Lontar Physics Today (e-ISSN: 2828-0970)
Vol. 4 No. 3 November 2025, p 178-182
Available online at http://journal.upgris.ac.id/index.php/upt
DOI: 10.26877/lpt.v4i3.25521

Effects of Integrating Deep Learning with a Project-Based Learning Model on Thermodynamics Learning Outcomes

Tineke Makahinda[1],*, Kenny Setiawan Lahope[1], and Meidy Atina Kuron[2]

[1]*Physics Education Program, Faculty of Mathematics, Natural Sciences and Earth, Universitas Negeri Manado, Tondano, Indonesia.*
[2]*Science Education Program, Faculty of Mathematics, Natural Sciences and Earth, Universitas Negeri Manado, Tondano, Indonesia.*

* Corresponding author(s), e-mail: tineke_makahinda@unima.ac.id

Article Info:

Article History:
Received: 1 November 2025
Accepted: 25 November 2025

Keyword:
Deep Learning, Project Based Learning, Learning Outcomes, Quasi-Experiment Thermodynamics

Abstract:

This study investigates the difference in Thermodynamics learning outcomes between students taught using a Project-Based Learning (PBL) model integrated with deep learning and those taught using the PBL model alone.. The research employed an experimental method with a quasi-experimental design, utilizing a *Nonequivalent Pretest-Posttest Control Group Design*. The study was conducted in the Physics Department of Manado State University for Physics Education and Physics programs during the Odd Semester of the 2025/2026 Academic Year. The research population included all active students from these programs, with a random sample of 40 students divided into an experimental class and a control class, each consisting of 20 students. Data were collected through essay-type tests, administered as pretests and posttests, and subsequently analyzed statistically using descriptive and inferential techniques with Python programming. The findings indicate that the experimental class, which implemented deep learning integrated with the Project Based Learning model, achieved a higher average Thermodynamics learning outcome (80.28) compared to the control class (72.35), demonstrating better data consistency (standard deviation of 7.93 versus 9.71). Shapiro-Wilk normality tests for both classes confirmed a normal distribution of data (p-value for experimental class is 0.3147 while control class is 0.0638), and Levene's homogeneity test confirmed homogeneous variances (p-value 0.2529). Furthermore, the independent sample t-test results showed a t-statistic of 2.8289 and a p-value of 0.0074, which is less than 0.05. This leads to the conclusion that there is a statistically significant difference in Thermodynamics learning outcomes between the experimental and control classes. These findings suggest that the integration of deep learning with the Project Based Learning model is effective in enhancing Thermodynamics learning outcomes.

1. Introduction

Creating a learning environment that optimizes student learning outcomes is the responsibility of every educator. One key factor in determining learning achievement is the educator's ability to design and implement learning materials and arrange learning activities. Various learning strategies have been employed to improve student learning outcomes. A learning strategy serves as a pattern in the learning process, providing general guidance for educators and students to create effective and efficient learning situations that impact learning interactions, leading to behavioral changes [1]. As an educator, improving the quality of students requires appropriate strategies and high innovation, especially in managing effective and efficient learning processes. Therefore, the approach taken is to implement a learning strategy that aligns with the characteristics of the material and the students.

Deep Learning represents a new innovation in contemporary learning paradigms, founded on three principles: Consciousness, Meaningfulness, and Enjoyment. The principle of consciousness refers to students' deep understanding of the material, involving reflection and personal connection with the concepts being learned. Meanwhile, the principle of meaningfulness emphasizes the relevance of the material to real life and students' experiences, encouraging the application of knowledge in a broader context. Furthermore, the principle of enjoyment focuses on creating a positive and engaging learning environment, motivating students to actively participate and enjoy the learning process. Through this approach, Deep Learning strives to foster holistic and sustainable understanding, extending far beyond rote memorization. The implementation of this deep learning model aligns with the goals of increasing student motivation, active engagement, critical thinking skills, communication, and collaboration abilities. Studies show that this approach is effective in enhancing student engagement, strengthening understanding, and developing critical thinking skills holistically [2]. This is because varied learning strategies, including the use of interactive methods and relevant activities, have been proven to increase student motivation and understanding of the concepts taught [3], [4].

