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The Influence of the Deep Learning Approach on Students' Physics Learning Outcomes

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Abstract

This study aims to analyze the effect of a Deep Learning approach combined with Problem-Based Learning (PBL) on students' physics learning outcomes regarding the topic of the First Law of Thermodynamics. The urgency of this research is based on students' low understanding of the concepts of energy, heat, and work, as well as the high rate of misconceptions that impact physics learning achievement. The research method used a quantitative approach with a quasi-experimental design of the Nonequivalent Control Group Design type. The sample was determined through purposive sampling, consisting of 31 students from class XI H as the experimental group and 28 students from class XI I as the control group at MAN 2 Palu. The research instruments were a learning outcome test (pretest-posttest) and an observation sheet. Data analysis included normality tests, homogeneity tests, hypothesis testing with the Mann-Whitney U Test, and N-Gain calculation. The results showed a significant difference between the experimental and control groups ($p = 0.000 < 0.05$). The average N-Gain score for the experimental group reached 87.70 (high category), while the control group only reached 69.08 (medium category). Observations of the learning implementation also obtained an average score of 93% (very good category). It can be concluded that the application of the PBL-based Deep Learning approach is effective in improving the understanding of physics concepts, specifically on the material of the First Law of Thermodynamics. This approach is able to foster learning that is more mindful, meaningful, and joyful, making it relevant for supporting the achievement of 21st-century competencies.

Keywords: *Deep Learning Approach, Learning Outcomes, Physics;*

Introduction

Physics is one of the core subjects in the field of science that plays an essential role in developing higher-order thinking skills, problem-solving abilities, and mastery of applicable scientific concepts (Haspen et al, 2022). These competencies are highly relevant to the demands of the 21st century, where students are expected not only to master theories but also to connect concepts with real-world phenomena, think critically, and collaborate in solving problems (Ardianti et al, 2022). However, the reality in the field shows that Indonesian students' achievement in science, including physics, remains relatively low. According to the PISA 2022 factsheet, the average science score of 15-year-old Indonesian students was 383, which is far below the OECD average of 485. Furthermore, only 34% of Indonesian students achieved at least Level 2 proficiency in science, compared to 76% across OECD countries. These findings highlight persistent challenges in fostering deep conceptual understanding in science learning (OECD, 2023).

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These statistics indicate persistent obstacles in achieving meaningful conceptual understanding in science learning. Ideally, physics education should enable students to acquire a deep and transferable understanding of concepts, allowing them to apply knowledge in various real-life contexts (Sutikno et al, 2020). Despite these objectives, empirical evidence indicates that student performance in physics remains significantly low and has not met the desired targets (Barokah et al, 2021). One of the physics topics that has proven to be particularly challenging for students is Thermodynamics. Many students have difficulty understanding the First Law of Thermodynamics, where the results are far below the set target (Sunardi, 2021). Misconceptions about the conservation of energy and P–V diagrams are also the main factors in students' low understanding (Andriadi et al, 2024). In fact, advanced students still have difficulty in applying the First and Second Laws of Thermodynamics systematically (Brown et al, 2021). This obstacle also contributes to low learning outcomes, especially in materials that require strong conceptual understanding, such as thermodynamics.

The problem of low achievement in physics is not only caused by the abstract nature of the material but also by the teaching methods implemented in the classroom (Sudarta, 2022). Teachers have in fact attempted to apply various approaches, ranging from conventional methods to more student-oriented models. However, teacher-centered learning still tends to make students passive, while the scientific approach promoted in the curriculum is often reduced to mere formalities without genuinely fostering higher-order thinking skills (Aprodita et al, 2023). Likewise, contextual approaches that seek to relate lessons to everyday life have also proven less effective in strengthening conceptual mastery (Sasmita et al, 2022). Consequently, many students perceive physics as a difficult and monotonous subject, which reduces their motivation to participate in the learning process and negatively impacts their learning outcomes (Putriyanti, 2021).

To address these problems, it is necessary to implement innovative learning strategies that can foster active student engagement, facilitate conceptual understanding, and provide enjoyable learning experiences. In this context, the Deep Learning approach has the potential to be a solution. This approach is characterized by active engagement, conceptual understanding, and personal reflection on the learning process (Marton et al, 1976; Popovic, 2013). Deep Learning connects new concepts with previous experiences, allowing students to understand and apply the material more deeply (Winje et al, 2020). This approach emphasizes critical analysis and crucial problem solving (Fine, 2023), and is in line with 21st-century learning (Kadarismanto et al, 2025). Deep Learning principles can be implemented through problem-based strategies that encourage active engagement and conceptual understanding (Hidayat et al, 2019; Kadarismanto et al, 2025).

