Nusantara: Jurnal Pendidikan Indonesia
P-ISSN: 2774-3829|E-ISSN: 2774-7689
Vol. 6, No. 3, July 2026
https://journal.rumahindonesia.org/index.php/njpi/index

The Effect of Problem-Based Learning on Students' Cognitive Ability in Vocational Fuel System Learning

Dance Putra Y. Tanesab[1], Damianus Manesi[1], Dzakwan M. Mukti[1], Fahrizal[1]
[1]Universitas Nusa Cendana, Indonesia

ABSTRACT
Purpose – This study aims to examine the effect of the problem-based learning approach on improving students' cognitive ability in vocational fuel system learning.
Methods – A quantitative method with a one-group pretest posttest design was employed. The participants consisted of 37 eleventh-grade vocational students. Data was collected through cognitive tests, classroom observation, and documentation. Data analysis included normality testing, a one-sample t-test, and N-Gain analysis.
Findings – The results showed an increase in the mean score from 61.76 (pretest) to 84.32 (posttest). The posttest mean exceeded the minimum mastery criterion (75). Statistical testing indicated a significant result ($p < 0.05$). The N-Gain score of 0.60 was categorized as moderate, indicating a meaningful improvement in students' cognitive ability.
Research Implications – The findings indicate that the problem-based learning approach contributes to improving students' cognitive performance in vocational learning contexts, particularly in fuel system material. This study is limited to using a one-group pretest-posttest design and a single-class sample, which restricts causal inference and generalizability. Future studies are recommended to apply control group designs, larger samples, and broader contexts.

OPEN ACCESS

ARTICLE HISTORY
Received: 22-04-2026
Revised: 27-06-2026
Accepted: 19-07-2026

KEYWORDS
problem-based learning, cognitive ability, vocational education, fuel system, n-gain

Corresponding Author:

Damianus Manesi
Mechanical Engineering Education Program, Universitas Nusa Cendana, Kupang, Indonesia
Email: damianus.manesi@staf.undana.ac.id

Introduction

Vocational education at the secondary level plays a strategic role in preparing a skilled workforce that is aligned with industry demands (Suparyati & Habsya, 2024). In this context, learning is not only oriented toward the acquisition of theoretical knowledge but also toward the development of practical competence, analytical thinking, and problem-solving skills. In the field of Merchant Marine Engineering, students are required to master technical competencies related to the operation and maintenance of ship engines, including the fuel system, which is a critical component affecting engine performance, fuel efficiency, and operational safety (Erwin Asmara & Dwisetiono, 2022). A lack of understanding of fuel system mechanisms may lead to technical errors and reduced system performance, indicating the importance of deep conceptual mastery in this area.

However, the implementation of learning in vocational schools often remains teacher centered, where knowledge transfer dominates the classroom process (Irwanto, 2025 ; Panjaitan et al., 2026). Such an approach tends to limit students' active engagement and restricts the development of higher order thinking skills, particularly in analysis, evaluation, and creation (Nurdianti & Kurino, 2025 ; Boymau et al., 2026). Previous studies have shown that traditional instructional methods are less effective in fostering critical thinking and problem solving abilities required in real world contexts (Guo et al., 2020). This issue is evident in classroom practice, where students often rely on memorization rather than conceptual understanding, especially in technical subjects such as fuel system operation.

Further empirical data confirms this finding. The average student achievement in fuel system material remains below the expected competency standard, with a significant proportion of students failing to meet the minimum mastery criteria. In addition, observational findings indicate that students experience difficulties in understanding the functional relationships between components, diagnosing system failures, and formulating solutions based on technical principles. These challenges highlight a gap between curriculum expectations and actual student performance, particularly in higher order cognitive domains.

