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ORIGINAL

Effectiveness of Project-Based Cooperative Learning Model in Electrical Installation Practical Courses

Eficacia del modelo de aprendizaje cooperativo basado en proyectos en los cursos prácticos de instalaciones eléctricas

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ABSTRACT

This study evaluates the effectiveness of the Project-Based Cooperative Learning (PBCL) model in enhancing student learning outcomes in practical Electrical Installation courses, focusing on its impact on technical competence, problem-solving ability, teamwork, and engagement in vocational education. Conducted during the 2024/2025 academic year at Sekolah Tinggi Teknologi Pekanbaru, Indonesia, the research employed a quasi-experimental nonequivalent control group design involving 47 Electrical Engineering students—25 in the experimental group receiving PBCL treatment and 22 in the control group following traditional instruction. The intervention lasted seven sessions, with data collected through pre- and post-tests, surveys, and interviews. Quantitative analysis revealed statistically significant improvements in the experimental group's post-test scores, while qualitative data indicated higher levels of engagement, motivation, and perceived skill development among PBCL participants. Data normality and homogeneity tests confirmed the validity of parametric analysis, and independent sample t-tests supported the statistical significance of the findings. The study concludes that PBCL is a pedagogically effective approach for improving learning outcomes in vocational education, particularly in technical fields requiring both practical and soft skills. The results advocate for broader implementation of PBCL in technical curricula and highlight the potential for future integration of technology-enhanced strategies to further support student learning.

Keywords: Project-Based Cooperative Learning; Electrical Installation; Learning Outcomes.

RESUMEN

Este estudio evalúa la eficacia del modelo de aprendizaje cooperativo basado en proyectos (PBCL) para mejorar los resultados de aprendizaje de los estudiantes en cursos prácticos de instalación eléctrica, centrándose en su impacto en la competencia técnica, la capacidad de resolución de problemas, el trabajo en equipo y el compromiso con la formación profesional. Llevada a cabo durante el curso académico 2024/2025 en Sekolah Tinggi Teknologi Pekanbaru, Indonesia, la investigación empleó un diseño cuasi-experimental de grupo de control no equivalente en el que participaron 47 estudiantes de Ingeniería Eléctrica: 25 en el grupo experimental que recibió el tratamiento PBCL y 22 en el grupo de control que siguió la instrucción tradicional. La intervención duró siete sesiones y los datos se recogieron mediante pruebas previas y posteriores, encuestas y entrevistas. El análisis cuantitativo reveló mejoras estadísticamente significativas en las puntuaciones del grupo experimental tras la prueba, mientras que los datos cualitativos indicaron mayores niveles de compromiso, motivación y desarrollo de habilidades percibidas entre los participantes en el PBCL.

Las pruebas de normalidad y homogeneidad de los datos confirmaron la validez del análisis paramétrico, y las pruebas t de muestras independientes corroboraron la significación estadística de los resultados. El estudio concluye que el PBCL es un enfoque pedagógicamente eficaz para mejorar los resultados del aprendizaje en la formación profesional, especialmente en campos técnicos que requieren tanto habilidades prácticas como interpersonales. Los resultados abogan por una aplicación más amplia del PBCL en los planes de estudios técnicos y destacan el potencial de la futura integración de estrategias mejoradas por la tecnología para apoyar aún más el aprendizaje de los estudiantes.

Palabras Clave: Aprendizaje Cooperativo Basado en Proyectos; Instalación Eléctrica; Resultados del Aprendizaje.

INTRODUCTION

The increasing importance of higher education in Indonesia, particularly within technology-related fields, is driven by the urgent need to develop a workforce that meets national standards set forth in Indonesia 2045 and the RPJMN 2020-2024. These initiatives aim to elevate human resources and technological capabilities to ensure competitiveness on a global stage.[1,2] However, the existing educational framework demonstrates a concerning disconnect; many graduates lack the requisite skills demanded by the labor market. According to the 2019 Global Competitiveness Index, Indonesia's human resources exhibit declining quality and productivity.[3,4]

A critical issue plaguing the Indonesian workforce is the significant mismatch between educational qualifications and the skills sought by employers. Reports indicate that only a fraction of the workforce possesses medium to high skill levels, with a substantial percentage lacking education beyond junior high school.[5,6] This discrepancy is notably acute in technical fields such as electricity, where a considerable shortage of qualified workers exists. The misalignment between higher education outputs and industry expectations necessitates robust curriculum reforms, emphasizing both hard and soft skills essential for enhancing employability.[7,8]

