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The Effect of Project-Based Learning Model on Creativity and Learning Outcomes of Basic Electrical Engineering

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Abstract— This study aims to determine the effect of project-based learning models on creativity and learning outcomes of Electrical Installation and Power Engineering students in the Basic Electrical Engineering subject in class XI of SMKN 1 Airmadidi. This study used an experimental method with a post-test-only control group design. The instruments used included learning outcome tests and creativity questionnaires. The results showed a significant difference in the learning outcomes of Basic Electrical Engineering between students who were involved in learning using project-based models and those who followed conventional methods. This indicates that applying project-based learning models substantially affects the learning outcomes of Basic Electrical Engineering in Class XI of SMKN 1 Airmadidi with a t_{table} value < t_{count} or 4.10 < 6.773. The project-based model also shows the level of creativity between students who undergo learning with a project-based approach and those who use conventional methods. These findings indicate a significant effect of the project-based learning model on student learning creativity in Class XI of SMKN 1 Airmadidi with a t_{table} value < t_{count} or 4.10 < 6.418.

Keywords: project-based learning model, basic electrical engineering, creativity, learning outcomes

I. INTRODUCTION

Project-based learning (PjBL) models are increasingly in demand at various levels of education. PjBL offers an active and relevant approach where students learn through real-life projects (Riyanti, 2024). Research shows that PBL has excellent potential to improve students' creativity and learning outcomes (Mega Farihatun & Rusdarti, 2019). Although Electrical Power Installation Engineering (EPIE) significantly demands creativity, students often still have difficulty developing new ideas. Various factors, such as monotonous learning methods, lack of opportunities for expression, or lack of motivation, can cause this (Setiawan & Adila Putri, 2024).

Using diverse and exciting learning models like project-based learning can stimulate creativity (Hanif et al., 2019). Conducive, interactive, and fun learning will encourage students to be more creative (Subramani & Iyappan, 2018). Clear and specific project objectives will help students determine the steps that need to be taken (Suskie, 2018). The availability of adequate resources, materials, equipment, and time will support the project's success (Englund & Graham, 2019).

Previous research has shown that PjBL has many opportunities to improve students' creativity. By giving students the freedom to design, develop, and complete projects, they are encouraged to think critically and innovatively. In addition, PjBL also contributes to improving student learning outcomes through its student-focused teaching process (Barus et al., 2022). Students become more motivated to learn and understand the subject matter in depth (Azhar & Wahyudi, 2024).

In an advanced era like today, innovation in teaching methods is very necessary so that students do not only gain knowledge passively, but actively in the teaching process (Sivarajah et al., 2019). One approach that is considered effective is the project-based learning model. This model emphasizes student involvement in real projects that are relevant in their daily lives, so that it can improve their creativity and learning outcomes (Almulla, 2020; Ghosheh Wahbeh et al., 2021; Silma et al., 2024; Wijayati et al., 2019).

The process of understanding is an essential factor in teaching Basic Electrical Engineering (BEE), and how an educator teaches to achieve this understanding is very important in achieving learning objectives (Mamahit et al., 2023). Basic Electrical Engineering is a field of science that studies the basic principles of electricity and its application in various electrical systems (Teguh Purnawanto, 2023). This includes understanding electric current, voltage, resistance, and fundamental laws such as Ohm's law. This field also includes electrical components such as resistors, capacitors, inductors, and measuring instruments such as multimeters (Eka Jati & Priyambodo, 2024; Hantje Ponto, 2018; Mamahit et al., 2024).

As one of the fundamental principles in electricity, Ohm's Law introduced by Georg Simon Ohm describes the relationship between voltage (V), current (I), and resistance (R). This law is stated in Formula 1:

$$V = I \times R \quad (1)$$

Formula 1 shows that the current flowing through a conductor between two points is proportional to the voltage and inversely proportional to the resistance (Eka Jati & Priyambodo, 2024; Hantje Ponto, 2018).