Several studies support the effectiveness of this approach, for example employing Deep Learning in mathematics instruction at the senior high school level has been shown to improve learners' reasoning abilities while simultaneously promoting greater self-assurance in their academic performance (Wahyudi et al, 2025). Similarly, improvements in elementary students' learning outcomes were reported when Deep Learning principles were combined with digital media (Asmi et al, 2025). The integration of mindful, meaningful, and joyful learning can improve critical thinking skills and learning motivation (Kadarismanto, et al, 2025). Reflective strategies and gamification in Deep Learning have further been proven to increase engagement and conceptual understanding (Feriyanto et al, 2024). However, these studies are still limited to the context of mathematics and other general fields, and have not been specifically directed at physics learning particularly in the topic of Thermodynamics.

Related studies also indicate that the use of innovative learning models plays an important role in building deeper conceptual understanding. The implementation of the Synectics model assisted by mind mapping can significantly reduce students' misconceptions while simultaneously improving cognitive learning outcomes (Sani et al, 2025). This is in line with the principles of deep learning, which emphasize meaningful learning processes in which students do not merely memorize concepts but construct knowledge meaningfully through reflective activities. Differences in students' attitudes and approaches to problem solving also influence the quality of problem-solving skills they achieve (Haeruddin et al, 2022). These findings reinforce that the application of a deep learning approach through Problem-Based Learning has the potential to foster critical and reflective thinking skills, thereby supporting the improvement of physics learning outcomes.

This research gap is important to investigate further, since the characteristics of physics learning differ from those of mathematics. In mathematics, learning primarily emphasizes symbolic reasoning and abstract logic, whereas in physics students are required not only to master mathematical aspects but also to understand the interconnection of concepts and their applications in real-world phenomena. Therefore, this study proposes a Deep Learning approach integrated with Problem-Based Learning (PBL) as an innovation in physics instruction. The integration of PBL with Deep Learning enables students to engage in contextual problem solving while simultaneously experiencing a mindful, meaningful, and joyful learning process. Thus, this study offers novelty by examining the effectiveness of this combined approach in the context of the First Law of Thermodynamics at the senior high school (SMA/MA) level, which has thus far received little attention in the literature. Based on these considerations, the objective of this study is to examine the influence of the PBL-based Deep Learning approach on students' physics learning outcomes, particularly their understanding of the First Law of Thermodynamics in grade XI at MAN 2 Palu. The findings are expected to provide empirical contributions to the development of innovative learning strategies that not only improve conceptual understanding but also strengthen 21st-century skills.

Method

This study employs a quantitative research approach utilizing a quasi-experimental design, specifically the Nonequivalent Control Group Design (Sugiyono, 2019). This design was selected due to its suitability for real-world educational settings where random assignment of participants is often impractical. It facilitates a robust comparison between an experimental group, which will receive the Deep Learning intervention based on Problem-Based Learning (PBL), and a control group, which will follow conventional instruction. By implementing this design, the research aims to isolate and more accurately determine the causative effect of the independent variable (the PBL-based Deep Learning approach) on the dependent variable (students' physics learning outcomes). Information : Y = Pretest (Initial Test) – Posttest (Final Test), and X = Treatment using a Deep Learning approach

Table 1. *Research Design*

Class	Pretest	Treatment	Posttest
Experiment	Y	X	Y
Control	Y	-	Y

The research population encompassed all eleventh-grade students enrolled at MAN 2 Palu City for the 2025/2026 academic year, distributed across ten individual classes. The selection of the study's sample employed a purposive sampling method, following a recommendation provided by the physics teacher. This resulted in two classes being chosen: Class XI H was assigned as the experimental group, comprising 31 students, while Class XI I served as the control group, containing 28 students. These two groups demonstrated comparable demographic profiles, with similar age distributions (ranging from 16 to 17 years, mean age of 16.4 years) and gender compositions (experimental group: 12 male, 19 female; control group: 10 male, 18 female). The research instruments consisted of two main tools. First, a learning outcome test was developed in the form of descriptive questions. This test was designed to measure students' cognitive achievement across the higher-order thinking domains of application (C3), analysis (C4), and evaluation (C5), based on the essential competencies of the First Law of Thermodynamics. This instrument was administered as both a pretest and a posttest to quantitatively determine the improvement in learning outcomes. Second, an observation sheet was used to qualitatively gauge the efficacy of implementing the Deep Learning framework within the Problem-Based Learning model during classroom activities.