The Project Based Learning (PjBL) model is highly beneficial in constructing student competencies to acquire broad and deep insights, as well as a comprehensive understanding of concepts and principles in various subjects, including physics, and their application in daily life. This model not only focuses on improving academic learning outcomes but also on developing various other important competencies such as critical thinking, problem-solving, creativity, independence, and interpersonal skills through real-world projects [5]. PjBL is effective in encouraging active student engagement in the learning process and connecting learned concepts with real-life contexts, thereby enhancing a deep understanding of the material [6]. PjBL also encourages students to design and create innovative projects to solve everyday problems and emphasizes contextual learning that is relevant to their experiences [7]. This model empowers students to actively participate in designing, implementing, and evaluating projects that have real-world applications, which in turn fosters their critical and creative thinking [8].

Thermodynamics, as a fundamental branch of physics, holds crucial relevance across various engineering and scientific disciplines, studying the relationship between heat and other forms of energy as well as their impact on physical systems. A thorough understanding of physics concepts, such as those in thermodynamics, is essential for students to analyze complex phenomena and develop innovative solutions [9]. However, the intricate nature of scientific concepts often presents a challenge in the learning process, thus necessitating innovative and integrated pedagogical strategies to significantly improve student comprehension [10], [11]. Therefore, the integration of Deep Learning with Project Based Learning is expected to be an effective solution to address these challenges, considering that PjBL can increase student interest, motivation, and creativity [12], [13], [14].

2. Method

The research was conducted at the Department of Physics, Manado State University, in the odd semester of 2025-2026. The method used was experimental research. The research population consisted of all students in the Physics Department, comprising students from the physics education and physics study programmes, while the research sample consisted of 40 students from the Physics Department, divided into two groups using the random sampling technique, namely 20 students in the experimental group (students taught using deep learning with the *project-based learning* model) and 20 students in the control group (students taught using the *project-based learning* model without deep learning*).* The research design applied a quasi-experimental design, namely *the nonequivalent pretest posttest control group design*. The treatment in the study was carried out over three weeks with two face-to-face meetings, each lasting 50 minutes for each class. The treatment used the PjBL model in each class through six phases, namely (1) Project Determination, (2) Designing the steps to complete the project, (3) Preparing a project implementation schedule, (4) Completing the project with facilitation and monitoring, (5) Presenting the results of the activities and presenting/publishing the project results, and (6) Evaluating the process and results of the project (adapted from Keser and Karagoca, 2010) [15]. The project was carried out using PhET simulations. Students observed the PhET simulations and followed the steps provided, explained the physical principles and concepts in the simulations, and wrote scientific reports based on their observations. The data in this study were obtained through a descriptive test consisting of five questions. The test was administered through a pretest to measure the students' initial abilities, followed by the learning treatment, and ended with a posttest to evaluate the improvement in learning outcomes after the intervention. Statistical data analysis was performed using two methods, namely descriptive statistical techniques (mean, median, mode, standard deviation) and inferential techniques (data normality test, homogeneity test, and t-test) using Python programming.

3. Results and Discussion

This research was motivated by the imperative to optimize learning outcomes, particularly in complex subjects like Thermodynamics, through innovative and effective instructional strategies, focusing on the principles of deep learning and the benefits of Project Based Learning in fostering comprehensive competence and understanding.