The project-focused and creativity-based learning model is innovative, emphasizing contextual learning experiences through complex activities (Bozkurt Altan & Tan, 2021). This approach allows students to investigate authentic problems, explore materials in-depth, and complete meaningful tasks (Krajcik & Czerniak, 2018). Thus, this model encourages students to operate independently, develop knowledge, and produce accurate and significant products or works (Fajra et al., 2020).

The project-oriented and creativity-oriented learning model offers several significant and beneficial advantages for students (Akbar et al., 2023). The process adopted in this model accustoms students to operate with a scientific approach. In addition, this model allows students to design learning activities, carry out projects collaboratively, and finally present their work to their classmates (Hertina et al., 2024). These characteristics and advantages are expected to solve the challenges faced in learning Basic Electrical Engineering (BEE).

In the era of globalization and technological advancement, the world of education faces the challenge of producing human resources with theoretical knowledge, practical skills, and creativity (Usman et al., 2022). Education in vocational high schools (abbreviated as SMK in Indonesian) plays a crucial role in preparing students to enter the world of work (Datundugon et al., 2021; Lembong & Tatali, 2023). Thus, the learning model applied in SMK needs to be designed to stimulate students' creativity while improving their learning outcomes.

II. Method

This research was conducted at SMKN 1 Airmadidi with a sample of 40 students divided into two classes, with 20 students in each class. The approach taken in this research is the experimental method, which is a structured and systematic method for building relationships that indicate the existence of cause-effect relationships.

This study adopted a quasi-experimental approach, also known as a quasi-experiment. This approach evolves from the true experimental method, which is often difficult to implement. Quasi-experiments include the presence of a control group, although they are not fully able to control external variables that may affect the implementation of the experiment. This method was created to overcome the challenges that arise when trying to implement a control group in a research context (Maciejewski, 2020).

The research design adopted is a post-test-only control group design. In this design framework, neither the experimental group nor the control group is randomly assigned. This design allows for comparison between the two groups, where the experimental group receives a specific treatment while the control group does not.

In this study, first, the validity and reliability tests were conducted on the research instruments to be used. After data collection, data analysis was conducted using the SPSS application to determine the data normality test, homogeneity test, and hypothesis test.

III. Results and Discussions

After conducting data collection and data processing, the calculation of descriptive research results is obtained as follows.

A. *Description of Research Results*

1. Description of Control Class Creativity

Table 1. Centralization of Control Class Creativity Data in the Post-Test

N	Valid	20
	Missing	0
Mean		55.80
Median		59.00
Mode		59[a]
Std. Deviation		14.362
Variance		206.274
Range		52
Minimum		22
Maximum		74

Based on the grouping of the control class's post-test creativity scores, the data obtained in Table 1 are as follows: from a total of 20 respondents, the average value (mean) is 55.80, a median of 59.00, mode 59, with a standard deviation of 14.362, variance 206.274, data range 52, minimum score 22, and maximum score 74. The bar chart for the control class's post-test creativity is shown in Figure 1.

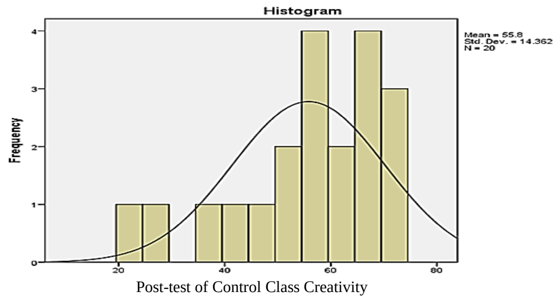

Figure 1. Post-test bar chart of control class creativity

2. Description of Experimental Class Creativity

Table 2. Centralization of Experimental and Post-Test Class Creativity Data

Data Centralization		
Post-Test of Experimental Class Creativity		
Experimental class creativity	Experimental class creativity	Experimental class creativity
	Missing	0
Mean		61.95
Median		61.00
Mode		80
Std. Deviation		15.343
Variance		235.418
Range		45
Minimum		35
Maximum		80

Based on the grouping of the experimental class's post-test creativity scores, the data obtained in Table 2 are as follows: from a total of 20 respondents, the average value (mean) is 61.95, median 61.00, mode 80, with a standard deviation of 15.343, variance 235.418, data range 45, minimum score 35, and maximum score 80. The bar chart for the experimental class's post-test creativity is shown in Figure 2.

