learning outcomes based on the N-Gain score, while 90% of students successfully achieved the minimum mastery criteria after the intervention. These findings suggest that integrating ChatGPT into PBL can serve as an effective pedagogical strategy to enhance students' learning achievement in vocational education, especially in technically oriented subjects.

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