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Implementation of Project-Based Learning in Electrical Engineering Materials to Improve Character Education of Engineering Students

Doni Setiawan[1], Nina Faoziyah[2]
[1,2] Universitas Muhammadiyah Tegal
Email: [1]donisukisno@gmail.com

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Abstract

This study aims to describe the implementation of the Project Based Learning (PjBL) model on Electrical material and its impact on Improving Character Education of Engineering Students. The main project implemented is the creation of a group Electrical Circuit Project. The type of research is Classroom Action Research which was carried out for two cycles with 15 Electrical Engineering and Mechanical Engineering students as subjects. The results of the analysis of assessment, observation, and documentation show that the implementation of Project Based Learning through the electrical circuit creation project is significantly able to increase collaboration, concern, and sharing of tasks among students, which are key indicators of mutual cooperation. This increase is evidenced by the percentage of completion of mutual cooperation attitudes which was originally 40% in the pre-action, increased to 73% in cycle I (Good category), and reached 93% in cycle II (Very Good category). This study concludes that the Project Based Learning model with electrical circuit projects is effective in fostering mutual cooperation attitudes in Students.

Corresponding Author:
Doni Setiawan
Universitas Muhammadiyah Tegal
Email: [1]donisukisno@gmail.com

1. INTRODUCTION

Character education is a key focus of the Indonesian elementary school curriculum. One important character value to develop from an early age is cooperation. As Mulyani *et al.*(2020) state, cooperation is a form of collaboration between individuals or between individuals and groups to address issues of common interest. In line with the demands of the Pancasila Student Profile, one of the fundamental character dimensions that must be instilled is cooperation. Gotong royong encompasses aspects of collaboration, caring, and sharing, which are essential social skills for the future.

Amalia and Haerani (2025) argue that teachers prefer to use conventional lectures and assignments that only focus on mechanical memory. As a result, students develop a shallow understanding of the material, and cognitive learning outcomes remain suboptimal. In line with this, Alfaeni *et al.*(2022) stated that the lecture learning method is not yet effective in improving students' collaboration skills, so a more active, participatory, and contextual learning model is needed so that the learning process is more preferred by students.

However, according to Hanafiah *et al.*(2023), when implementing character education, schools often face challenges because many students still exhibit selfish tendencies. Therefore, the Project-Based Learning (PjBL) approach is expected to encourage students to learn actively through projects that require collaboration, problem-solving, and creativity.

Based on field facts, particularly in the Basic Physics 2 Electrical subject, engineering students have found a low level of collaborative work. This is evident in students' lack of initiative in sharing assignments and their lack of concern for group work outcomes. A lack of variety in classroom learning methods is a major contributing factor to this low level of character development, as monotonous learning makes students less active in group activities.

To address these issues, it is necessary to implement the Project-Based Learning (PjBL) model. According to Nasution et al. (2024), the PjBL model is an approach that positions students as active subjects in the learning process through direct involvement in a real-life project. PjBL was chosen because this model is strategically designed to foster students' mutual cooperation character through authentic collaborative experiences that require sharing responsibilities, expressing ideas, and working together to complete real-life tasks.

The Center for Development, Research, and Community Service at Muhammadiyah University of Tegal (UMT) identifies the characteristics of Project-Based Learning as a learning model that focuses on real-world problems, finding solutions, and working on projects in groups to solve them. These characteristics align with the principles of 21st-century learning, which emphasize the development of the 4C skills (Communication, Collaboration, Critical Thinking, and Creativity). Therefore, Sulistyowati et al. (2020) recommend that teachers use project-based learning models related to science learning as an option to improve students' creative thinking skills and learning activities.

The chosen project is the creation of an Electrical Circuit Project, which requires intensive role division and collaboration to achieve complex end results.

This study aims to improve students' character, namely the attitude of cooperation in the material of Electrical Circuits, through the implementation of the PjBL learning model with the Electrical Circuit project.