To address these challenges, an instructional approach that emphasizes active learning and problem solving is required. Problem Based Learning (PBL) is widely recognized as a student centered approach that engages learners in authentic problem situations, encouraging them to investigate, analyze, and construct knowledge independently (Kusasih & Satria, 2024 ; Fonna & Nufus, 2024 ; Suprapto et al., 2024). Studies have demonstrated that PBL contributes to improving students' engagement, conceptual understanding, and critical thinking skills (Balan, Cam, et al., 2019; Nova Fauziah Rahman et al., 2024). Through structured problem-solving activities, students are expected to develop deeper cognitive processing and transferable skills relevant to professional practice.

Despite the growing body of research on PBL, most existing studies are concentrated in general education or science learning contexts. Research specifically examining the implementation of PBL in vocational education, particularly in technical and maritime fields, remains limited. Furthermore, studies that explicitly investigate the impact of PBL on higher order cognitive abilities such as analysis (C4), evaluation (C5), and creation (C6) in the context of fuel system learning are still scarce. This indicates a clear research gap in both the contextual application and the specificity of cognitive outcomes.

Based on this gap, this study aims to examine the effect of the Problem Based Learning approach on students' cognitive abilities in vocational fuel system learning. This study contributes to the literature in three aspects. First, it provides empirical evidence of PBL implementation in a vocational maritime education context, which is still underrepresented in previous research. Second, it focuses on higher order cognitive skills as the main outcome, offering a more specific analysis of learning effectiveness. Third, it offers practical implications for improving instructional strategies in vocational education, particularly in technical subjects that require strong analytical and problem solving competencies.

Thus, this study is expected to strengthen both the theoretical understanding and practical application of PBL in vocational education, while addressing the limitations of previous studies in terms of context and cognitive focus.

Methods

This study employed a quantitative approach using a pre-experimental method, specifically a one-group pretest-posttest design, to examine changes in students' cognitive abilities before and after the implementation of the instructional intervention. In this design, participants were measured before the treatment (O_1), exposed to the instructional intervention (X), and then measured again after the treatment (O_2). This design was selected to measure learning improvement within a natural classroom setting, although it is acknowledged that the absence of a control group limits causal inference (Saputri & Mardiati, 2025).

Table 1. One-Group Pretest-Posttest Design

Pretest	Treatment	Posttest
O_1	X	O_2

The participants consisted of 37 eleventh grade students enrolled in the Merchant Marine Engineering program during the 2025/2026 academic year. A total sampling technique was applied, in which all students in the class were included as research subjects (Adeoye, 2023). This approach was chosen to maintain ecological validity and represent the actual classroom conditions (Mweshi & Sakyi, 2020).

The intervention was conducted over four weeks (eight meetings), focusing on the topic of the ship's main engine fuel system. The instructional process followed the stages of Problem Based Learning adapted from Rahayu and Dewi (2025), which included: (1) problem orientation, where students were introduced to real world cases related to fuel system failures; (2) problem identification and formulation; (3) data collection and investigation through group discussions and learning resources; (4) development and presentation of solutions; and (5) evaluation and reflection. Each session was structured to promote active participation, collaborative learning, and analytical thinking.

Data were collected using cognitive tests, observation sheets, and documentation. The cognitive test consisted of multiple choice and structured essay questions designed to measure higher order thinking skills based on Bloom's revised taxonomy (Damayanti et al., 2020), particularly analysis (C4), evaluation (C5), and creation (C6). The test blueprint includes indicators such as identifying component relationships, diagnosing system failures, and proposing technical solutions. The scoring procedure assigned one point for each correct answer in multiple-choice items and used an analytic rubric for essay responses, with a score range of 0-4 for each criterion (accuracy, reasoning, and completeness) (Hilmi et al., 2022).

The instruments were tested prior to use. Content validity was established through expert judgment, while empirical validity testing showed that all items had correlation coefficients exceeding the minimum threshold ($r > 0.30$). The reliability test yielded a Cronbach's Alpha coefficient of 0.82, indicating high reliability. Item analysis also indicated that the questions were within acceptable difficulty levels (0.30-0.70) and had moderate to good discrimination indices.