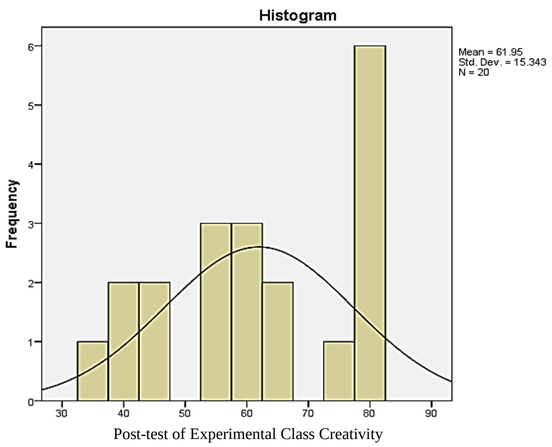

Figure 2. Post-test bar chart of experimental class creativity

3. Description of Control Class Learning Outcomes

Student learning outcomes for the control class pre-test are presented in Table 3.

Table 3. Grouping of Pre-test Values of Control Class Students

No	Students score	Category	Total
1	> 80	Very good	2
2	60-79	Good	2
3	50-59	Less	3
4	< 49	Very less	13

Based on Table 3, two students are included in the very high score category, with a score range exceeding 80. In the high score category, two students get scores in the range of 60-79. On the other hand, two students are in the low score category, with a range of 50-59, while 13 other students are in the deficient score category, namely, with scores below 49.

The student learning outcomes for the control class pre-test are presented in Table 4.

Table 4. Grouping of Post-test Scores of Control Class Students

No	Students score	Category	Total
1	> 80	Very good	5
2	60-79	Good	3
3	50-59	Less	2
4	< 49	Very less	10

From Table 4, five students are included in the very high-value category in learning. For students with high values in the score range of 60-79, there are three students. There was an increase, where in the pre-test, only four students had very high values. At the high-value level, there are two students, two in the low-value category and ten at the shallow level. This decrease is seen in Table 4.

4. Description of Experimental Class Learning Outcomes

After getting the grades, students are grouped according to the predetermined criteria. The results of grouping student grades are in Table 5.

Table 5. Grouping of Pre-test Values of Experimental Class Students

No	Students score	Category	Total
1	> 80	Very good	1
2	60-79	Good	0
3	50-59	Less	3
4	< 49	Very less	16

From the grouping of pre-test scores of the experimental class based on the established criteria, it was found that there was one student who had a very high score, with a score range above 80. In the high score category, namely the score range of 60-79, students still need to achieve that score. Meanwhile, in the low score category with a range of 50-59, 3 students obtained that score. In addition, 16 students were included in the deficient score category, with a score range below 49. From these results, it can be concluded that more than half of the students in the experimental class had low scores on the pre-test.

After obtaining the post-test scores in the experimental class, students were grouped according to the established criteria. The results of grouping student scores during the post-test in the experimental class are as in Table 6.

Table 6. Grouping of Post-test Values of Experimental Class Students

No	Students score	Category	Total
1	> 80	Very good	13
2	60-79	Good	6
3	50-59	Less	1
4	< 49	Very less	0

Table 6 shows that the number of students in the very high score category increased to 13. Meanwhile, students with high scores in the score range of 60-79 were six people. There was also one student who was included in the low-score category. Thus, student learning outcomes have increased significantly after implementing the project-based learning model.

