Salud, Ciencia y Tecnología. 2025; 5:2223
doi: 10.56294/saludcyt20252223

ORIGINAL

Effectiveness of Blended Project-Based Learning in Enhancing Computer Network Education: An Evaluation Based on Student Learning Outcomes

Efectividad del Aprendizaje Basado en Proyectos Combinados para Mejorar la Educación en Redes Informáticas: Una Evaluación Basada en los Resultados de Aprendizaje de los Estudiantes

Samsir[1,2], M. Giatman[3], Riki Mukhaiyar[4]

[1]Universitas Negeri Padang, Doctoral Program of Technical Vocational and Education. Padang. Indonesia.
[2]Universitas Al Washliyah Labuhan Batu, Department of Informatics Engineering. Medan. Indonesia.
[3]Universitas Negeri Padang, Department of Electrical Engineering. Padang. Indonesia.
[4]Universitas Negeri Padang, Department of Civil Engineering. Padang. Indonesia.

Cite as: Samsir, Giatman M, Mukhaiyar R. Effectiveness of Blended Project-Based Learning in Enhancing Computer Network Education: An Evaluation Based on Student Learning Outcomes. Salud, Ciencia y Tecnología. 2025; 5:2223. https://doi.org/10.56294/saludcyt20252223

Submitted: 28-04-2025 **Revised:** 17-07-2025 **Accepted:** 18-09-2025 **Published:** 19-09-2025

Editor: Prof. Dr. William Castillo-González

Corresponding author: Samsir

ABSTRACT

This study evaluates the effectiveness of Blended Project-Based Learning (PBL) in enhancing student learning outcomes in Computer Network Education. As traditional methods often fall short in preparing students for industry demands, the research aimed to determine if a blended PBL model could lead to statistically superior gains in students' theoretical and practical skills. A quasi-experimental, nonequivalent control group design was employed. The experimental group (*n*=28) participated in a blended PBL intervention, while the control group (*n*=27) received traditional instruction. Data were collected via pre- and post-tests to assess technical skills and problem-solving abilities. Quantitative analysis, including one-way ANCOVA, compared post-test scores while controlling for pre-test scores, and paired-samples t-tests measured learning gains. Qualitative data from student surveys and interviews were analyzed thematically. The results indicated a significant difference in adjusted post-test scores between the groups, with the experimental group showing substantially greater learning gains. Qualitative findings further revealed that the blended PBL approach significantly enhanced student motivation, engagement, and the development of teamwork and critical thinking skills. In conclusion, the Blended PBL model is a highly effective pedagogical approach for technical education. Its success advocates for a fundamental paradigm shift toward active, student-centered methodologies that truly prepare graduates for a complex and evolving professional landscape.

Keywords: Blended Project-Based Learning; Computer Network Education; Student Learning Outcomes; Effectiveness.

RESUMEN

Este estudio evalúa la eficacia del aprendizaje combinado basado en proyectos (PBL) para mejorar los resultados académicos de los estudiantes en la formación en redes informáticas. Dado que los métodos tradicionales suelen ser insuficientes para preparar a los estudiantes para las exigencias del sector, la investigación tenía como objetivo determinar si un modelo combinado de PBL podía conducir a mejoras estadísticamente superiores en las habilidades teóricas y prácticas de los estudiantes. Se empleó un diseño cuasi-experimental con grupo de control no equivalente. El grupo experimental (n = 28) participó en una intervención PBL mixta, mientras que el grupo de control (n = 27) recibió instrucción tradicional. Los datos se recopilaron mediante pruebas previas y posteriores para evaluar las habilidades técnicas y la capacidad

de resolución de problemas. El análisis cuantitativo, que incluyó un ANCOVA unidireccional, comparó las puntuaciones de la prueba posterior controlando las puntuaciones de la prueba previa, y las pruebas t de muestras emparejadas midieron los avances en el aprendizaje. Los datos cualitativos de las encuestas y entrevistas a los estudiantes se analizaron temáticamente. Los resultados indicaron una diferencia significativa en las puntuaciones ajustadas de la prueba posterior entre los grupos, y el grupo experimental mostró avances en el aprendizaje sustancialmente mayores. Los resultados cualitativos revelaron además que el enfoque PBL mixto mejoró significativamente la motivación y el compromiso de los estudiantes, así como el desarrollo del trabajo en equipo y las habilidades de pensamiento crítico. En conclusión, el modelo PBL mixto es un enfoque pedagógico muy eficaz para la educación técnica. Su éxito aboga por un cambio de paradigma fundamental hacia metodologías activas y centradas en el estudiante que preparen verdaderamente a los graduados para un panorama profesional complejo y en constante evolución.