Data in this study were collected through a learning outcomes test and classroom observations. The test, which was administered as both a pretest and a posttest, was designed to measure students' cognitive achievement related to the First Law of Thermodynamics, particularly in the domains of application (C3), analysis (C4), and evaluation (C5). In addition, classroom observations were conducted by two independent observers to evaluate the implementation of the PBL-based Deep Learning approach. The observation sheet included indicators such as student engagement, collaboration, and conceptual understanding, ensuring that the principles of mindful, meaningful, and joyful learning were properly reflected during the learning process. To ensure the quality of the data, the test instrument underwent a thorough evaluation of its validity and reliability. This process was conducted in two stages. First, content validity was established by having the instrument reviewed by subject matter experts (in physics) and experts in educational assessment. Second, a pilot test was administered to students in classes outside the study population to empirically assess its reliability. This two-stage process verified that the instrument was valid, reliable, and suitable for accurately measuring the intended learning objectives. The data underwent multiple phases of analysis. To ascertain if the data were normally distributed, a normality test was first conducted using the Shapiro-Wilk test. According to data were deemed abnormal if the significance value (Sig.) was less than 0.05 and normal if it was greater than 0.05. Second, to ascertain the similarity of variance between groups, a homogeneity test was performed using Levene's test. If the Sig. value is greater than 0.05, the data is considered homogeneous; if it is less than 0.05, it is considered non-homogeneous.

Next, hypothesis testing was conducted by considering the results of normality and homogeneity tests. If the data were normally distributed and homogeneous, the parametric Independent Sample T-Test was used. However, if either requirement was not met, the nonparametric Mann–Whitney U test was used (OECCD, 2023). The significance level used was 0.05. The criteria for hypothesis testing were defined as follows: the null hypothesis (H_0) is accepted if the significance value (Sig. or p-value) is greater than or equal to 0.05 ($p \geq .05$), indicating that the Deep Learning approach has no statistically significant influence on students' physics learning outcomes. Conversely, the alternative hypothesis (H_a) is accepted if the significance value is less than 0.05 ($p < .05$), demonstrating a statistically significant influence of the Deep Learning approach (Qolby, 2014). The difference between the pretest and posttest scores normalized to the maximum score is known as the N-Gain, and it is used to determine whether learning outcomes have improved. The N-Gain formula is shown in Equation (1):

$$g = \frac{Skor\ posttest - Skor\ pretest}{Skor\ maksimal - Skor\ pretest} x100\%$$

Table 2. *N-Gain Level Criteria*

N-Gain Score	Criteria
g < 30	Low
30 ≤ g ≤ 70	Enough
g ≥ 70	Tall

The categories in Table 2 are used to assess improvements in student learning outcomes after the learning treatment. The Deep Learning approach is declared effective if it produces an average N-Gain score.≥ 30. SPSS software version 25 was used for all data analysis.

Results

Prerequisite Analysis Test

Based on the scores obtained from the pre-test and post-test in both sample groups, data normality was tested using the Shapiro-Wilk test via the SPSS application. The test results are presented in Table 3.

Table 3. *Results of Normality Test (Shapiro-Wilk)*

Group	N	Sig.	Note
Experiment	31	0.015	Abnormal
Control	28	0.371	Normal

Table 3 shows that the experimental class data is not normally distributed (p = 0.015), while the control class data is normally distributed (p = 0.371). Next, continue with the homogeneity test using the Levene test.

Table 4. *The Homogeneity Test (Levene's Test)*

Levene Statistics	df1	df2	Sig.	note
2,317	1	59	0.134	Homogeneous

The homogeneity test yielded a p value of 0.134 > 0.05, indicating that the variance of the results was homogeneous for both groups.

Hypothesis Test Results

Based on the results of the second test, one of the variables did not meet the requirements for parametric statistical hypothesis testing. Therefore, hypothesis testing was continued using the nonparametric Mann-Whitney U test.