3.1. Descriptive Statistical Analysis

Table 1. *Descriptive Statistical Analysis*

Class	Mean	Median	Mode	Variance	Standart Deviation	Coefficien of Variance (%)	Min	Max	Range
Experiment Class	80.28	80.95	81.3	62.85	7.93	9.88	60.0	91.3	31.3
Control Class	72.35	73.10	73.1	94.31	9.71	13.42	55.0	84.4	29.4

a. Analysis of Measures of Central Tendency

Table 1 presents the measures of central tendency: Mean, Median, and Mode. The Mean serves as a primary indicator of group performance. The experimental class demonstrated an average score of 80.28, whereas the control class had an average of 72.35. This difference suggests that, generally, students instructed with deep learning and the Project Based Learning model achieved higher learning outcomes compared to those who only used the Project Based Learning model.

The Median represents the middle value in an ordered dataset, dividing the data into two equal halves. The median for the experimental class was 80.95, and for the control class, it was 73.10. These figures provide insight into the midpoint of the score distribution, affirming that the majority of scores in the experimental class tended to be higher. Meanwhile, the Mode is the most frequently occurring value. The experimental class had a mode of 81.3, and the control class had 73.1. These modes indicate the most common learning outcomes achieved by students in each group, again highlighting the tendency for higher scores in the experimental class.

a. Analysis of Measures of Data Dispersion

Measures of data dispersion provide information on the variability or consistency of values within a group. Variance and Standard Deviation are two critical measures for this purpose. The variance for the experimental class was 62.85, significantly lower than the control class's variance of 94.31. Variance quantifies how far each data point is from the mean, squared. Standard deviation, the square root of the variance, provides a measure of dispersion in the same units as the original data. The experimental class showed a standard deviation of 7.93, while the control class had 9.71. These figures indicate that the learning outcome data in the experimental class were more concentrated around their mean, implying that student scores were more homogeneous or consistent, compared to the control class, which exhibited a wider spread of scores.

The Coefficient of Variation is a relative measure of dispersion, expressed as a percentage, which compares the standard deviation to the mean. The experimental class has a coefficient of variation of 9.88%, while the control class has 13.42%.

b. Analysis of Extreme Values and Data Range

Table 1 also includes the minimum, maximum, and range values. The Minimum score for the experimental class was 60.0, and for the control class, it was 55.0, indicating the lowest scores achieved in each group. The Maximum score for the experimental class was 91.3, and for the control class, it was 84.4, representing the highest scores achieved. Finally, the Range is the difference between the maximum and minimum values. The experimental class had a range of 31.3, and the control class had 29.4. Although the ranges are similar, the higher minimum and maximum values in the experimental class suggest that this group not only has a better average but also achieves higher scores overall

3.2. Inferential Statistical Analysis

a. Data Normality Test

Table 2. *Results of Data Normality Test*

Class	Test Method	Statistic	p-value	Results
Experiment Class	Shapiro–Wilk Test	0.9463	0.3147	The data is normally distributed (p-value > 0.05)
Control Class		0.9100	0.0638	The data is normally distributed (p-value > 0.05)

Table 2 presents the results of the statistical test for normality of the learning outcome data from both the experimental and control classes. The Shapiro-Wilk Test was employed, a method widely recommended, especially for small to medium sample sizes, due to its power in detecting deviations from normality [16]. The null hypothesis of the Shapiro-Wilk test is that the data are drawn from a normally distributed population [17]. For the null hypothesis to be rejected, the p-value must be smaller than the predetermined significance level, commonly 0.05 [18].

For the experimental class, the Shapiro-Wilk statistic was 0.9463 with a p-value of 0.3147. As the p-value is greater than 0.05, the null hypothesis is not rejected, leading to the conclusion that the learning outcome data for the experimental class are normally distributed. Similarly, for the control class, the Shapiro-Wilk statistic was 0.9100 with a p-value of 0.0638. This p-value is also greater than 0.05, resulting in the non-rejection of the null hypothesis. Therefore, the learning outcome data for the control class are also concluded to be normally distributed [18].

