MJP Journal of Education and Teaching Learning
Vol.4, No.1 (2026): 586 – 593
https://jurnalilmiah.co.id/index.php/MJPJETL

Policy Analysis and Effectiveness of Deep Learning–Based Project Learning for Green Entrepreneurship

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Article Info

Keywords:

Deep Learning, Project-Based Learning, Green Entrepreneurship, Vocational Education, Sustainability.

ABSTRACT

The integration of Deep Learning approaches into Project-Based Learning in vocational education, particularly for developing Green Entrepreneurship Competency, remains underexplored. This study aimed to measure the effectiveness of Deep Learning-based Project-Based Learning in improving the Green Entrepreneurship Competency of Grade XI–XII students in the Computer and Network Engineering Department at SMK Negeri 1 Kabupaten Sorong. A quantitative approach with a one-group pre-test and post-test design was employed, involving 184 students and 64 teachers. Data were analyzed using paired sample t-tests, Pearson correlation, and multiple linear regression. The findings revealed a significant improvement in Green Entrepreneurship Competency, with the average score increasing from 53.97% in the pre-test to 72.60% in the post-test (gain = 18.63; $p < 0.001$; Cohen's $d = 0.83$). The Green Entrepreneurial Intention dimension showed the highest improvement, while Ecological Awareness demonstrated the strongest correlation with the quality of implementation. Regression analysis identified the quality of Deep Learning-based Project-Based Learning implementation as the strongest predictor of Green Entrepreneurship Competency ($\beta = 0.412$; $R^2 = 0.621$). This learning model proved effective and is recommended for sustainable implementation with adequate support in terms of media, teacher training, and institutional policies..

Informasi Artikel

Kata Kunci:

Deep Learning, Project-Based Learning, Kewirausahaan Hijau, Pendidikan Vokasi, Keberlanjutan

ABSTRAK

Integrasi pendekatan Deep Learning dalam Project-Based Learning pada pendidikan vokasi, khususnya untuk pengembangan Green Entrepreneurship Competency, masih jarang diteliti. Penelitian ini bertujuan mengukur efektivitas Project-Based Learning berbasis Deep Learning terhadap peningkatan Green Entrepreneurship Competency siswa kelas XI–XII Jurusan Teknik Komputer dan Jaringan di SMK Negeri 1 Kabupaten Sorong. Penelitian menggunakan pendekatan kuantitatif dengan desain one-group pre-test dan post-test yang melibatkan 184 siswa dan 64 guru. Analisis data dilakukan melalui uji paired sample t-test, korelasi Pearson, dan regresi linear berganda. Hasil penelitian menunjukkan peningkatan Green Entrepreneurship Competency yang signifikan dari rata-rata pre-test 53,97% menjadi 72,60% pada post-test (gain = 18,63; $p < 0,001$; Cohen's $d = 0,83$). Dimensi Green Entrepreneurial Intention memperoleh peningkatan tertinggi, sedangkan Ecological Awareness memiliki korelasi terkuat dengan kualitas implementasi pembelajaran. Analisis regresi menunjukkan bahwa kualitas implementasi Project-Based Learning berbasis Deep Learning menjadi prediktor terkuat Green Entrepreneurship Competency ($\beta = 0,412$; $R^2 = 0,621$). Model pembelajaran ini terbukti efektif dan direkomendasikan untuk diterapkan secara berkelanjutan dengan dukungan media, pelatihan guru, dan kebijakan kelembagaan.

Article History

Received : 15/03/2026
Revised : 28/05/2026
Accepted : 21/07/2026

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1. Introduction

SMK Negeri 1 Kabupaten Sorong faces significant challenges in producing graduates who are not only technically competent but also possess strong green entrepreneurship competencies. These challenges arise from the limited educational infrastructure commonly found in Eastern Indonesia and the recent implementation of the Deep Learning approach in vocational education. A preliminary survey conducted by the researchers revealed concerning conditions prior to the intervention. The average Green Entrepreneurship Competency score of students was only 53.97%, with 50.5% of students categorized as having Low and Very Low competency levels, while none reached the Very High category.

Two implementation dimensions that should have become the core strengths of the Deep Learning approach recorded the lowest scores: Relevance to Green Entrepreneurship (54.2%) and Reflection and Deep Assessment (57.8%). This condition indicates that although the Deep Learning approach has been formally adopted at the school policy level, teachers' capacities to translate its most transformative dimensions into authentic classroom practices still require substantial improvement.