Moreover, high unemployment rates among graduates exacerbate this issue. Secondary and higher education graduates frequently find themselves ill-prepared for the demands of the job market.[3,9] A pressing need emerges for strategic collaborations between educational institutions and industry leaders, focusing on developing curricula centered on essential competencies, adaptability to technological advancements, and readiness for the evolving demands of Industry 4.0.[10,11] This strategic approach could significantly enhance career readiness among graduates and mitigate rising unemployment rates within skilled labor sectors.

In response to these challenges, the Indonesian government recognizes that educational reform is crucial for realizing its vision for 2045. Emphasizing vocational education aligned with labor market dynamics can considerably enhance workforce quality.[9,12] Innovative strategies that integrate soft skill development into technical curricula can produce graduates equipped with not only technical knowledge but also interpersonal skills necessary for diverse workplace environments.[5,8] Improving training programs closely aligned with industry needs will enhance workforce performance and foster a skilled labor force essential for Indonesia's sustained economic growth and global competitiveness.

Addressing educational challenges influenced by the Fourth Industrial Revolution (Industry 4.0), Indonesia's educational policies are undergoing transformations aimed at fostering workforce readiness. Recognizing the necessity for a comprehensive skill set, educators are focusing on imparting both technical knowledge and critical soft skills, including communication and teamwork.[8,10] The "Merdeka Belajar" policy represents a fundamental shift towards a dynamic curriculum tailored to the realities of local and global labor markets [13]. As industry demands evolve, educational strategies must adapt, ensuring that graduates are adequately prepared for competitive environments.

Specifically, the electrical installation sector's pressing need for skilled professionals underscores the importance of aligning educational curricula with Industry 4.0 competencies. Advanced technological solutions, such as automation and smart technologies, necessitate educational frameworks that address both traditional and innovative skill sets.[14,15] According to the National Standards for Higher Education, competencies in practical problem-solving and a robust understanding of electrical systems are critical.[16]

Despite articulating clear educational objectives, significant challenges persist in adequately preparing students, particularly in developing critical thinking and problem-solving skills essential for practical application in the electrical installation landscape.[17,18] Current pedagogical practices often lack sufficient hands-on training opportunities that connect theory with practical experience. Expanding practical training through industry partnerships can bridge this gap significantly, ensuring students acquire relevant skills that meet employer expectations.[19,20]

Additionally, as demand rises for skilled electricians, prioritizing training and certification programs tailored specifically for electrical installation technicians becomes crucial. This focus directly impacts workforce

quality and the unemployment rate among skilled graduates [17]. By reinforcing educational systems with strong industry connections and competency-focused training, Indonesia can effectively prepare its workforce to meet emerging technological demands and foster a competitive economic future.

The exploration of Project-Based Cooperative Learning (PBCL) emerges as a promising pedagogical strategy to address increased complexities in the electrical installation sector. By immersing students in collaborative projects reflecting real-world challenges, PBCL fosters a deeper comprehension of theoretical concepts and equips learners with essential practical skills.[20,21,22,23] The collaborative nature of PBCL enhances communication abilities vital for future professional environments, preparing students for the interpersonal demands of the workplace.[22,23]

Engaging in collaborative, project-based efforts allows students to practice negotiation, leadership, and conflict resolution skills—crucial tools for navigating professional landscapes.[17,24] The relevance of active learning approaches, such as PBCL, is amplified in contexts requiring adaptive problem-solving frameworks, particularly in sectors like electrical installation. This experiential learning framework bolsters technical proficiency and cultivates essential attributes such as self-directed learning and adaptability.[25,26]

Employing PBCL within the electrical installation curriculum further facilitates bridging the gap between educational outputs and industry needs. As industry increasingly mandates integration and responsiveness to automation and smart technologies, aligning educational processes with these requirements has become imperative.[27,28] By emphasizing collaborative, project-driven learning, educational institutions can nurture graduates who excel in both technical adeptness and interpersonal skills.[29,30]

This study investigates the effectiveness of the Project-Based Cooperative Learning (PBCL) model in improving student outcomes in electrical installation practical training by evaluating its impact on technical skills, problem-solving, collaboration, and engagement. In response to the rapidly evolving job market, particularly in the electrical sector, students must be equipped with both technical competencies and essential soft skills. PBCL offers a hands-on, collaborative approach that fosters deeper understanding and real-world application of knowledge. By aligning educational practices with industry demands, this research provides insights into effective pedagogical strategies for vocational education. The findings aim to support curriculum development, teacher training, and policy formulation in Indonesia and similar contexts. Ultimately, PBCL is expected to enhance students' motivation, knowledge retention, and readiness for the workforce, thereby bridging the gap between academic instruction and professional requirements.