In the experimental class, the minimum pre-test score recorded was 10, while the maximum score reached 80. In the post-test, the lowest score was 55, while the highest score reached 100. The average pre-test score for the experimental class was 30.55, with a standard deviation of 19.050, while the average post-test score was 83.25, with a standard deviation of 15.583.

B. *Analysis of Prerequisite Tests*

1. Normality Test

Table 7. One-Sample Kolmogorov-Smirnov Test

		Post-test of Control Class Creativity	Post-Test of Experimental Class Creativity
N		20	20
Normal Parameters[a,b]	Mean	55.80	61.95
	Std. Deviation	14.362	15.343
Most Extreme Differences	Absolute	.173	.170
	Positive	.111	.120
	Negative	-.173	-.170
Test Statistic		.173	.170
Asymp. Sig. (2-tailed)		.120[c]	.132[c]

The basis for decision-making in the context of normality testing is determined as follows: if the significance value exceeds 0.05, then the data can be categorized as normally distributed. Conversely, if the significance value is less than 0.05, the data is considered not to follow a normal distribution. We were referring to the output produced by SPSS version 23, the Asymp. Sig. (2-tailed) value for the control class post-test is 0.120, while for the experimental class post-test, it is recorded as 0.132. Therefore, the learning creativity data in both control and experimental classes show a normal distribution, considering that the significance value is above 0.05.

Table 8. Normality Test of Learning Outcome Data

One-Sample Kolmogorov-Smirnov Test					
		Pre-Test of Learning Outcomes of Control Class	Post-Test of Learning Outcomes of Control Class	Pre-Test of Experimental Class Learning Outcomes	Post-Test of Learning Outcomes of Experimental Class
N		20	20	20	20
Normal Parameters[a,b]	Mean	39.90	57.05	30.55	83.25
	Std. Deviation	22.639	21.778	19.050	15.583
Most Extreme Differences	Absolute	.183	.159	.170	.175
	Positive	.183	.159	.170	.141
	Negative	-.126	-.145	-.142	-.175
Test Statistic		.183	.159	.170	.175
Asymp. Sig. (2-tailed)		.076[c]	.197[c]	.134[c]	.112[c]

a. Test distribution is Normal.
b. Calculated from data.
c. Lilliefors Significance Correction.

Based on the results of the Kolmogorov-Smirnov One-Sample Test, the normality test for the control class learning outcome data shows a significance value above 0.05. Thus, the data's distribution can be considered normal and suitable for further analysis.

2. Homogeneity Test

Table 9. Results of the Creativity Variable Homogeneity Test

Levene Statistic	df1	df2	Sig.
.355	1	38	.555

The homogeneity test conducted for the learning creativity variable between the control and experimental classes produced a significance value of 0.555, which exceeded the threshold of 0.05. The statistical value measured in this analysis was 0.355. Based on the F distribution table with degrees of freedom df1 = 1 and df2 = 38 at a significance level of 0.05, the F_{table} value was obtained as 4.10. Thus, it can be concluded that the F_{count} is below the F_{table}, which is 0.355 < 4.10.

Tabel 10. Results of Homogeneity Test of Learning Outcome Variables

Levene Statistic	df1	df2	Sig.
.283	1	38	.598

The results of the homogeneity analysis for the learning outcome variable show a significance value of 0.598, which exceeds the limit of 0.05. The statistical value listed in the table is 0.283. In addition, the F_{table} value for the degrees of freedom df1 = 1 and df2 = 28 in the F distribution table with a significance level of 0.05 is 4.23. Thus, a comparison is obtained that $F_{count} < F_{table}$, which is 0.283 < 4.23. This finding confirms that the student learning outcome data from the two classes comes from a homogeneous population.