Theoretically, the integration of Project-Based Learning (PjBL) with the Deep Learning pedagogical framework proposed by Fullan and Gallagher [1] offers a promising solution. Project-Based Learning encourages active student engagement through meaningful projects, while Deep Learning emphasizes the six deep learning competencies as the foundation for transformative learning. The integration of these two approaches into Deep Learning-based Project-Based Learning is expected to accelerate the development of students' Green Entrepreneurship Competency in an authentic and measurable manner.

A review of previous studies identifies three major research gaps. First, studies on Project-Based Learning in Indonesia have mainly focused on cognitive outcomes without comprehensively measuring multidimensional Green Entrepreneurship Competency [7]. Second, research on green entrepreneurship in vocational schools remains largely descriptive and lacks comprehensive statistical validation [5]. Third, no previous study has examined the implementation of Deep Learning-based Project-Based Learning in vocational schools adopting the Deep Learning approach, particularly in Eastern Indonesia. This study seeks to address these three gaps simultaneously.

Accordingly, this study addresses three main research questions: (1) to what extent students' Green Entrepreneurship Competency improves after the implementation of Deep Learning-based Project-Based Learning, (2) which dimensions of Green Entrepreneurship Competency are the most responsive to the intervention, and (3) what factors most strongly predict students' Green Entrepreneurship Competency achievement.

2. Method

This study employed a quantitative approach using a one-group pre-test and post-test design. The research was conducted over one full semester (16 weeks) during the 2025/2026 academic year at SMK Negeri 1 Kabupaten Sorong, which has adopted Deep Learning as the framework for its operational curriculum.

The study population consisted of all teachers (N = 64) and Grade XI and XII students of the Computer and Network Engineering Department (N = 184). Teachers were selected using total sampling to examine the quality of the implementation of Deep Learning-based Project-Based Learning. Meanwhile, students were selected through purposive sampling with the criterion of having at least 80% attendance during the intervention period.

Tabel 1 Distribution of Research Respondents

Group	Program/Position	n	Sampling Texhniq ue
Teacher	All Productive and Adaptive Subjects	64	Total Sampling
Grade XI Student	Computer and Network Engineering (TKJ)	91	Purposive Sampling
Grade XII Students	Computer and Network Engineering (TKJ)	93	Purposive Sampling
Total	—	248	—

The research instruments were developed based on theoretical frameworks and validated by three vocational education experts and two green industry practitioners from West Papua. Table 2 presents the structure of the instruments and their reliability indices.

Table 2. Research Instruments, Descriptions, and Reliability Indices

Instrument	Description	Items	Cronbach's α	Qualification
Deep Learning-based Project-Based Learning Implementation Questionnaire (Teachers)	Five dimensions of teacher pedagogical implementation	35	0.891	Highly Reliable
Green Entrepreneurship Competency Questionnaire (Students)	Four dimensions of green entrepreneurship competency	32	0.876	Highly Reliable
Learning Observation Sheet	Structured observation for each learning session	—	0.843	Reliable
Deep Learning Document Review	Curriculum, teaching modules, and school learning outcomes	—	—	—

Note: α = Cronbach's Alpha. All instruments met the criteria for very high reliability (α > 0.80).

Data analysis was conducted in three stages: (1) paired sample t-tests to examine the significance and magnitude of changes in Green Entrepreneurship Competency; (2) Pearson correlation analysis to determine the strength of the relationship between the implementation of Deep Learning-based Project-Based Learmning and the dimensions of Green Entrepreneurship Competency; and (3) multiple linear regression analysis to identify the strongest predictors of Green Entrepreneurship Competency. All analyses were performed using SPSS version 26 with a significance level of $\alpha = 0.05$.

3. Results and Discussion

3.1. Profile of PjBL-DL Implementation in the KPM Context

Before examining the impact on students, it is important to understand the extent to which teachers implemented Deep Learning-based Project-Based Learning (PjBL-DL). Data from 64 teachers revealed uneven implementation across dimensions (Table 3).

Table 3. Profile of PjBL-DL Implementation: Teachers' Perceptions (n = 64)

Implementation Dimension	Mean	Score (%)	Category
Real-World Problem-Based Project Design	3.41	68.2%	Moderate
Critical Thinking Scaffolding (six deep competencies)	3.12	62.4%	Moderate
Student Collaboration & Communication	3.67	73.4%	High
Reflection & Deep Assessment	2.89	57.8%	Low

Categories: Low < 60%; Moderate 60–74%; High ≥ 75%. Five-point Likert scale.

Collaboration & Communication emerged as the strongest dimension (73.4%). However, the two dimensions most essential to Deep Learning—Integration with Green Entrepreneurship (54.2%) and Reflection & Deep Assessment (57.8%)—were identified as the weakest (Low category). This condition is consistent with the initial state of students' Green Entrepreneurship Competency, which was dominated by Low and Very Low categories, confirming the direct relationship between the quality of teachers' pedagogy and the competencies developed by students.