Palabras Clave: Aprendizaje Basado en Proyectos Combinado; Educación en Redes Informáticas; Resultados de Aprendizaje de los Estudiantes; Efectividad.

INTRODUCTION

In recent years, computer networking courses have struggled to keep pace with rapid technological changes, particularly in providing students with the hands-on skills demanded by industry. Lecture-dominant instruction and occasional lab work often fall short in preparing students for network design, troubleshooting, or configuring real network infrastructures. For instance, a study in Surakarta found that using a *project-based blended learning* approach significantly improved student achievement compared to conventional online or face-to-face methods.[1,2] The another example, students in an Information Technology program who engaged in blended project-based modules for website design showed marked gains in practical competencies.[1,3]

Computer network education has followed a fairly conventional pedagogical approach, where theoretical concepts are delivered in the classroom and practical applications are often relegated to separate, more limited lab sessions.[1,2] This separation between theory and practice has led to a disconnect in how students learn and apply their knowledge. While this traditional method has produced some success, it is increasingly clear that a more integrated and experiential approach to teaching is necessary.[4,5] The gap between theoretical knowledge and practical skills has been a well-recognized issue in many technical and vocational education programs globally, including in computer network education.[6,7]

In higher education, the gap between theory and practice has sparked calls for pedagogical reform. A promising solution is blended learning, which combines online resources with traditional face-to-face instruction, offering a more dynamic approach to education, especially in computer network education.[8,9] Blended learning offers students the flexibility to engage with content outside the classroom while maintaining the benefits of in-person interaction.[10,11] This hybrid model facilitates the integration of theoretical knowledge and practical application in a more cohesive and engaging way, enhancing the learning experience in computer network education.[9,12]

To further improve the effectiveness of blended learning, Project-Based Learning (PBL) has become a central pedagogical approach. PBL focuses on learning through the execution of real-world projects, motivating students to address practical challenges, work collaboratively, and develop both critical thinking and technical skills, particularly in the context of computer network education.[13,14] In computer network education, Project-Based Learning (PBL) offers an effective framework for students to apply theoretical concepts in the design and management of computer networks, resulting in a more engaging and impactful learning experience.[15,16]

Despite the potential advantages of blended project-based learning, its implementation in computer network education has not been without challenges. One of the primary obstacles is the need for adequate instructional design that effectively integrates both online and in-person components, ensuring that students can move between theoretical and practical learning smoothly.[17,18] Additionally, the level of student engagement and the ability to assess learning outcomes in such a flexible, dynamic environment remains a concern for many educators.[19,20]

Computer network education has seen a gradual shift from traditional teaching methods to more modern approaches that incorporate technology.[1,21] However, this shift has not always been well-aligned with the needs of students who are more accustomed to hands-on, real-world learning experiences. The increasing reliance on digital tools and online platforms has the potential to bridge this gap, but only if the integration of these tools is done thoughtfully and with a clear focus on student learning outcomes.[22,23]

This study focuses on evaluating the effectiveness of a blended project-based learning model in the context of computer network education, specifically analyzing how it enhances students' learning outcomes.[24,25] The integration of traditional classroom methods with project-based tasks aims to equip students with the essential

tools to enhance both their technical skills and their capacity for critical thinking in real-world situations, particularly in computer network education.[26,27] The central question this research seeks to answer is: How effective is blended project-based learning in enhancing students' ability to apply computer networking concepts practically?