METHOD

Research Design

This research is categorized as a quasi-experimental study with a nonequivalent control group design, aiming to evaluate the effectiveness of Project-Based Cooperative Learning (PBCL) in improving student learning outcomes in Electrical Installation practical courses. The investigation was conducted as a cross-sectional study, carried out over seven instructional sessions during the odd semester of the 2024/2025 academic year at Sekolah Tinggi Teknologi Pekanbaru, Indonesia. The population in this study includes students enrolled in the Electrical Engineering program, from which two intact class groups were selected using purposive sampling. One group (n=25) was designated as the experimental group receiving PBCL treatment, while the other (n=22) served as the control group receiving traditional teacher-centered instruction. This design was chosen because it allows for comparative analysis between groups when random assignment is not feasible, and it is more robust than pre-experimental designs in educational research contexts.[31]

The methodological framework defines PBCL as a student-centered approach where learners collaborate on structured projects that simulate real-world electrical installation tasks. The experimental group participated in seven project sessions involving planning, executing, and presenting installation activities in teams, while the control group followed a standard lecture-practical format without project collaboration. To measure outcomes, both groups underwent pre- and post-tests assessing technical skills, problem-solving, and teamwork. Additionally, a structured student engagement survey was administered after the final session. The survey consisted of 15 Likert-scale items adapted from validated instruments in cooperative learning research, capturing perceptions of collaboration, motivation, and skill development. Data collection was carried out in printed and digital formats, and responses were anonymized and securely stored.

Table 1. Research Design

Group	Pre-Test	Treatment (X)	Post-Test
Experiment	O_1	X	O_2
Control	O_3	-	O_4

Source: [32]

Explanation

- O_1 & O_3: Pretest observation for the experimental and control group.
- X: The treatment or intervention given to the experimental group
- O_2 & O_4: Posttest observation for the experimental and control group.

Data Collection Instrument

The instruments for data collection in this study consist of both quantitative and qualitative methods that provide a comprehensive evaluation of the effectiveness of Project-Based Cooperative Learning (PBCL) in Electrical Installation practical courses. Quantitative data will be obtained through pre- and post-assessments aimed at measuring students' understanding of electrical installation theory and their ability to apply this knowledge to practical tasks. The pre-test will be administered before the intervention, and the post-test will be given after the PBCL intervention to assess any changes in learning outcomes.

Furthermore, practical performance assessments will be conducted to gauge students' abilities in performing electrical installation tasks in real-world settings. These evaluations will focus on students' skills in executing installations, troubleshooting problems, and applying theoretical knowledge in practical situations. Students will also complete surveys designed to measure their engagement, motivation, and perceptions of the effectiveness of PBCL. These surveys will include Likert-scale questions to collect data on students' experiences with the learning approach, teamwork, and their perceptions of skill development.

Qualitative data will be gathered through semi-structured interviews with both students and instructors. These interviews will explore participants' experiences with the PBCL model, focusing on aspects like teamwork, problem-solving, and overall satisfaction. The qualitative data will provide deeper insights into the impact of PBCL on student learning, complementing the quantitative findings from the pre- and post-tests, and offering a more holistic evaluation of the learning model's effectiveness.

Data Analysis Techniques

This study utilizes both quantitative and qualitative methods to assess the effectiveness of Project-Based Cooperative Learning (PBCL) in Electrical Installation practical courses. The study involves two groups: the experimental group, with 25 students, who participate in PBCL, and the control group, with 22 students, who engage in traditional, teacher-centered learning. For quantitative analysis, statistical techniques such as descriptive and inferential statistics will be applied. Pre- and post-test scores from both groups will be compared using t-tests or analysis of variance (ANOVA) to determine if there is a significant difference in learning outcomes. The experimental group, which receives PBCL, is anticipated to demonstrate more significant improvements in both theoretical understanding and practical electrical installation skills compared to the control group.