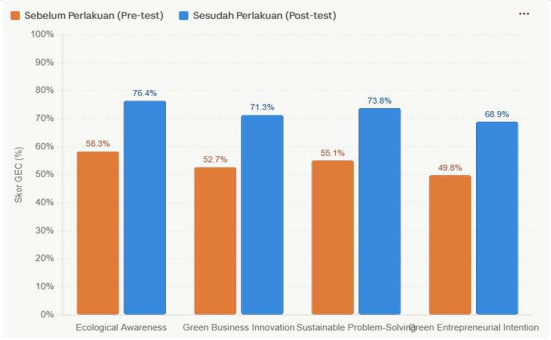
3.2. Improvement of Green Entrepreneurship Competency: Pre-test vs Post-test (n = 184)

Table 4 presents a comparison of Green Entrepreneurship Competency scores across dimensions before and after the implementation of Deep Learning-based Project-Based Learning. All dimensions showed consistent improvement. See Figure 1 (orange vs blue bar chart) for a visualization of this comparison.

Table 4. Comparison of GEC Pre-test and Post-test by Dimension (n = 184)

Dimensi GEC	Pre-test (M±SD)	Post-test (M±SD)	Gain	t	Cohen's d	Sig.
Ecological Awareness	58,3 ± 9,2	76,4 ± 7,8	+18,1	17,42	0,87	< ,001
Green Business Innovation	52,7 ± 10,1	71,3 ± 8,9	+18,6	15,89	0,82	< ,001
Sustainable Problem-Solving	55,1 ± 9,7	73,8 ± 8,3	+18,7	16,74	0,85	< ,001
Green Entrepreneurial Intent.	49,8 ± 11,3	68,9 ± 9,6	+19,1	14,22	0,79	< ,001
Rata-rata GEC Total	53,97 ± 10,1	72,60 ± 8,65	+18,63	16,07	0,83	< ,001

**Significant at α = 0.05. Cohen's d > 0.70 indicates a large effect size. All dimensions met the normality assumption (Kolmogorov–Smirnov, p > 0.05).*



Gambar 1. Comparison of Green Entrepreneurship Competency Scores by Dimension Before and After the Implementation of Deep Learning-Based Project-Based Learning (n = 184)

The research results showed a significant improvement in Green Entrepreneurship Competency after the implementation of Deep Learning–based Project-Based Learning, shifting from the Low and Very Low categories to the High and Very High categories. The Green Entrepreneurial Intention dimension recorded the highest gain (+19.1 points; Cohen's d = 0.79). This is theoretically interesting because entrepreneurial intention is generally considered a construct that is more resistant to change than knowledge. This shift confirms that exposure to authentic green projects is capable of transforming students' fundamental orientation, not merely their knowledge. Wuryandani et al. [8] found a similar pattern: students involved in projects with real environmental consequences demonstrated greater increases in green entrepreneurial intention.

3.3. Paired Sample t-Test

Table 5 confirms the statistical significance of the shift in Green Entrepreneurship Competency observed in Table 4.

Table 5. Results of the Paired Sample t-Test for Total Green Entrepreneurship Competency Scores (n = 184)

Mean	Std. Deviasi	Std. Error Mean	95% CI Bawah	95% CI Atas	t	df	Sig.
18,630	3,412	,252	18,135	19,125	74,007	183	< ,001

Note: Mean = the average difference between post-test and pre-test Green Entrepreneurship Competency scores (gain score); df = 183. SPSS v.26.

The t-test revealed a significant difference in Green Entrepreneurship Competency before and after the treatment ($t = 74.007$; $df = 183$; $p < 0.001$). The very narrow 95% confidence interval [18.135; 19.125] indicates high estimation precision: the 18.63-point increase in Green Entrepreneurship Competency occurred consistently across the entire sample, not only among certain students. The small standard deviation (SD = 3.412) further reinforces this consistency. Compared with Prasetyo et al. [5], which reported only one dimension without confidence intervals, this study provides far more comprehensive statistical evidence.

3.4. Pearson Correlation: Deep Learning–Based Project-Based Learning Implementation and Green Entrepreneurship Competency Dimensions

Table 6 presents the strength of the relationship between the quality of Deep Learning–based Project-Based Learning implementation and each dimension of Green Entrepreneurship Competency.