The rationale for this study stems from the growing need for graduates who possess not only theoretical knowledge but also the ability to apply that knowledge in practical settings. The traditional approach to computer network education has frequently faced challenges in producing graduates who are fully prepared for immediate employment in the industry.[28,29] Integrating blended learning with project-based strategies creates an educational environment that more effectively equips students to navigate the complexities of the modern digital landscape, particularly in computer network education.[30,31]

Furthermore, the adoption of this model could have broader implications for educational practices in other technical fields. As such, this study is not limited to computer network education alone but also serves as a potential model for other disciplines that face similar challenges in bridging the gap between theory and practice.[32,33] The results of this study will provide valuable insights into how blended project-based learning can enhance educational practices within the technical education field, particularly in computer network education.

As the study focuses on evaluating the effectiveness of blended project-based learning, the research will primarily assess the impact on student learning outcomes. These outcomes will be measured through a combination of formative and summative assessments, including surveys, performance evaluations, and direct observation of students' ability to apply their learning in real-world projects.[24,34] This comprehensive approach will allow for a holistic understanding of how well the blended project-based model supports student development in the area of computer networking.

The objectives of this study are twofold. First, it aims to evaluate the effectiveness of the blended project-based learning model in enhancing students' technical abilities, such as network configuration, troubleshooting, and system integration. Second, it seeks to explore whether this approach improves students' cognitive and critical thinking skills, which are crucial for problem-solving in the dynamic field of computer network education. This study is positioned to make significant contributions to the field by assessing an innovative pedagogical model that aligns with the evolving demands of the industry. By integrating blended learning and project-based learning, the study aims to enhance educational outcomes and provide a more effective transition for students from academic knowledge to professional practice.

METHOD

Research Design

This study employed a quasi-experimental design with a nonequivalent control group to evaluate the effectiveness of the Blended Project-Based Learning (PBL) model in improving student learning outcomes in computer network education. The research was conducted at Universitas Al Washliyah Labuhan Batu, Indonesia, during the odd semester of the 2024/2025 academic year. The quasi-experimental design was selected as it allowed for a comparative analysis of outcomes between two groups when random assignment was not feasible. This design was highly relevant for evaluating instructional interventions in a natural educational setting.

Sample and Context

The study participants were students from the Informatics Engineering program enrolled in the Advanced Computer Networks course, a mandatory subject for fourth-semester students. Two intact class groups were selected using purposive sampling: the experimental group (n=28) received the Blended PBL model intervention, while the control group (n=27) followed traditional, lecture-based instruction. The selection of these pre-existing groups was based on convenience and availability, as the students were naturally registered in separate classes.

Procedures

Intervention Implementation

a. Experimental Group: Students participated in seven Blended PBL sessions. The blended ratio was approximately 50 % online (asynchronous) and 50 % in-class (synchronous). The online component involved the delivery of theoretical content, tutorials, and initial discussions via Google Classroom and Telegram platforms. In-class sessions were dedicated to collaborative teamwork on projects, direct mentoring, and presentations. The seven projects were designed to cover specific learning objectives, including:

a) Project 1: Configuring a Local Area Network (LAN) for a Small Office.
b) Project 2: Implementing and securing a Wi-Fi network for a dormitory building.
c) Project 3: Designing a Wide Area Network (WAN) topology to connect two branch offices.
d) Project 4: Implementing DHCP and DNS services on a server.

e) Project 5: Building and securing a Virtual Private Network (VPN).
f) Project 6: Conducting a basic network security audit on a system.
g) Project 7: Establishing a wireless network in a campus area.

b. Control Group: Students followed a traditional, teacher-centered instructional format. The learning process consisted of lectures and practical demonstrations led by the instructor, followed by individual exercises. No collaborative project elements or structured online interaction for core tasks were used.

Measurement

a. Pre- and Post-tests: To measure cognitive learning outcomes and technical skills, both groups were administered pre- and post-tests. The tests comprised 20 multiple-choice questions to assess conceptual understanding and 5 short-answer essay questions focusing on problem-solving abilities.

b. Student Engagement Survey: After the final session, a 15-item Likert-scale survey was administered to both groups. This survey was designed to capture students' perceptions of collaboration, motivation, and skills development.

Research Instruments and Validation

1. *Instrument Development*

I. Theoretical Tests (Pre- and Post-test): Test items were developed based on the Advanced Computer Networks course syllabus and aligned with specific learning objectives.