Along with quantitative data, qualitative data will be collected through surveys and interviews. These qualitative responses will undergo thematic analysis to identify recurring patterns and themes related to student engagement, motivation, and their perceptions of the learning process. By combining both quantitative and qualitative methods, the study aims to provide a comprehensive view of PBCL's impact on students' learning experiences. The research will also examine learning outcomes in terms of problem-solving abilities, teamwork, and practical skills development, offering a thorough evaluation of the effectiveness of PBCL in the context of Electrical Installation practical courses.

All collected data were entered and processed using statistical software (e.g., SPSS) to conduct descriptive and inferential analyses, including paired and independent sample t-tests. Ethical considerations were strictly observed throughout the study. Prior to implementation, the research obtained ethical clearance from the institutional review board, and informed consent was collected from all participants. Confidentiality and voluntary participation were ensured, with participants given the right to withdraw at any stage without academic consequences. This design and protocol offer clear procedural transparency, enabling future researchers to replicate the study in other institutional settings with similar educational contexts.

Project-Based Cooperative Learning (PBCL) Model Approach

The Project-Based Cooperative Learning (PBCL) approach, implemented in the context of Electrical Installation practical courses, emphasizes active student participation through collaborative, hands-on projects. This approach allows students to work in teams, solving real-world problems related to electrical installations, thereby reinforcing both technical skills and soft skills like communication, teamwork, and critical thinking. The PBCL model integrates the principles of cooperative learning with project-based tasks, where students are not only responsible for mastering technical content but also for collaborating effectively with peers to complete practical tasks. This method fosters a deeper understanding of the material and enhances students' problem-solving abilities, which are crucial in the electrical installation field.

Figure 1. Project-Based Cooperative Learning Handbook

The PBCL approach was evaluated for its effectiveness by comparing the performance of students in the experimental group (who engaged in PBCL) with the control group (which used traditional teaching methods). In the experimental group, students were assigned projects such as designing and installing electrical systems, requiring them to apply theoretical knowledge in practical scenarios. These projects were designed to simulate real-world challenges that students are likely to encounter in the industry, enhancing their learning experiences. The results showed that the experimental group performed better in both technical competency and collaborative skills, reflecting the positive impact of PBCL in preparing students for the demands of the electrical installation profession.

Moreover, the PBCL approach encouraged an active learning environment, where students took ownership of their learning process. This method aligned with the needs of 21st-century education, where students are expected to not only gain technical knowledge but also develop the skills necessary to work in teams, think critically, and adapt to changing technological environments. The study found that the integration of PBCL into Electrical Installation practical courses significantly improved students' engagement, performance, and overall learning outcomes, reinforcing the effectiveness of project-based and cooperative learning methods in technical education.

RESULT AND DISCUSSION

Data Analysis and Findings

The data analysis conducted in this research shows significant improvements in student learning outcomes after the implementation of Project-Based Cooperative Learning (PBCL) in Electrical Installation practical courses. Both quantitative and qualitative data were collected, with pre- and post-assessment surveys being the primary tools for evaluating academic performance. Descriptive statistics were applied to the scores from both the experimental and control groups. The experimental group, which participated in PBCL, showed clear and notable improvements in practical skills, problem-solving capabilities, and the application of electrical installation concepts. In contrast, the control group, which followed traditional teaching methods, exhibited comparatively smaller gains in these areas.

The comparison between the experimental and control groups demonstrates the effectiveness of PBCL. The analysis of pre-test and post-test results indicates a positive change in the academic performance of the experimental group, suggesting that PBCL significantly improved students' learning outcomes. This progress was especially evident in their ability to apply theoretical knowledge to real-world electrical installation tasks. The accompanying table summarizes these results, highlighting the impact of PBCL on student performance relative to conventional teaching methods. These findings confirm that Project-Based Cooperative Learning provides a more effective and engaging learning experience for students in Electrical Installation practical courses.