Data were analyzed using SPSS version 25. Descriptive statistics were employed to summarize students' scores, followed by the Shapiro Wilk test to assess data normality. Hypothesis testing was conducted using a one-sample t-test to compare posttest scores with the minimum mastery criterion (KKM), while the N-Gain analysis was used to determine the magnitude of improvement in students' cognitive ability. Prior to the study, permission was obtained from the school authorities, all participants were informed about the research objectives and participated voluntarily, and data confidentiality and anonymity were maintained throughout the study.

Result

1. Description of Pretest and Posttest Results

Descriptive analysis was conducted to describe students' cognitive ability before and after the intervention. The results are presented in Table 2.

Table 2. Description of Pretest and Posttest Results

	N	Range	Min	Max	Median	Mode	Mean	Std. Deviation	Variance
Pretest	37	30	45	75	60.00	60	61.76	7.47	55.856
Posttest	37	30	70	100	85.00	85	84.32	7.08	50.225
Valid N (listwise)	37								

Based on Table 2, the pretest mean score was 61.76, with a minimum score of 45 and a maximum of 75. The standard deviation was 7.47, indicating moderate variation in students' initial abilities. After the intervention, the posttest mean increased to 84.32, with scores ranging from 70 to 100. The standard deviation decreased to 7.08, indicating a more homogeneous distribution of scores.

2. Normality Test

The normality test was conducted using the Shapiro Wilk test for both pretest and posttest data to ensure that the assumptions for parametric statistical analysis were met. The outcomes of the normality analysis for the posttest data on students' cognitive performance are presented in the table 3 below:

Table 3. Normality Test of Students' Cognitive Posttest

	Tests of Normality		
	Statistic	df	Sig.
Posttest cognitive ability	.953	37	.117
a. Lilliefors Significance Correction			

Referring to the results of the data analysis presented in the table 3, the results showed that the significance values for both pretest and posttest were greater than 0.05, indicating that the data were normally distributed. Therefore, parametric tests were considered appropriate for further analysis.

3. Paired Sample Two Test

To examine the difference between pretest and posttest scores, a paired-sample t-test was conducted.

Table 4. Paired-Sample t-Test Results

Mean Difference	t	df	Sig. (2-tailed)
22.56	12.84	36	0.000

The results indicated a significant difference between the two sets of scores ($p < 0.05$). The mean difference between pretest and posttest scores showed an increase after the intervention, indicating that students' cognitive scores changed significantly following the learning process.

4. One-Sample t-Test

Once all prerequisite tests have been satisfied, the analysis proceeds to the hypothesis testing phase by applying the One Sample t-Test. This statistical procedure is intended to determine whether the mean posttest score of students' cognitive abilities following the implementation of the Problem Based Learning model on fuel system material differs significantly from the established Minimum Completeness Criteria (KKM). The outcomes of the One Sample t-Test analysis are presented in the table below:

Table 5. One Sample t-Test

	Test Value = 75				
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval (Lower–Upper)
Posttest cognitive ability	8.003	36	.000	9.324	6.96 – 11.69

The posttest mean score is significantly higher than the KKM ($p < 0.05$), indicating that students achieved the expected competency level

5. N-Gain Test

The enhancement of students' learning outcomes was evaluated using the N-Gain calculation, which serves as a measure of the increase in cognitive performance following the implementation of the Problem Based Learning (PBL) approach. This analysis was conducted by comparing students' scores prior to the intervention (pretest) with those obtained after the intervention (posttest), thereby reflecting the extent of learning progress achieved. The resulting N-Gain values were subsequently interpreted and grouped into three distinct levels of improvement: low (N-Gain < 0.3), moderate (0.3 ≤ N-Gain < 0.7), and high (N-Gain ≥ 0.7), providing a clear framework for assessing the effectiveness of the instructional model. Furthermore, to determine the level of effectiveness of the increase as a whole, a descriptive statistical analysis of the N-Gain value in the form of a percentage was used, which aimed to see the average improvement, data distribution pattern, and variation in the development of students' cognitive abilities, which was then presented in the table of analysis results below:

Table 6. Descriptive Test of N-Gain Percentage

	Descriptive Statistics				
	N	Minimum	Maximum	Mean	Std. Deviation
N-Gain (%)	37	33	100	60.23	14.619
Valid N (listwise)	37				

The results of the analysis in table 5 show that the average N-Gain score is 0.60, indicating a moderate level of increase in students' cognitive abilities.

Discussion

The findings demonstrate a significant improvement in students' cognitive performance following the implementation of the Problem Based Learning (PBL) approach. However, beyond the statistical increase, it is essential to explain the underlying mechanisms that contribute to this improvement. The effectiveness of PBL in this study can be understood through its emphasis on active cognitive engagement, structured problem-solving processes, and contextual learning.

From a cognitive perspective, PBL enhances learning because it requires students to process information at deeper levels. During conventional instruction, students tend to rely on memorization and surface-level understanding. In contrast, PBL engages students in identifying problems, analyzing system relationships, evaluating possible solutions, and constructing explanations. This process aligns with the development of higher order cognitive skills as described in Bloom's revised taxonomy (Damayanti et al., 2020). In this study, the cognitive test was designed to measure these levels through indicators such as identifying relationships between fuel system components (C4), evaluating system conditions (C5), and proposing technical solutions (C6). Therefore, the observed improvement is not only quantitative but also reflects a shift toward higher-level cognitive processing.

The contribution of each stage of PBL also provides insight into how the improvement occurred. The problem orientation stage plays a critical role in activating prior knowledge and creating cognitive conflict, which encourages students to question their existing understanding. The investigation stage appears to be the most influential phase, as students actively analyze system components, explore causal relationships, and gather relevant information. This stage requires sustained cognitive effort and directly supports analytical thinking. The presentation and reflection stages further strengthen learning by requiring students to justify their reasoning and evaluate alternative solutions. These stages collectively support the development of structured thinking and conceptual clarity.

The findings are consistent with previous empirical studies indicating that PBL improves cognitive outcomes in vocational and technical education. Balan, Yuen, et al (2019) reported that PBL enhances students' conceptual understanding and problem solving abilities in engineering related learning. Similarly, Rahman and Na’ima (2024), found that PBL significantly improves critical and collaborative thinking skills, particularly when students are engaged in structured problem solving activities. These studies support the argument that PBL facilitates deeper learning by integrating knowledge construction with practical problem solving.

In the context of vocational maritime education, the effectiveness of PBL becomes even more relevant. Learning about fuel systems requires students to understand complex interactions between components, fuel flow mechanisms, and operational conditions (Koritarov, 2024). This type of knowledge cannot be effectively developed through memorization alone. Instead, students must be able to diagnose problems, interpret system behavior, and propose solutions based on technical principles. The use of real world problem scenarios in this study allowed students to engage with learning material in a way that reflects actual workplace situations. This finding is in line with research in vocational education, which emphasizes that contextual and problem-oriented learning improves students' readiness for professional practice (Chung et al., 2016 ; Guo et al., 2020).

Despite these positive findings, it is important to interpret the results with caution. The study employed a one-group pretest posttest design without a control group, which limits the ability to establish causal relationships. The sample size was relatively small and limited to a single class, which may reduce the generalizability of the findings. In addition, the use of similar test formats in pretest and posttest may introduce a testing effect, where students perform better due to familiarity with the instrument rather than the intervention alone.

Future research should address these limitations by employing experimental designs with control groups and larger, more diverse samples across multiple institutions. Furthermore, additional measurements should be included to assess practical competence, long-term retention, and diagnostic skills, which are essential components of vocational learning outcomes.