II. Student Engagement Survey: The instrument was developed by adapting items from established and validated scales used in previous Blended PBL research. The development process involved:

a. Content Validity: Three experts in educational technology and curriculum reviewed the survey items to ensure their relevance and clarity.

b. Pilot Study: The instrument was piloted on 30 third-semester students from a different study program to identify ambiguities and potential issues.

2. Validity and Reliability

The results from the pilot study were used to test the validity and reliability of the instruments. Item validity was assessed through correlation analysis, and the instrument's reliability was measured using the Cronbach's Alpha (α) coefficient with SPSS software. Items with an α value of less than 0,70 or low correlation with the total score were revised or removed to ensure the instruments used were both reliable and valid.

To measure the effectiveness of the intervention, both groups underwent pre- and post-tests that assessed technical skills, problem-solving abilities, and teamwork. Additionally, a student engagement survey, consisting of 15 Likert-scale items adapted from established blended project-based learning instruments, was administered after the final session. The survey aimed to capture students' perceptions of collaboration, motivation, and skills development. Data were collected in both printed and digital formats, with responses anonymized and securely stored to ensure confidentiality.[35,36]

Table 1. Research Design

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

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.

The study adhered to ethical standards in research by ensuring informed consent was obtained from all participants, with full disclosure about the study's purpose and their right to confidentiality. Participants were informed that their participation was voluntary, and they were given the option to withdraw at any time without consequence. All responses from the pretest, posttest, and engagement survey were anonymized to protect the privacy of the participants. Data were securely stored and only accessible to the research team to ensure confidentiality and compliance with ethical research practices.

Data Analysis Techniques

This study employed both quantitative and qualitative research methods to assess the effectiveness of the Blended Project-Based Learning (PBL) model in enhancing student learning outcomes. The study involved two

groups: the experimental group (n=28) who engaged in the blended PBL approach, and the control group (n=27) who received traditional, teacher-centered instruction. The primary aim of this study was to assess whether the blended Project-Based Learning (PBL) model resulted in greater improvements in students' theoretical understanding and practical skills in computer network education compared to traditional teaching methods.

The quantitative analysis of the pre- and post-test scores from both the experimental and control groups was conducted using specific statistical techniques. These methods facilitated comparisons between the groups to determine if there was a statistically significant difference in learning outcomes. It was hypothesized that the experimental group, which participated in the blended PBL model, would show more substantial improvements in both their grasp of computer network concepts and their ability to apply this knowledge in real-world network configurations, compared to the control group.

Alongside the quantitative data, qualitative data were gathered through surveys and semi-structured interviews with both students and instructors. The responses were analyzed using thematic analysis to identify recurring themes related to student engagement, motivation, teamwork, and perceptions of the learning process. By combining both quantitative and qualitative approaches, this study aimed to offer a comprehensive evaluation of how blended PBL impacted students' learning experiences and outcomes in computer network education, focusing on critical skills such as problem-solving, collaboration, and technical proficiency in network management. Ethical guidelines, including informed consent, confidentiality, and voluntary participation, were strictly observed throughout the study to ensure the protection of participants' rights.

Blended Project-Based Learning in Computer Network Education

The Blended Project-Based Learning (PBL) approach, implemented in the context of Computer Network Education, focuses on engaging students through collaborative, hands-on projects. This teaching method encourages students to work in teams, tackling real-world networking problems while developing both technical competencies and essential soft skills like communication, teamwork, and critical thinking. The PBL model combines traditional face-to-face instruction with online learning elements, where students are responsible not only for mastering theoretical concepts but also for collaborating effectively with their peers to complete practical assignments. This integration of theoretical knowledge and practical application fosters a deeper understanding of the subject matter and enhances students' problem-solving skills, which are crucial for success in the computer networking field.