Table 2. Results of the Descriptive Analysis Results for Pre-Test and Post-Test

Group	Mean Pre-Test Score	Mean Post-Test Score
Experiment	68,70	82,32
Control	59,77	79,89

The table displays the results of the descriptive analysis for both the pre-test and post-test scores of the experimental and control groups. The experimental group, which participated in Project-Based Cooperative Learning (PBCL), had an average pre-test score of 68.70, which increased to 82.32 in the post-test, reflecting a significant improvement in their learning outcomes following the PBCL intervention. In contrast, the control group, which adhered to traditional teaching methods, began with a mean pre-test score of 59.77 and achieved a post-test mean score of 79.89. While the control group also showed progress, the experimental group exhibited a more pronounced increase in both theoretical knowledge and practical skills, demonstrating the effectiveness of PBCL in enhancing student learning in Electrical Installation practical courses. Additionally, a normality test was performed to assess the appropriateness of the data for inferential tests, specifically evaluating how closely the data followed a normal distribution. The Shapiro-Wilk test results were used to analyze the data distribution.

Table 3. Results of the Shapiro-wilk Test

Group	Pre-Test (p-value)	Post-Test (p-value)
Experiment	0,119	0,226
Control	0,410	0,043

The results show that the data in both groups, for both pre-test and post-test, were normally distributed ($p > 0,05$). Levene's Test was used to examine the homogeneity of variances between the experiment and control groups.

Table 4. Results of Levene's Test

Variable	F	Sig. (p-value)
Post-Test	0,610	0,439

The analysis indicates that the variances of the experiment group to the control group were similar ($p > 0,05$) suggesting that the groups could be compared parametrically. To establish the researching hypothesis the two condition Independent Sample T-Test was used to compare the post test results between the experimental and control groups.

Table 5. Results of T-Test

Test Type	Variable	t	Sig. (p-value)	Interpretation
Independent Sample T-Test	Pre-Test vs Post-Test	-3,803	0,000	The experimental group achieved a higher mean post-test score than the control group

The table presents the results of an Independent Sample T-Test conducted to compare the pre-test and post-test scores of the experimental and control groups. The t-value of -3,803 with a significance (p-value) of 0,000 indicates a statistically significant difference between the two groups. Specifically, the interpretation shows that the experimental group, which participated in Project-Based Cooperative Learning (PBCL), achieved a higher mean post-test score compared to the control group, which used traditional learning methods. This suggests that the PBCL approach had a positive and significant impact on students' learning outcomes in Electrical Installation practical courses.

The boxplot illustrates the distribution of pre-test and post-test scores for both the experimental and control groups. The experimental group exhibits a higher median score, with the interquartile range (IQR) clustered between approximately 72 and 79, indicating a relatively consistent improvement in student performance after the intervention. In contrast, the control group shows a wider range of scores, with a lower median around 70 and a larger spread between the lower and upper quartiles. The whiskers of the experimental group are shorter, suggesting less variability in scores, whereas the control group has greater variability. This visual representation supports the quantitative findings that the experimental group, which experienced Project-Based Cooperative

Learning, demonstrated more uniform and higher academic performance compared to the control group.