Table 5. *Mann-Whitney U Test Results*

Group	N	Mean Rank	Sum Of Ranks
Experiment	31	41.08	1273.50
Control	28	17.73	496.50
Total	59		

Based on Table 5, The experimental class and the control class vary, as indicated by Table 5, with an Asymp. Sig. (2-tailed) value of 0.000 (p < 0.05). The experimental class's mean rank value (41.08) is higher than the control class's (17.73), suggesting that the PBL-based Deep Learning technique improves learning outcomes in physics.

Table 6. *Statistics Test*

Statistics Test	Mark	Description
Mann-Whitney University	90,500	
Z	-5,217	
Asymp. Sig. (2-tailed)	0,000	Significant (p < 0.05)

Table 6's analytical findings indicate that the Mann-Whitney test yielded a significance value of 0.000 ($p < 0.05$). This indicates that the learning outcomes of the experimental and control classes differ.

Learning Outcome Improvement Test (N-Gain)

To see the improvement in student learning outcomes before and after the Deep Learning Approach was implemented, the N-Gain formula was used. The calculation results are presented in Tables 7 and 8.

Table 7. *N-Gain Test Results (Descriptives)*

Class	Mean	Min	max	Category
Experiment	87.70	62	100	Tall
Control	69.08	38	93	Currently

According to Table 7, the experimental class's average N-Gain value was 87.70, which is regarded as high, whereas the control class's average score was only 69.08, which is regarded as moderate. This suggests that the experimental class outperformed the control class in terms of learning outcomes.

Table 8. Descriptive Statistics

	N	Min	Max	Mean	Standard Deviation
Gain_Score	59	,38	1.00	,7886	,14435
Gain_Percentage	59	38	100	78.86	14,435
Class	59	1	2	1.47	,504
Valid N (listwise)	59				

As presented in Table 8, the analysis yielded an average N-Gain score of 0.79 (78.86%), which is categorized as high. This result demonstrates enhancement in the students' mastery of the material, confirming the efficacy of the implemented learning approach.

Observation of Learning Implementation

Table 9. *Observation Results of the Implementation of the PBL-Based Deep Learning Approach*

Meeting	Observer 1%	Observer 2%	Average%	Note
1	89	92	91	Very good
2	92	96	94	Very good
Average			93	Very good

The data in Table 9 reveal a 93% average score for the implementation of the PBL-based Deep Learning approach, confirming that its application was of a very high standard (Very Good category).

Discussion

The Influence of Deep Learning Approach on Physics Learning Outcomes

Findings from the research indicated that the integration of Deep Learning with a Problem-Based Learning (PBL) model has an effect on students' achievement in physics, especially in mastering the First Law of Thermodynamics. Statistical analysis using the Mann-Whitney U test revealed a highly significant result 0.000 ($p < 0.05$), indicating a difference in learning outcomes between the experimental class and the control class. The N-Gain calculation also showed that the average improvement in learning outcomes for the experimental class was in the high category (87.70), where as the control class only reached the medium category (69.08). Conversely, the learning improvement in the control group was substantially lower, with an N-

Gain score of 69.08, which is classified in the medium category. This significant disparity provides a robust basis for concluding that the implementation of the Deep Learning approach is proven to be far more effective in enhancing students' academic achievement compared to conventional teaching methods. These results are consistent with previous studies. reported that Deep Learning strategies in mathematics learning improved students' reasoning ability and confidence (Wahyudi et al, 2025). Found significant improvements in elementary students' learning outcomes when Deep Learning principles were combined with digital media demonstrated that mindful, meaningful, and joyful learning increased students' critical thinking skills and motivation (Artadhewi, 2025). Although most of these studies were conducted in mathematics and general learning contexts, the present study proves that similar benefits can also be applied to physics learning, particularly in thermodynamics (Wijaya et al, 2025).

Deep Learning Principles in PBL

The effectiveness of this model can be explained through the characteristics of Deep Learning. The principle of Mindful Learning encourages students to focus and manage their emotions during the learning process. In this study, students used Mentimeter to reflect on their emotional state and learning goals, helping them stay prepared and concentrated. Meaningful Learning ensured that new knowledge was connected to prior experiences. For instance, when analyzing real-world problems such as rising temperatures in Palu City, students linked thermodynamic concepts to environmental issues, making the learning process more relevant. Joyful Learning created a positive classroom atmosphere through interactive games using Wordwall (flashcards) and reflection with Padlet, which increased motivation and supported long-term conceptual retention. The findings of this study can also be linked to those of who demonstrated that variations in students' attitudes and approaches to problem solving influence the quality of their problem-solving skills (Haeruddin et al, 2022). This indicates that the implementation of deep learning within Problem-Based Learning is relevant for fostering critical thinking and problem-solving skills among physics students.