Figure 1. Blended Project-Based Learning Handbook

To assess the effectiveness of the Blended Project-Based Learning (PBL) approach, the performance of students in the experimental group, who participated in blended PBL, was compared with the control group, which followed traditional, teacher-centered instruction. In the experimental group, students engaged in projects that required them to design and implement computer networks, applying theoretical knowledge to real-world situations. These projects were designed to replicate industry challenges, providing students with a more authentic and engaging learning experience. Furthermore, the blended PBL approach fostered an active learning environment, encouraging students to take responsibility for their own learning. This approach aligns with the demands of 21st-century education, which emphasizes the development of both technical expertise and essential skills such as teamwork, critical thinking, and adaptability in a rapidly evolving technological

landscape

RESULT

Data Analysis and Findings

The data analysis in this study demonstrates significant improvements in student learning outcomes after the implementation of Blended Project-Based Learning (PBL) in Computer Network Education. Both quantitative and qualitative data were collected, with pre- and post-assessment surveys used as the primary tools to assess academic performance. Descriptive statistics were applied to the pre-test and post-test scores from both the experimental group, which participated in the blended PBL approach, and the control group, which followed traditional, teacher-centered methods. The experimental group showed substantial improvements in technical skills, problem-solving abilities, and the practical application of computer networking concepts. In contrast, the control group, which adhered to conventional teaching methods, demonstrated smaller gains in these areas.

The comparison between the experimental and control groups highlights the effectiveness of the blended PBL model in enhancing student learning outcomes. The analysis of pre- and post-test data revealed significant academic progress in the experimental group, especially in their ability to apply theoretical knowledge to real-world computer network tasks. These findings suggest that blended PBL greatly enhanced students' technical competencies and problem-solving skills, providing a more engaging and effective learning experience. The accompanying data table further supports the impact of the blended PBL approach on student performance, emphasizing its superior effectiveness compared to traditional instructional methods in computer network education.

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

Group	Mean Pre-Test Score	Mean Post-Test Score
Experiment	63,80	89,32
Control	66,77	80,89

The table presents the results of the descriptive analysis for both the pre-test and post-test scores of the experimental and control groups in the context of Computer Network Education. The experimental group, which participated in Blended Project-Based Learning (PBL), had an average pre-test score of 63,80, which increased to 89,32 in the post-test, demonstrating a significant improvement in students' learning outcomes after the PBL intervention. This improvement underscores the effectiveness of the blended PBL approach in enhancing both theoretical understanding and practical network skills. In contrast, the control group, which followed traditional, teacher-centered methods, had a pre-test mean score of 66,77 and a post-test mean of 80,89. Although the control group also showed progress, the experimental group demonstrated a more significant improvement, emphasizing the benefits of the PBL model in promoting deeper learning outcomes in computer network education. Furthermore, a normality test was conducted to determine the suitability of the data for inferential analysis, specifically to assess the extent to which the data followed a normal distribution. The Shapiro-Wilk test was utilized to analyze the distribution of the data.

Table 3. Results of the Shapiro-wilk Test

Group	Pre-Test (p-value)	Post-Test (p-value)
Experiment	0,487	0,452
Control	0,984	0,711

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	0,574	0,452

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	Post-Test scores of Experimental Group vs Control Group	2,051	0,045	The experimental group achieved a higher mean post-test score than the control group

The results of an Independent Sample T-Test comparing the post-test scores of the experimental and control groups in the context of Blended Project-Based Learning (PBL) in Computer Network Education reveal a statistically significant difference. The t-value of 2,051 with a p-value of 0,045 indicates that the experimental group, which participated in the blended PBL approach, achieved a significantly higher mean post-test score than the control group, which followed traditional teaching methods. This outcome suggests that the blended PBL model positively impacted students' learning outcomes, enhancing both their theoretical knowledge and practical networking skills, thereby demonstrating its effectiveness in technical education. The gain scores (Post-Test – Pre-Test) were calculated for both groups to evaluate the improvement from pre- to post-test. The experimental group showed a larger gain compared to the control group.

Table 6. Gain Score Analysis

Group	Mean Pre-Test Score	Mean Post-Test Score	Gain Score (Post - Pre)
Experiment	63,80	89,32	25,52
Control	66,77	80,89	14,12

The gain score analysis demonstrated that both groups improved from pre-test to post-test; however, the experimental group exhibited a substantially higher gain. Specifically, students in the experimental group increased their scores by an average of 25,52 points, compared to only 14,12 points for the control group. This 11,40-point difference indicates that the blended project-based learning (PBL) intervention produced a stronger impact on student learning outcomes than traditional instruction. An ANCOVA was conducted to adjust for pre-test differences. After controlling for pre-test scores, the post-test differences remained significant, confirming the effectiveness of the intervention.