2. METHOD

The research subjects assigned to improve learning were 28 people who were engineering students. The Electrical Engineering and Mechanical Engineering study program, Muhammadiyah University of Tegal, became the location of this research and took place in the even semester of the 2025/2026 academic year. The course that became the focus of improvement was Basic Physics 2. The type of research chosen was Classroom Action Research, which is a contemplative research method because it involves certain actions more professionally so that classroom learning practices can be improved and enhanced (Parnawi, 2020). Each stage in this research can be repeated, and each stage can consist of several steps or be preceded by them.

This study uses a qualitative descriptive approach with supporting data from quantitative analysis techniques to analyze the implementation of PjBL in fostering the value of cooperation in students. The qualitative approach was chosen because this study aims to deeply understand the process, dynamics, and development of students' cooperation character in the specific context of Muhammadiyah University of Tegal. Quantitative data in the form of percentages and scores are used as supporting data to strengthen the qualitative description and facilitate the visualization of development patterns. The study was conducted at Muhammadiyah University of Tegal in the even semester of the 2025/2026 academic year. The research subjects were 28 Engineering students, consisting of 21 male students and 8 female students. Students were divided into six heterogeneous groups, with Groups 1, 2, and 3.

The PjBL implementation was carried out through three learning meetings, each lasting 4 x 35 minutes. The project theme was the creation of an Electrical Circuit Project, divided into three groups.

Data were collected through participant observation, documentation, a character assessment rubric for cooperation with four indicators (mutual assistance, deliberation, tolerance, and shared responsibility), and field notes. The assessment rubric used a scale of 1-4: 1 (Not Yet Developing/BB), 2 (Starting to Develop/MB), 3 (Developing as Expected/BSH), and 4 (Developing Very Well/BSB). Data analysis was conducted using qualitative analysis techniques of the Miles and

Huberman model, including data reduction, data presentation, and conclusion drawing. Data validity was maintained through source triangulation, method triangulation, member checking, and peer debriefing.

3. RESULTS AND DISCUSSION

The implementation of Project-Based Learning (PjBL) was carried out through three learning meetings. In line with the opinion of Aziziy et al. (2024), by using the Project-Based Learning method, students participate in creating projects, either alone or in groups, with the aim of creating a product. After being divided into groups and assigned a project theme, each group conducted a literature study to identify the components of the electrical circuit to be visualized. As stated by Utomo (2018), cooperation means social interaction in which people help each other to achieve a common goal. At this planning stage, students began to practice deliberation to determine the design of teaching aids, divide tasks, and compile a list of needed materials.

At each meeting, each group finalized the final details and presented their projects. According to Amalia and Haerani (2025), cognitive learning outcomes include students' abilities to understand, remember, apply, and analyze a concept or material. Group 1 presented an automatic water pump project explaining how it works. Group 2 presented an electrical energy consumption monitoring system, explaining the concept and how it works. Group 3 gave a very interesting presentation about the GPS monitoring system on an anti-theft helmet, explaining the concept and how it works.

Development of Student Mutual Cooperation Values

The development of students' cooperation values is measured through four main indicators and shows significant improvement, as shown in Table 1 below:

Table 1. Observation Results of the Development of Mutual Cooperation Values

Indicator	Meeting 1	Meeting 2	Meeting 3	Improvement
Help each other	58% (MB)	78% (BSH)	93% (BSB)	35%
Deliberation	46% (MB)	68% (BSH)	86% (BSB)	40%
Tolerance	57% (MB)	73% (BSH)	86% (BSB)	29%
Shared Responsibility	56% (MB)	71% (BSH)	88% (BSB)	32%
Rate-Rate	**54,2%(MB)**	**72.5% (BSH)**	**88,2%(BSB)**	**34%**

Formula :
Increase = Final Meeting Percentage – Initial Meeting Percentage

Table 1 shows significant improvements across all indicators. The deliberation indicator showed the sharpest increase (40%), indicating that PjBL was highly effective in developing communication, active listening, and collaborative decision-making skills.