Overall, the results presented in Table 2 statistically confirm that the learning outcome data from both research groups meet the assumption of normality. This conclusion is crucial as it provides a strong foundation for applying subsequent parametric inferential statistical analyses, such as the t-test, for comparing the mean learning outcomes between the experimental and control classes [19]. Visually, the normality test results can be seen in Figure 1 (as mentioned in the original document, though the image itself is not provided here).

b. Homogeneity Test

Table 3. *Results of Data Homogeneity Test*

Test Method	Statistic	p-value	Decision Criteria	Results
Levene Test	1.3479	0.2529	If p > 0.05 variance is homogeneous	The variance of both classes is homogeneous (p > 0.05)

The Levene's test results show a p-value of 0.2529, which is greater than the significance threshold of 0.05. This indicates that the variances between the two groups are homogeneous [20][21]. This condition of variance homogeneity fulfils one of the crucial assumptions for advanced parametric inferential statistical analyses, such as the independent samples t-test, thereby enhancing the validity of comparisons between the two groups [13].

c. T-Test

Table 4. *Results of T-Test*

Test Method	calculated t-statistic	t-table (α = 0.05)	p-value	Decision Criteria	Results
Independent Sample t-test	2.8289	2.000	0.0074	If t calculated > t table or p-value < 0.05, then it is significant.	There was a significant difference between the Experimental Class and the Control Class (p-value < 0.05).

Based on Table 4, the resulting p-value is 0.0074. Because this p-value is less than 0.05, and the calculated t-statistic (2.8289) is greater than the critical t-table (2.000), according to the decision criterion, it is concluded that there is a statistically significant difference between the Experimental Class and the Control Class [22], [23]. This finding indicates that the implementation of deep learning integrated with the Project Based Learning model in the experimental class significantly resulted in higher average Thermodynamics learning outcomes compared to the control class, which exclusively used the Project Based Learning model without deep learning. This provides indicates for the effectiveness of a learning approach that incorporates deep learning in improving academic achievement [24], [25], [26].

4. Conclusion

This study concludes that the integration of deep learning with the Project Based Learning model significantly enhances Thermodynamics learning outcomes. This is evidenced by higher academic achievements and better performance consistency in the experimental group compared to the control group. These findings are supported by both descriptive analysis and inferential statistical tests, which reveal a significant difference between the two groups. For future research, it is recommended to broaden the scope of the study to more diverse populations and other fields or topics, further analyze the contribution of each deep learning principle, and investigate the long-term impact while comparing it with other innovative learning strategies.

References

[1] A. M. D. L. Prapsetyo, T. D. A. D. Putri, and A. Prapsetyo, "Efektivitas Model Project Based Learning Untuk Meningkatkan Keterampilan Berpikir Kritis Peserta Didik," *J. Dwija Kusuma*, vol. 13, no. 1, p. 1, Mar. 2025.

[2] G. X. Sinaga and E. Simbolon, "Penerapan Pembelajaran Mendalam Dalam Meningkatkan Keterampilan Berpikir Kritis Siswa Pada Pelajaran Agama Katolik Di Sekolah Menengah Negeri 1 Delitua," *Learn. J. Inov. Penelit. Pendidik. Dan Pembelajaran*, vol. 5, no. 3, p. 1192, Aug. 2025, doi: 10.51878/learning.v5i3.6127.

[3] D. Dirman, W. Kusumaningsih, and R. B. Ginting, "Implementasi Pembelajaran Berdiferensiasi Untuk Mencapai Standar Proses Pendidikan Di SMP," *Learn. J. Inov. Penelit. Pendidik. Dan Pembelajaran*, vol. 5, no. 1, p. 384, Mar. 2025, doi: 10.51878/learning.v5i1.4568.

[4] S. Maysaroh, H. J. Sada, and A. Susanti, "Implementasi Kurikulum Merdeka Dalam Meningkatkan Kemandirian Belajar Peserta Didik: Studi Kasus Di SMP Negeri 4 Bandar Lampung," Mar. 2025.