A closer analysis of learning activities further clarifies how students' learning outcomes improved. In the first meeting, students constructed initial solutions using the basic equation of the First Law of Thermodynamics ($\Delta U = Q - W$), connecting contextual problems with formal representations of heat, work, and internal energy. In the second meeting, students re-evaluated their initial solutions by analyzing different thermodynamic processes (isothermal, isobaric, isochoric, and adiabatic). They identified the type of process represented in their initial solutions while also comparing the strengths and limitations of each process within the given problem context. This reflection process not only helped students correct their early misconceptions but also reinforced their conceptual understanding of the differences among thermodynamic processes and their real-world relevance. This iterative cycle of constructing and evaluating solutions reflects the essence of PBL, which involves continuous questioning, reflection, and clarification of information to strengthen conceptual understanding (Smith et al, 2022). This explains why the experimental group achieved significant improvements in higher-order thinking skills, particularly in analysis (C4) and evaluation (C5).

Classroom observations further reinforced the quantitative findings, with an implementation score of 93% categorized as "very good." Students actively collaborated, engaged in discussions, and solved contextual thermodynamics problems. These observations are consistent with, who reported that gamification and reflective strategies in Deep Learning enhanced students' engagement and motivation (Feriyanto et al, 2024). Thus, this study highlights that Deep Learning not only improves test results but also develops 21st-century skills such as communication, collaboration, and critical thinking. Compared with studies that showed less significant results, such as with contextual learning, it becomes clear that contextualization alone is not sufficient; it must be integrated with mindful and joyful elements to be effective (Sasmita et al, 2022). This explains why combining Deep Learning with PBL provides a stronger approach by merging authentic problem-solving with both cognitive and emotional engagement.

When compared to previous research in physics, challenges in teaching thermodynamics remain significant. found that even at the university level, students still face difficulties and misconceptions regarding the First and Second Laws of Thermodynamics, especially in understanding the relationships between heat, work, and internal energy (Brown et al, 2021). In Indonesia reported that students' performance on HOTS questions related to thermodynamics remained low (Barokah et al, 2021). Similarly, , through classroom action research, showed that although inquiry-based models improved learning outcomes, students' initial scores were still low and the improvements were not optimal (Sunardi, 2021). Within this context, the present study contributes new insights by demonstrating that integrating Deep Learning into PBL offers a more effective strategy to improve physics learning outcomes, particularly in the First Law of Thermodynamics.

Theoretically, this study strengthens the empirical foundation of applying Deep Learning in physics education. While previous research has primarily focused on mathematics and general subjects, this study provides the first evidence that Deep Learning principles are effective in physics learning. This supports constructivist perspectives, which emphasize that meaningful and reflective learning fosters deeper understanding compared to rote memorization (Marton et al, 1976; Popovic, 2013). By contextualizing real-world problems and integrating reflection with joyful elements, students gain not only cognitive benefits but also emotional and motivational advantages. Practically, this study offers important implications for physics teachers. The integration of Deep Learning principles into PBL not only enhances learning outcomes but also encourages students' participation and motivation. Teachers may adopt similar strategies by designing contextual problem scenarios, utilizing interactive media, and engaging students in reflective activities. Such strategies align with 21st century competencies that emphasize critical thinking, collaboration, creativity, and communication.

Conclusion

This study demonstrates that the integration of Deep Learning within Problem-Based Learning (PBL) has a significant effect on students' physics learning outcomes in the topic of the First Law of Thermodynamics. The Mann–Whitney U test confirmed a significant difference ($p = 0.000 < 0.05$), while the N-Gain analysis indicated a higher improvement in the experimental class (87.70, high category) compared to the control class (69.08, medium category). Observations of learning implementation also showed a very good result (93%), with active student engagement. Theoretically, these findings reinforce constructivism, which emphasizes that reflective and contextual learning fosters deep conceptual understanding. Practically, this strategy provides a reference for teachers to integrate mindful, meaningful, and joyful learning within PBL to enhance students' motivation, collaboration, and 21st-century skills. The limitations of this study lie in the relatively small sample size, the single-school research setting, and the narrow scope of the material covered. Therefore, further research should involve larger samples, be conducted in different schools, and examine other physics topics such as the Second Law of Thermodynamics or fluid mechanics to test the consistency of this approach's effectiveness.

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