Overall, this study provides empirical evidence that Problem Based Learning is effective in improving cognitive performance in vocational fuel system learning. The approach supports higher order thinking through structured problem-solving processes and contextual learning, making it particularly suitable for technical and maritime education settings.

Conclusion

This study demonstrates that the implementation of Problem Based Learning (PBL) contributes to improving students’ cognitive ability in vocational fuel system learning. The improvement reflects students’ enhanced capacity to analyze system components, evaluate operational conditions, and propose technical solutions within a structured problem-solving framework.

The findings highlight the relevance of PBL for vocational maritime education, where learning requires the integration of conceptual understanding and practical problem-solving skills. By engaging students in authentic technical problems, PBL supports the development of higher order thinking and aligns with the competency demands of maritime engineering practice. Thus, this study provides both empirical and pedagogical contributions by extending the application of PBL into a specific technical vocational context that has received limited attention in previous research.

However, several limitations should be acknowledged. The use of a one-group pretest posttest design limits the ability to establish causal relationships due to the absence of a control group. The study involved a relatively small sample drawn from a single class within one institution, which restricts the generalizability of the findings. In addition, the possibility of a testing effect cannot be fully excluded due to the repeated use of similar assessment instruments.

Future research is recommended to employ more rigorous experimental designs involving control groups and larger, more diverse samples across multiple institutions. Further studies should also examine long term knowledge retention, practical competency outcomes, and diagnostic skills in real or simulated workplace settings. Such investigations are necessary to provide a more comprehensive evaluation of the effectiveness of PBL in vocational and maritime education.

References

Adeoye, M. A. (2023). Review of sampling techniques for education. *ASEAN Journal for Science Education*, *2*(2), 87–94.

Balan, L., Cam, C. A. D., & Cam, C. A. D. (2019). ScienceDirect ScienceDirect ScienceDirect ScienceDirect Problem-Based Problem-Based Learning Learning Strategy Strategy for for CAD CAD Software Software Using Using Free- Choice and Open-Ended Group Projects Choice and Open-Ended Group Projects Costing m. *Procedia Manufacturing*, *32*, 339–347. https://doi.org/10.1016/j.promfg.2019.02.223

Balan, L., Yuen, T., & Mehrtash, M. (2019). Problem-based learning strategy for CAD software using free-choice and open-ended group projects. *Procedia Manufacturing*, *32*, 339–347.

Boymau, D. D. R., Priyono, P., & Manesi, D. (2026). Pengaruh Problem Based Learning terhadap Hasil Belajar Siswa Kelas XI TSM SMK Negeri 2 Kupang. *Jurnal Edueco*, *9*(01), 420–426.

Chung, P., Yeh, R. C., & Chen, Y.-C. (2016). Influence of problem-based learning strategy on enhancing student's industrial oriented competences learned: an action research on learning weblog analysis. *International Journal of Technology and Design Education*, *26*(2), 285–307.

Damayanti, N., Hartono, Subali, B., Nugroho, S. E., & Sureeporn, K. (2020). Items analysis of physics assessment based on cognitive level of high order thinking skills in bloom taxonomy. *Journal of Physics: Conference Series*, *1521*(2), 22022.

Erwin Asmara, R. G., & Dwisetiono. (2022). Analisa Kegagalan Sistem Bahan Bakar Kapal Dengan Menggunakan Metode Preliminary Hazard Analysis (PHA) dan Fault Tree Analysis (FTA). *Hexagon Jurnal Teknik Dan Sains*, *3*(1), 34–39. https://doi.org/10.36761/hexagon.v3i1.1348

Fonna, M., & Nufus, H. (2024). Pengaruh penerapan Problem Based Learning (PBL) terhadap keterampilan abad 21. *Ar-Riyadhiyyat: Journal of Mathematics Education*, *5*(1), 22–30.