[5] W. Ahmad, G. Abdullah, and K. Kudus, "Pengaruh Model Pembelajaran Project Based Learning (Pjbl) Berbantuan Media Canva Terhadap Hasil Belajar Siswa Pada Materi Siklus Air Di Kelas V SD," *Sci. J. Inov. Pendidik. Mat. Dan IPA*, vol. 5, no. 2, p. 536, May 2025, doi: 10.51878/science.v5i2.4881.

[6] N. Indrawati and Nurafni, “Penerapan Model Problem Based Learning Dengan Pemberian Tugas Proyek Terhadap Hasil Belajar Matematika,” *Kogn. J. Ris. HOTS Pendidik. Mat.*, vol. 1, no. 2, pp. 81–89, Dec. 2021, doi: 10.51574/kognitif.v1i2.71.

[7] M. Sinta, H. Sakdiah, N. Novita, F. W. Ginting, and S. Syafrizal, “Penerapan Model Pembelajaran Project Based Learning (PjBL) untuk Meningkatkan Kemampuan Berpikir Kreatif Siswa pada Materi Hukum Gravitasi Newton di MAS Jabal Nur,” *J. Phi J. Pendidik. Fis. Dan Fis. Terap.*, vol. 3, no. 3, pp. 24–33, Aug. 2022, doi: 10.22373/p-jpft.v3i3.14546.

[8] R. Jannah and S. Nisa, “Pendekatan Pembelajaran Berbasis Proyek untuk Meningkatkan Kemampuan Berpikir Kritis dan Kreatif Siswa Sekolah Dasar,” *TSAQOFAH*, vol. 4, no. 4, pp. 3148–3161, June 2024, doi: 10.58578/tsaqofah.v4i4.3214.

[9] Y. E. E. Putri, A. D. Lesmono, and L. Nuraini, “Profil Sikap Ilmiah Siswa Menggunakan Model Problem Based Learning Dengan Pendekatan STEM Pada Pembelajaran Fisika,” *J. Inov. Dan Pembelajaran Fis.*, vol. 9, no. 1, pp. 42–52, June 2022, doi: 10.36706/jipf.v9i1.14247.

[10] M. F. Rosadah, Y. Yuliani, and A. Kurniawan, “Penggunaan Model Pembelajaran Problem Based Learning Untuk Meningkatkan Keterampilan Berpikir Kritis,” *Learn. J. Inov. Penelit. Pendidik. Dan Pembelajaran*, vol. 4, no. 2, pp. 354–363, June 2024, doi: 10.51878/learning.v4i2.2896.

[11] M. M. Pasinggi, “Penerapan Model Pembelajaran Problem Based Learning Dalam Meningkatkan Hasil Belajar Fisika,” *Sci. J. Inov. Pendidik. Mat. Dan IPA*, vol. 3, no. 1, pp. 49–58, Apr. 2023, doi: 10.51878/science.v3i1.2078.

[12] S. Sakilah and others, “Pengaruh Project Based Learning Terhadap Motivasi Belajar Sekolah Dasar Negeri 167 Pekanbaru,” *JMIE J. Madrasah Ibtidaiyah Educ.*, vol. 4, no. 1, pp. 127–138, June 2020, doi: 10.32934/jmie.v4i1.175.

[13] M. S. I. N. Tika, I. G. M. N. Budiana, and H. H. Wulakada, “Analisis Komparasi Minat Belajar Dan Model Pembelajaran Berbasis Proyek (Pjbl) Terintegrasi Pembelajaran Sosial Emosional (Pse) Terhadap Hasil Belajar Kimia Peserta Didik SMA Negeri 6 Kupang,” *Sci. J. Inov. Pendidik. Mat. Dan IPA*, vol. 5, no. 3, pp. 1046–1059, Aug. 2025, doi: 10.51878/science.v5i3.6665.