3. Hypothesis Testing

a. The Influence of Project-Based Learning Models on Creativity in Learning Basic Electrical Engineering

Table 11. The Influence of Project-Based Learning Models on Learning Creativity

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Learning Creativity Results	Equal variances assumed	7.467	.009	6.418	38	.000	32.1500	5.0096	22.0086	42.2914
	Equal variances not assumed			6.418	33.473	.000	32.1500	5.0096	21.9633	42.3367

Table 11 presents the results of the comparative analysis of the level of learning creativity between the control and experimental classes. From the Independent Sample Test output in the ***Equal variances assumed*** section, the Sig. (2-tailed) value is 0.000, which shows that this value is lower than 0.05. Based on the established decision-making criteria, the null hypothesis (H_0) is rejected, and the alternative hypothesis (H_a) is accepted. Thus, there is a significant difference in the level of creativity between students taught using conventional methods in the control class and those who receive learning through a project-based cooperative model.

b. The Influence of Project-Based Learning Models on Basic Electrical Engineering Learning Outcomes.

Table 12. The Influence of Project-Based Learning Models on Basic Electrical Engineering Learning Outcomes

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Learning outcomes	Equal variances assumed	8.156	.007	6.773	38	.000	43.1500	6.3713	56.0480	30.2520

Equal variances not assumed	6.773	32.718	.000	43.1500	6.3713	56.1168	30.1832

The t-count value was recorded at 6.773. By considering that the t-table value is 4.10, it is clear that 6.773 exceeds 4.10, or mathematically, it can be stated that the t-count is greater than the t-table. Based on the comparative analysis between the t-count and t-table, the null hypothesis (H_0) is rejected. In contrast, the alternative hypothesis (H_a) is accepted, which indicates a significant difference in learning outcomes between the control class that applies the conventional learning model and the experimental class that uses the Project-Based Learning approach. Thus, the application of the Project-Based Learning model in the context of teaching Basic Electrical Engineering has a significant impact on the achievement of student learning outcomes in class XI of SMKN 1 Airmadidi.

c. The Influence of Project-Based Learning Models on Creativity and Learning Outcomes of Basic Electrical Engineering

Table 13. The Influence of Project-Based Learning Models on Creativity and Learning Outcomes of Basic Electrical Engineering

		Control Class Creativity	Experimental Class Creativity	Control Class Learning Outcomes	Experimental Class Learning Outcomes
N	Valid	20	20	20	20
	Missing	20	20	20	20
Mean		51.75	61.95	57.05	83.25
Median		56.50	61.00	50.00	85.00
Mode		24[a]	80	42[a]	100
Std. Deviation		18.527	15.343	21.778	15.583
Variance		343.250	235.418	474.261	242.829
Range		53	45	68	45
Minimum		24	35	22	55
Maximum		77	80	90	100

a. Multiple modes exist. The smallest value is shown

It can be understood that the greater the standard deviation value, the lower the level of influence produced, and vice versa. The control class showed a standard deviation of 18.527 for the creativity variable, while the experimental class recorded a figure of 15.343. This finding indicates that students' creativity in the experimental class is more influenced by implementing the project-based learning model than the control class's creativity using a conventional learning approach.

In the analysis of learning outcome variables, the control class showed a standard deviation value of 21.778, while the experimental class recorded a figure of 15.583. This finding implies that students' learning outcomes in the experimental class are more influenced by implementing the project-based learning model than the effects produced by implementing the conventional learning model in the control class.

C. Discussions

The research process began by grouping two classes: the control class, which adopted a conventional learning approach, and the experimental class, which implemented a project-based learning model. This study aimed to identify significant differences in aspects of learning creativity and learning outcomes between the two groups. Before implementing the learning, the researcher conducted a pre-test in each class to measure students' creativity and learning outcomes before implementing the established learning model. After implementing the learning model, the researcher conducted a post-test to evaluate the final results achieved by the students. The values obtained from the pre-test and post-test in the control and experimental classes were then analyzed and used as the primary data in this study.