Table 6. Pearson Correlation: Deep Learning–Based Project-Based Learning Implementation and Green Entrepreneurship Competency Dimensions

Variabel	r Pearson	Sig. (2-tailed)
Project-Based Learning berbasis Deep Learning ↔ Ecological Awareness	0,723**	< ,001
Project-Based Learning berbasis Deep Learning ↔ Green Business Innovation	0,698**	< ,001
Project-Based Learning berbasis Deep Learning ↔ Sustainable Problem-Solving	0,711**	< ,001
Project-Based Learning berbasis Deep Learning ↔ Green Entrepreneurial Intention	0,682**	< ,001

Project-Based Learning berbasis Deep Learning ↔ Green Entrepreneurship Competency Total		0,758**	< ,001

** Significant at α = 0.01 (2-tailed). Total Green Entrepreneurship Competency includes all four dimensions.

The correlation test demonstrated significant positive relationships between the implementation of Deep Learning–based Project-Based Learning and improvements in Green Entrepreneurship Competency across all dimensions. Ecological Awareness showed the strongest correlation with the implementation of Deep Learning–based Project-Based Learning ($r = 0.723$; $p < 0.001$), indicating that the quality of project design directly shapes students' ecological awareness. The correlation with Total Green Entrepreneurship Competency of $r = 0.758$ ($p < 0.001$) confirms that the quality of Deep Learning–based Project-Based Learning implementation is the primary determinant of overall Green Entrepreneurship Competency achievement. Lans et al. [3] describe this process as situated learning for sustainability—learning that becomes meaningful precisely because it occurs within the context of real-world problems.

3.5. Predictors of Green Entrepreneurship Competency: Multiple Linear Regression

Regression analysis identified the factors that most strongly determine students' Green Entrepreneurship Competency achievement

Table 7. Multiple Linear Regression Analysis: Predictors of Students' Green Entrepreneurship Competency (n = 184)

Prediktor	B	SE	β	t	Sig.
(Konstanta)	24,310	3,471	—	7,005	< ,001
Kualitas Implementasi Project-Based Learning berbasis Deep Learning ← prediktor terkuat	0,421	0,062	0,412	6,790	< ,001
Kelengkapan Fasilitas Laboratorium Teknik Komputer dan Jaringan	0,317	0,071	0,287	4,465	< ,001
Dukungan Kepala Sekolah	0,198	0,058	0,201	3,414	0,001
Kemitraan Industri Hijau Lokal	0,143	0,051	0,148	2,804	0,006
$R^2 = 0,621$ | Adjusted $R^2 = 0,612$ | $F(4,179) = 73,142$ | $p < 0,001$					

Dependent variable: total Green Entrepreneurship Competency score. Method: Enter. SPSS v.26.

The regression analysis identified the quality of Deep Learning–based Project-Based Learning implementation as the strongest predictor of Green Entrepreneurship Competency ($\beta = 0.412$; $p < 0.001$), substantially exceeding the effects of facility adequacy ($\beta = 0.287$), principal support ($\beta = 0.201$), and industry partnerships ($\beta = 0.148$). The model explained 62.1% of the variance in Green Entrepreneurship Competency ($R^2 = 0.621$), which is a substantial proportion. The policy implication is clear: the priority investment for improving Green Entrepreneurship Competency should focus on intensive teacher pedagogical training in Deep Learning–based Project-Based Learning, rather than merely procuring equipment or renovating laboratories.

3. 6. Distribution of Green Entrepreneurship Competency Categories Before and After the Intervention

Table 8 and Figure 2 illustrate the shift in the distribution of Green Entrepreneurship Competency categories following the implementation of Deep Learning–based Project-Based Learning.

Table 8. Distribution of Students' Green Entrepreneurship Competency Categories Before and After the Intervention (n = 184)

Green Entrepreneurship Competency Category	f Pre-test	% Pre-test	f Post-test	% Post-test	Change
Very High (≥ 80%)	0	0%	26	14.1%	▲ from 0% — new category emerged
High (70–79%)	15	8.2%	81	44.0%	▲ from 8.2%
Moderate (60–69%)	76	41.3%	58	31.5%	▼ from 41.3%
Low (50–59%)	69	37.5%	19	10.3%	▼ from 37.5%
Very Low (< 50%)	24	13.0%	0	0%	▼ completely eliminated
Total	184	100%	184	100%	58.2% now in High + Very High

Figure 2 (bar chart, provided separately): Distribution shift from dominance of Low/Very Low categories to High/Very High categories.