Table 2. Distribution of the Development of Students' Mutual Cooperation Values

Criteria	Meeting 1	Meeting 2	Meeting 3
Not Yet Developed (BB)	8 students (28.6%)	1 student (3.6%)	0 people (0%)
Starting to Grow (MB)	15 students (53.6%)	4 students (14.3%)	1 student (3.6%)
Developing as Expected (BSH)	5 students (17.8%)	18 students (64.3%)	2 students (7.1%)
Very Well Developed (BSB)	0 students (0%)	5 students (17.8%)	25 students (89.3%)
Total	**28 students (100%)**	**28 students (100%)**	**28 students (100%)**

To calculate the percentage distribution of student development in each category, the following formula is used:

$$\text{Category Percentage} = \frac{\text{Number of Students in Category}}{\text{Total Students}} \times 100\%$$

Table 2 shows a dramatic transformation. At the first meeting, no students reached the BSB criteria, but at the third meeting, 89.3% of students reached the BSB criteria.

Data analysts can be reflected in Table 1 below.

Table 3. Student Success Based on Mutual Cooperation Indicators

Indicator	Behavior Description	Meeting 1	Meeting 3	Status
Help each other	Take the initiative to help friends	12 (43%)	27 (96%)	**Very Successful**
	Sharing tools and materials	18 (64%)	28 (100%)	**Very Successful**
	Teaching skills	6 (21%)	24 (86%)	**Very Successful**
Deliberation	Actively express opinions	10 (36%)	25 (89%)	**Very Successful**
	Listening to all members	11 (39%)	26 (93%)	**Very Successful**
	Reaching an Agreement	2 groups (33%)	6 groups (100%)	**Very Successful**
Tolerance	Be patient with slow friends	14 (50%)	26 (93%)	**Very Successful**
	Accepting differences of opinion	13 (46%)	24 (86%)	**Very Successful**
Responsibility	Complete tasks according to role	15 (54%)	27 (96%)	**Very Successful**
	Care about group results	12 (43%)	25 (89%)	**Very Successful**

Amalia and Haerani (2025) stated that learning using the Project-Based Learning (PjBL) model significantly supports students in achieving high cognitive learning outcomes. The findings of this study reinforce this statement and add an important dimension: PjBL not only improves cognitive learning outcomes but is also highly effective in developing social character traits such as cooperation. The following results of the learning outcomes of each group's teaching aids are shown in Table 4.

Table 4. Achievement of Teaching Aid Products

Group	Project	Quality	Creativity	Accuracy	Aesthetics	Total
1	automatic water pump	90	85	92	88	88,75 (A)
2	electrical energy consumption monitoring system	92	90	90	90	90,50 (A)
3	system monitoring GPS	92	90	90	90	90,50 (A)

Assessment of group demonstration product uses four aspects with equal weight:

$$\text{Product Value} = \frac{\text{Product Quality} + \text{Creativity} + \text{Concept Accuracy} + \text{Aesthetic Value}}{4}$$

With a rating scale:

- 85 - 100 = A (Very Good)
- 70 - 84 = B (Good)
- 55 - 69 = C (Enough)
- < 55 = D (Less)

Table 4 shows that all groups achieved an A grade with an average of 90.38. The conceptual accuracy aspect recorded the highest score (92.17), indicating a deep understanding of ecosystems and food chains.

Table 5. Qualitative Description of the Development of Mutual Cooperation Values per Group

Group	Project	Meeting 1	Meeting 2	Meeting 3
1	automatic water pump	Smart students dominate, while other members are passive. Tasks are not evenly distributed.	Start sharing tasks. Less skilled students are given tasks based on their abilities (gluing, tidying).	All members actively contribute. Perfectionist students learn to trust the team. Collaborative results are excellent.
2	electrical energy consumption monitoring system	Long debate about design. Difficulty reaching an agreement.	There was an incident where the background was torn. Instead of blaming each other, focus on a shared solution.	Excellent coordination. Finishing the final details with a natural division of labor. High tolerance.
3	system monitoring GPS	Some students hesitate to express creative ideas. Shy students tend to be passive.	A student skilled in origami taught the entire group. Everyone learned to make paper fish.	Creative ideas emerged from all members. Shy students became active contributors. Work synchronization was excellent.