Before conducting data analysis, the researcher first conducted a normality test and a homogeneity test as a requirement that must be met for further analysis. The test aims to ensure that the data to be analyzed meets the required criteria before hypothesis testing is carried out. The findings from the normality test indicate that the data analyzed follows a normal distribution, as evidenced by the results of the One-Sample Kolmogorov-Smirnov Test for the variables of learning creativity and learning outcomes, which can be obtained from the following table.

Based on the results obtained from the One-Sample Kolmogorov-Smirnov test, it can be concluded that the significance value for the learning outcome data from the control class is above 0.05, which indicates that the data distribution is normal and thus can be used for further analysis. Furthermore, a homogeneity test was conducted to assess whether the two groups of students came from a homogeneous population. Levene's Test for Equality of Variances showed that the values for the creativity and learning outcome variables were 0.555 and 0.598, respectively, more significant than 0.05. This indicates that the data collected in this study came from a homogeneous population. After all the analysis requirements were met, the next step was to conduct a hypothesis test through the T-test. The results obtained from the T-test showed that the t-count value related to the impact of the project-based learning model on learning creativity was 6.418. Compared with the t-table value, it can be seen that 6.418 is more significant, which means that the t-count exceeds the t-table.

In addition, the significance value (2-tailed) obtained was recorded at 0.000, less than 0.05. Thus, there is a significant difference in the level of student creativity between the control and experimental classes that apply the project-based learning model. Related to the effect of the project-based learning model on learning outcomes, the t-count value obtained was 6.773, significantly more significant than the t-table value. In addition, the significance value (2-tailed) produced was 0.000, which was clearly below the threshold of 0.05. This finding clearly shows a significant difference in learning outcomes between the experimental class that adopted the project-based learning model and the control class that applied conventional learning methods.

Analyzing the influence of project-based learning models on creativity and learning outcomes, the control class recorded a standard deviation for creativity of 18.527, while for learning outcomes, it reached 21.778. On the other hand, the experimental class showed a standard deviation value for creativity of 15.343 and for learning outcomes of 15.583. These findings indicate that the application of project-based learning models in experimental classes is more effective in stimulating creativity and improving student learning outcomes than the lecture approach in the control class.

The results of this study are in line with the findings published by Ade Sintia Wulandari, I Nyoman Suardana, and N. L. Pande Latria Devi in 2018 in their study entitled: *The Effect of Project-Based Learning Models on Junior High School Students' Creativity in Science Learning* (Wulandari et al., 2018). This study compared classes that implemented project-based learning models and classes that used the STAD-type cooperative approach. The analysis showed that classes adopting the project-based model recorded higher average pre-test and post-test scores.

As support for this finding, a study conducted by Daria Sofia Tanjung in 2022, entitled *The Effect of Project-Based Learning Models on Elementary School Students' Mathematics Learning Outcomes*, is provided (Tanjung, 2022). The results of the study indicate that the project-based learning model has a significant impact on the mathematics learning outcomes of fifth-grade students, as can be seen from the t-count value exceeding the t-table value.

The findings obtained from this study, supported by various relevant studies and underlying theories, suggest that implementing the project-based learning model significantly impacts the creativity and learning outcomes of students in class XI of SMKN 1 Airmadidi.

IV. Conclusions

There is a significant difference in the learning outcomes of Basic Electrical Engineering between students who are involved in learning using the project-based model and those who follow the conventional method. This indicates that the application of the project-based learning model substantially affects the learning outcomes of Basic Electrical Engineering in Class XI of SMKN 1 Airmadidi. There is a striking difference in the level of creativity between students who undergo learning with a project-based approach and those who use the conventional method. This finding indicates a significant influence of the project-based learning model on students' learning creativity in Class XI of SMKN 1 Airmadidi. The project-based learning model is proven to have a more significant influence on creativity and learning outcomes of Basic Electrical Engineering compared to the conventional learning approach.

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