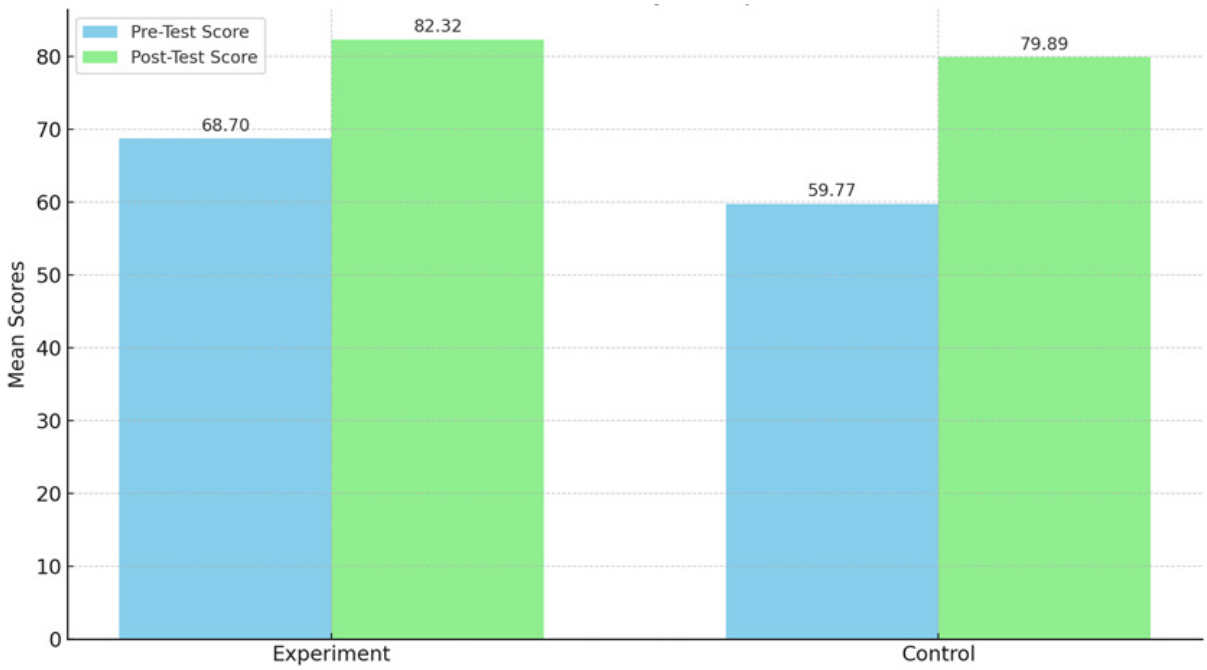

Figure 2. Pre-Test and Post-Test Scores Bar Chart

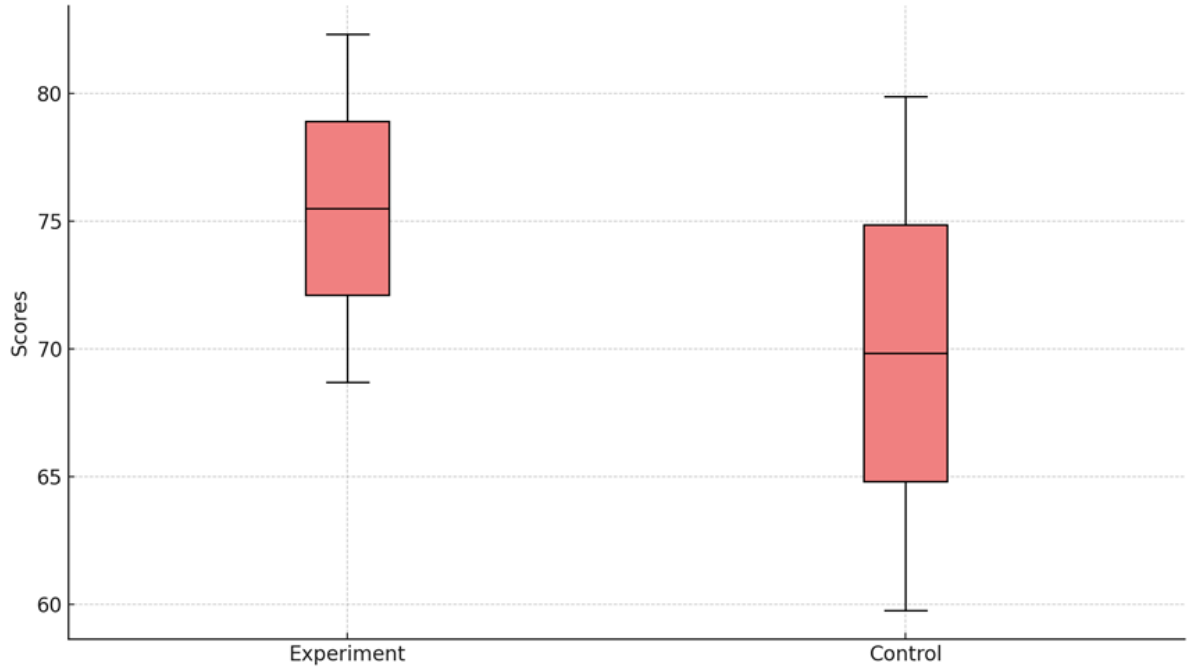

Figure 3. Box Plot Pre-Test and Post-Test Scores

DISCUSSION

The results of this study support the effectiveness of Project-Based Cooperative Learning (PBCL) in enhancing student learning outcomes in Electrical Installation practical courses. The significant improvement in the experimental group's post-test scores compared to the control group confirms that PBCL fosters better comprehension and application of technical concepts. This finding aligns with earlier studies mentioned in the introduction, which emphasize the need for education to evolve and meet the demands of Industry 4.0 by integrating both hard and soft skills.[6] The PBCL model's emphasis on teamwork and hands-on projects appears to directly address the skill gaps identified in Indonesia's electrical workforce, thereby supporting national educational goals.