Obstacles and Handling Strategies

The implementation of PjBL faces several obstacles that can be overcome through appropriate strategies, as shown in Table 5.

Table 5. Constraints and Handling Strategies

No	Constraint	Frequency of Occurrence	Handling Strategy	Effectiveness
1	Limitations of students' social maturity (conflict, dominance, passivity)	18 incidents	Emotional scaffolding, dialogue facilitation, assertive communication techniques, and role	Very Effective (94% of incidents resolved)

			playing	
2	Disparity in academic competency and skills	12 incidents	Heterogeneous groups, clear role division, affirmation of unique contributions, reframing of dominant roles	Very Effective (100% of students contributed at the end)
3	Limited facilities and materials	8 incidents	Optimization of used materials, cross-subsidies, "material banks", and tool sharing systems	Effective (all groups can complete the project)
4	Time constraints	5 incidents	Tight timeline, task breakdown per meeting, off-hours work (voluntary)	Effective (83% of groups finished on time)
5	Classroom management difficulties	15 incidents	Clear class rules, daily group leaders, round robin monitoring, and additional observers	Very Effective (conducive class, all groups monitored)

Table 6 shows that all obstacles can be overcome effectively or very effectively through appropriate strategies. Student reflections on collaborative learning are shown in Table 6.

Table 6. Student Reflections on Mutual Cooperation Learning

Learning Aspects	Number of students	Percentage
Learn the importance of cooperation	28	100%
Learn to respect differences of opinion	25	89%
Learn to share tasks and responsibilities	27	96%
Learn to be patient and tolerant	24	86%
Learn to communicate well	26	98%
Learn to solve problems together	23	82%
Feel the results of working together are better	26	93%
Feel the learning process is enjoyable	27	96%
Want to implement cooperation in life	25	89%

Table 6 shows that 100% of students realized the importance of cooperation, and 89% of students wanted to apply mutual cooperation in their daily lives, indicating a deep internalization of values.

The transformation of the value of cooperation is not only seen from the increase in percentage (Table 1), but also from student statements such as: "Initially, I wanted to do everything myself, but it turns out that when we work together, the results are actually better." This statement shows that students not only experience changes in behavior, but also experience changes in understanding the value of cooperation.

The key to the success of PjBL in fostering the value of cooperation lies in its characteristics, which provide authentic collaborative experiences in solving real problems, create conditions where cooperation becomes a necessity rather than an obligation, provide opportunities for each student to contribute according to their unique strengths, produce meaningful, real products, and involve structured reflection for internalization of values.

4. CONCLUSION

The implementation of the Project-Based Learning (PjBL) model on the Electrical material is effective in fostering the value of cooperation among Engineering Students at the University of Muhammadiyah Tegal. The increase in students' cooperation values from the criteria of Starting to Develop (54.8%) to Very Well Developed (88.3%) shows a significant positive impact. The four indicators of cooperation values have increased: mutual assistance (58% to 93%), deliberation (46% to 86%), tolerance (57% to 86%), and shared responsibility (56% to 88%). The sharpest increase in the deliberation indicator (40%) indicates that PjBL is very effective in developing communication skills and joint decision-making.

The Electrical Circuit demonstration project provided a meaningful, authentic collaborative experience. Students not only learned the concept of Electrical Circuits cognitively (59% increase in understanding), but also experienced and internalized the values of harmony and cooperation in the group work process. All groups achieved an A grade for the demonstration product (average 90.38), indicating that good collaboration produces high-quality products. The obstacles faced were overcome through scaffolding strategies, forming heterogeneous groups, optimizing materials, strict time planning, and establishing clear class rules.

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