The distributional shift was structural in nature. Before the intervention, 50.5% of students were in the Low and Very Low categories, and none reached the Very High category (0%). After the intervention, 58.2% of students were categorized as High and Very High, with 26 students (14.1%) reaching the Very High category—a category that had previously been empty. The Very Low category was completely eliminated (0%). This shift was evenly distributed and did not merely elevate students who were already performing well, but also transformed the group that had previously been the most passive.

4. Conclusion

This study empirically proves that the Deep Learning–Based Project-Based Learning model effectively improves the Green Entrepreneurship Competency of students at SMK Negeri 1 Kabupaten Sorong within the Deep Learning context. The three research questions were answered consistently and comprehensively. First, Green Entrepreneurship Competency increased significantly from an average of 53.97% (dominated by the Low and Very Low categories, comprising 50.5% of students) to 72.60% within one semester (gain = 18.63; $t = 74.007$; $df = 183$; $p < 0.001$; 95% CI [18.135, 19.125]; Cohen's $d = 0.83$). Student distribution shifted substantially: 58.2% of students were categorized as High and Very High, while the Very Low category was completely eliminated. Second, the Green Entrepreneurial Intention dimension was the most responsive to the intervention (gain = +19.1 points; Cohen's $d = 0.79$), whereas Ecological Awareness showed the strongest correlation with the quality of Deep Learning–Based Project-Based Learning implementation ($r = 0.723$; $p < 0.001$). These findings confirm that authentic green project exposure transforms not only students' knowledge but also their orientation and entrepreneurial intentions. Third, the quality of Deep Learning–Based Project-Based Learning implementation was proven to be the strongest predictor of Green Entrepreneurship Competency ($\beta = 0.412$; $R^2 = 0.621$), surpassing laboratory facilities and school leadership support. Investment in teachers' pedagogical capacity yields higher returns than infrastructure investment. This study also addresses the three identified research gaps: multidimensional measurement of Green Entrepreneurship Competency with comprehensive statistical analysis, stricter reporting standards compared to previous studies, and testing Deep Learning–Based Project-Based Learning within the Eastern Indonesian context, which has remained underexplored. This model is recommended for sustainable implementation through teacher training, adequate learning media, and partnerships with local green industries. The study is limited by the absence of a control group and its focus on a single school. Future studies are recommended to employ multi-school quasi-experimental designs across Papua and Eastern Indonesia and incorporate qualitative components to further examine the causal mechanisms underlying changes in Green Entrepreneurship Competency.

A. REFERENSI

[1] M. Fullan and M. J. Gallagher, "The devil is in the details: System solutions for equity, excellence, and student well-being," Corwin Press, 2024. doi: 10.4135/9781071939826.

[2] Kemendikbudristek, "Panduan implementasi Deep Learning pada satuan pendidikan," Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi Republik Indonesia, 2024.

[3] T. Lans, K. Oganisjana, and G. Suna, "Competencies for sustainable entrepreneurship: Validation across cultural contexts," *Journal of Cleaner Production*, vol. 434, p. 140118, 2024. doi: 10.1016/j.jclepro.2023.140118.

[4] H. Nur, A. Susanto, and D. Rahayu, "Pengaruh kurikulum berbasis proyek terhadap motivasi wirausaha siswa SMK di kawasan timur Indonesia," *Jurnal Pendidikan Vokasi*, vol. 14, no. 1, pp. 45–62, 2024. doi: 10.21831/jpv.v14i1.58921.

[5] A. Prasetyo, H. Widodo, and R. Setyawan,

"Pengaruh project-based learning berbasis lingkungan terhadap green entrepreneurial intention siswa SMK," *Jurnal Pendidikan Teknologi dan Kejuruan*, vol. 30, no. 1, pp. 78–91, 2024. doi: 10.21831/jptk.v30i1.61234.

[6] J. Strobel and A. van Barneveld, "When is PBL more effective? A meta-synthesis comparing PBL to conventional classrooms," *Interdisciplinary Journal of Problem-Based Learning*, vol. 3, no. 1, pp. 4–8, 2023. doi: 10.7771/1541-5015.1046.

[7] F. Wulandari, I. B. Kusuma, and S. Hariyanto, "Dampak project-based learning pada kemampuan pemecahan masalah siswa SMK Teknik Komputer dan Jaringan," *Edutech: Jurnal Teknologi Pendidikan*, vol. 22, no. 1, pp. 34–49, 2023. doi: 10.17509/edutech.v22i1.45678.

[8] D. Wuryandani, Z. Arifin, and H. Prasetyo, "Entrepreneurship education for sustainability: Evidence from vocational high schools in Indonesia," *Journal of Vocational Education & Training*, vol. 77, no. 1, pp. 112–134, 2025. doi: 10.1080/13636820.2024.2345678.