[14] Á. Roco-Videla, S. Flores, M. Olguín-Barraza, and R. Aguilera-Eguía, “Considerations when using the Shapiro–Wilk test when working with small samples,” *Angiología*, Jan. 2024, doi: 10.20960/angiologia.00568.

[15] E. Kosasih, *Strategi Belajar dan Pembelajaran Implementasi Kurikulum 2013*. Bandung: Yrama Widya, 2014.

[16] B. D. Prasetiyo, Q. Sholihah, Aulanni’am, and H. Riniwati, “Modelling Bioconversion Processes in Hospital Food Waste Management Using Black Soldier Fly Larvae,” *Int. J. Environ. Impacts*, vol. 7, no. 2, pp. 305–314, June 2024, doi: 10.18280/ijei.070215.

[17] I. Machali, *Metode Penelitian Kuantitatif Panduan Praktis Merencanakan, Melaksanakan dan Analisis dalam Penelitian Kuantitatif*. 2016. Accessed: Nov. 01, 2025. [Online]. Available: https://digilib.uin-suka.ac.id/id/eprint/24023/

[18] A. Ghasemi and S. Zahediasl, “Normality Tests for Statistical Analysis: A Guide for Non-Statisticians,” *Int. J. Endocrinol. Metab.*, vol. 10, no. 2, pp. 486–489, July 2012, doi: 10.5812/ijem.3505.

[19] D. Miranda, R. Noël, J. Godoy, C. Escobedo, C. Cechinel, and R. Muñoz, “Quantitative analysis of communication dynamics in agile software teams through multimodal analytics,” *Sci. Rep.*, vol. 15, no. 1, p. 9898, Mar. 2025, doi: 10.1038/s41598-025-91328-x.

[20] I. Toifur and A. Santoso, “The Effectiveness of Problem Based Learning Model and Learning Style on Mathematical Creative Thinking Ability of Students of SMA Negeri 1 Salaman Magelang,” *Sci. J. Inov. Pendidik. Mat. Dan IPA*, vol. 5, no. 3, Aug. 2025.

[21] E. Purwanto, *Metodologi penelitian kuantitatif*. 2016. Accessed: Nov. 01, 2025. [Online]. Available: https://perpustakaan.kemendagri.go.id/opac/index.php?p=show_detail&id=3378&keywords=

[22] J. Shreffler and M. Huecker, *Hypothesis Testing, P Values, Confidence Intervals, and Significance*. in StatPearls. 2021. Accessed: Oct. 01, 2025. [Online]. Available: https://pubmed.ncbi.nlm.nih.gov/32491353/

[23] J. C. Ferreira and C. M. Patino, “What does the p value really mean?,” *J. Bras. Pneumol.*, vol. 41, no. 5, pp. 485–485, Oct. 2015, doi: 10.1590/s1806-37132015000000215.

[24] C.-H. Chen and Y.-C. Yang, “Revisiting the effects of project-based learning on students’ academic achievement: A meta-analysis investigating moderators,” *Educ. Res. Rev.*, vol. 26, pp. 71–81, Jan. 2019, doi: 10.1016/j.edurev.2018.11.001.

[25] N. Barokah and U. Mahmudah, “Transformasi Pembelajaran Matematika SD Melalui Deep Learning: Strategi untuk Meningkatkan Motivasi dan Prestasi,” *Khatulistiwa J. Pendidik. Dan Sos. Hum.*, vol. 5, no. 1, pp. 574–585, May 2025, doi: 10.55606/khatulistiwa.v5i1.6105.

[26] Z. Nurazizah, A. S. Mubarok, E. Herawan, and D. P. Putri, “Deep Learning with Project-Based Learning (PjBL) Model for Student Creativity,” *Pedagog. J. Pendidik.*, vol. 14, no. 2, pp. 239–251, July 2025, doi: 10.21070/pedagogia.v11i1.1544.