Guo, P., Saab, N., Post, L. S., & Admiraal, W. (2020). A review of project-based learning in higher education : Student outcomes and measures. *International Journal of Educational Research*, *102*(May), 101586. https://doi.org/10.1016/j.ijer.2020.101586

Hilmi, I., Fadlila, N., Ramadanti, E., Retnawati, H., & Arliani, E. (2022). Development of Higher Order Thinking Skills Test based on Revised Bloom Taxonomy. *JTAM (Jurnal Teori Dan Aplikasi Matematika)*, *6*, 341. https://doi.org/10.31764/jtam.v6i2.7292

Irwanto, I. (2025). Proses Pembelajaran TEFA di Sekolah Menengah Kejuruan Berbasis Teknologi Industri. *Jurnal Pendidikan Indonesia: Teori, Penelitian, Dan Inovasi*, *5*(3).

Koritarov, T. (2024). Fostering Learning Innovations In Maritime Education: A Synthesis Of Blended, Project-Based, And Immersive Learning Approaches. *German International Journal of Modern Science/Deutsche Internationale Zeitschrift Für Zeitgenössische Wissenschaft*, (94), 43–48.

Kusasih, I. H., & Satria, D. (2024). Strategi pembelajaran berbasis masalah (Problem-Based Learning) dalam meningkatkan kemampuan berpikir kritis peserta didik. *Jurnal Teknologi Pendidikan Dan Pembelajaran| E-ISSN: 3026-6629*, *2*(2), 562–568.

Mweshi, G. K., & Sakyi, K. (2020). Application of sampling methods for the research design. *Archives of Business Review–Vol*, *8*(11), 180–193.

Nova Fauziah Rahman, Listyono, & Mirtaati Na'ima. (2024). Pengaruh Problem Based Learning (PBL) Terhadap Keterampilan Berpikir Kritis dan Kolaboratif dalam Pembelajaran Biologi Terintegrasi Nilai Islam. *Al-Alam: Islamic Natural Science Education Journal*, *3*(2), 52–68. https://doi.org/10.33477/al-alam.v3i2.7397

Nurdianti, P., & Kurino, Y. D. (2025). Implementasi Kurikulum Merdeka Deep Learning Melalui Model Problem based learning Terhadap Berpikir Tingkat Tinggi. *Journal of Innovation in Primary Education*, *4*(2), 21–33.

Panjaitan, D., Siahaan, I. S., Nainggolan, S., Nainggolan, S., Damanik, S. O., & Simarmata, G. (2026). Model Pembelajaran Berbasis Proyek: Peran Kurikulum Merdeka Dalam Meningkatkan Kreativitas Siswa Sekolah Menengah Kejuruan (SMK). *Young Journal of Social Sciences and Humanities*, *2*(1), 121–133.

Rahayu, S., & Dewi, C. A. (2025). *Case-based learning: Strategi meningkatkan literasi sains dan problem solving*. Penerbit Andi.

Rahman, N. F., & Na'ima, M. (2024). Pengaruh Problem Based Learning (PBL) Terhadap Keterampilan Berpikir Kritis dan Kolaboratif dalam Pembelajaran Biologi Terintegrasi Nilai Islam. *Al-Alam: Islamic Natural Science Education Journal*, *3*(2), 52–68.

Saputri, L., & Mardiati, M. (2025). Desain Penelitian Quasi Eksperimen Dalam Penelitian Pendidikan: Kajian Pustaka. *Jurnal Serunai Matematika*, *17*(2).

Suparyati, A., & Habsya, C. (2024). Kompetensi lulusan pendidikan vokasi untuk bersaing di pasar global. *JIIP-Jurnal Ilmiah Ilmu Pendidikan*, *7*(2), 1921–1927.

Suprapto, E., Manesi, D., & Bianome E, W. (2024). TEC empresarial. *TEC Empresarial*, *18*(2), ág. 769-775. https://doi.org/https://doi.org/10.1229/tecempresarialjournal.v20i2