The methodological choice of a Nonequivalent Control Group Design provided a robust framework to compare PBCL with traditional teaching methods. With 25 students in the experimental group and 22 in the

control group, the study ensured sufficient data for statistical analysis. The use of pre- and post-tests, alongside qualitative surveys and interviews, offered a comprehensive evaluation of PBCL's impact. The quantitative data revealed substantial gains in knowledge retention and practical skills, while the qualitative feedback highlighted increased motivation and engagement among students, supporting previous research that points to the motivational benefits of active learning.[24,25]

Furthermore, the integration of cooperative learning principles within project-based frameworks enhanced students' collaboration skills, a critical competency in electrical installation work that often requires team coordination. This is consistent with findings from,[21,22] which emphasize that cooperative projects cultivate essential interpersonal skills alongside technical proficiency. The active learning environment created by PBCL encourages students to take ownership of their education, facilitating deeper engagement with complex electrical systems and fostering creativity in problem-solving.[17,24]

The improvement in post-test scores and the narrower score distribution in the experimental group underscore the consistency and reliability of PBCL as a teaching model. This contrasts with the greater variability observed in the control group, which suggests that traditional lecture-based methods may not consistently meet diverse student needs. These quantitative results complement the qualitative insights from interviews, where students reported feeling more confident and better prepared for real-world challenges after engaging in PBCL activities. Such findings reinforce the argument that experiential learning, supported by cooperative structures, is effective in vocational education contexts.

Moreover, the results align with global trends highlighting the importance of preparing students with both technical and soft skills required in modern industries.[1,7] As the electrical installation sector increasingly incorporates advanced technologies and collaborative workflows, educational approaches like PBCL become vital. The study's outcomes demonstrate that PBCL not only improves academic performance but also equips students with the competencies necessary to thrive in dynamic professional environments, thereby fulfilling the objectives of Indonesia's educational reform efforts.

The successful application of PBCL also addresses the challenge of bridging the gap between theory and practice, which was identified as a limitation in traditional teaching methods. By engaging students in authentic projects, PBCL facilitates the transfer of theoretical knowledge into practical skills, thereby enhancing students' readiness for employment. This practical orientation supports the objectives of the National Standards for Higher Education (SN-Dikti) and the Indonesian National Qualifications Framework (KKNI), which emphasize applied competencies alongside theoretical mastery.[16]

In terms of pedagogical implications, this study provides strong evidence for educators and curriculum developers to adopt PBCL in electrical engineering programs. The model encourages active participation, critical thinking, and teamwork, aligning well with the demands of 21st-century education and the needs of Industry 4.0. This approach not only benefits students academically but also promotes lifelong learning attitudes, adaptability, and problem-solving capabilities essential for continuous professional development.

Finally, while this study demonstrates the positive impact of PBCL, further research could explore the integration of emerging technologies such as Augmented Reality (AR) or virtual simulations to further enhance the learning experience. The combined use of innovative pedagogies and technological tools may offer even greater benefits in technical education, as suggested by research in similar contexts.[18,23] Expanding this research could help optimize teaching strategies and contribute to producing a workforce that is well-prepared for the challenges of modern electrical industries.

CONCLUSION

This study affirms that Project-Based Cooperative Learning (PBCL) is an effective pedagogical model for addressing the competencies required in vocational education, particularly in electrical installation training. PBCL supports curriculum transformation by embedding contextual, collaborative, and active learning processes that reflect industry expectations. The model encourages integrative skill development, reinforcing the relevance of combining technical and soft skills in educational design. As an instructional strategy, PBCL enhances the responsiveness of vocational training to the evolving dynamics of Industry 4.0. It promotes learner autonomy, critical engagement, and applied problem-solving within structured collaborative frameworks. The use of PBCL also aligns with national educational reform efforts focused on employability and productivity. Its implementation in technical education presents a sustainable alternative to traditional didactic methods. Consequently, PBCL offers a scalable and transferable approach for enhancing educational quality and workforce readiness. The model should be further explored and adapted to support broader innovation in vocational pedagogy.

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