Table 7. ANCOVA Result

Source	F	Sig. (p-value)	Interpretation
Pre-Test (covariate)	-	n.s	Initial differences controlled
Group (Experimental vs. Control)	≈ 4,20	0,045	Significant group effect on post-test

An ANCOVA was conducted with post-test scores as the dependent variable, pre-test scores as the covariate, and group membership as the factor. The analysis revealed a significant group effect ($F \approx 4,20$, $p = 0,045$), while pre-test scores were not a significant predictor of post-test performance. These findings confirm that the advantage of the experimental group persisted even after controlling for initial differences, demonstrating that blended PBL was more effective than traditional instruction in improving students' cognitive and technical skills in computer networking.

The boxplot illustrates the distribution of pre-test and post-test scores for both the experimental and control groups in the context of Blended Project-Based Learning (PBL) in Computer Network Education. The experimental group, which participated in PBL, shows a higher median post-test score (89,32) compared to the control group (80,89), reflecting a consistent improvement in performance following the intervention. The interquartile range (IQR) for the experimental group is clustered between approximately 80 and 95, indicating more uniform improvement across students. In contrast, the control group has a wider range of scores, with the

IQR between 75 and 85, suggesting greater variability in learning outcomes. The whiskers for the experimental group are shorter, showing less variability in scores, while the control group demonstrates a broader spread, indicating more inconsistency in performance. These results, visually represented in the boxplot, reinforce the quantitative findings that the experimental group, engaged in Blended PBL, outperformed the control group, demonstrating a more significant and consistent enhancement in learning outcomes.

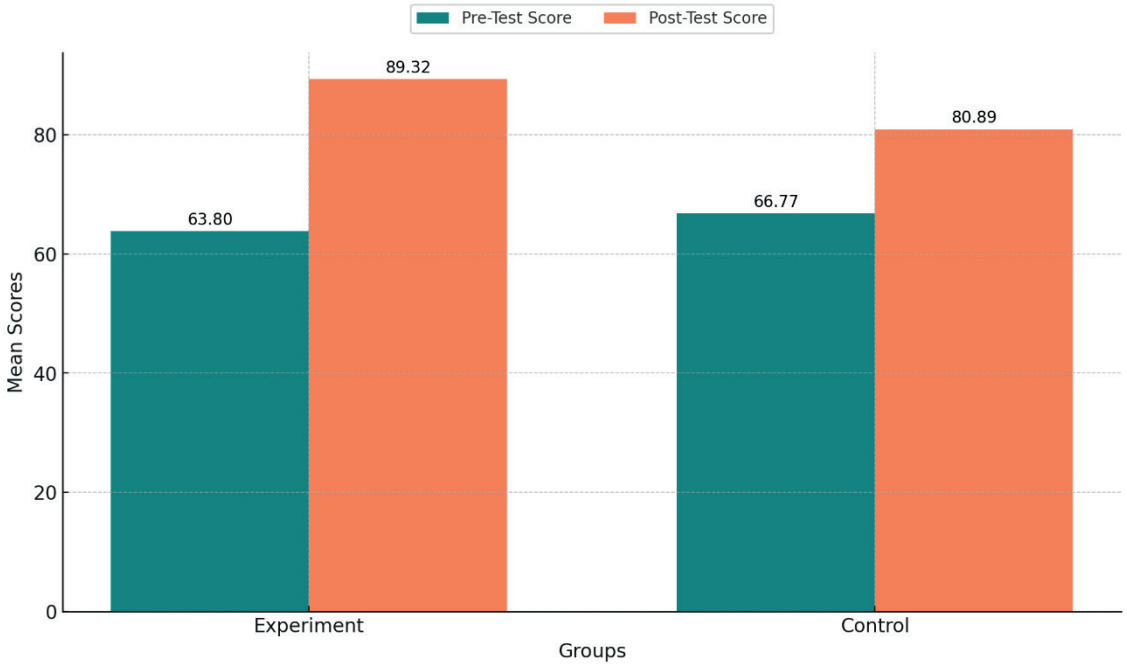

Figure 2. Pre-Test and Post-Test Scores Bar Chart

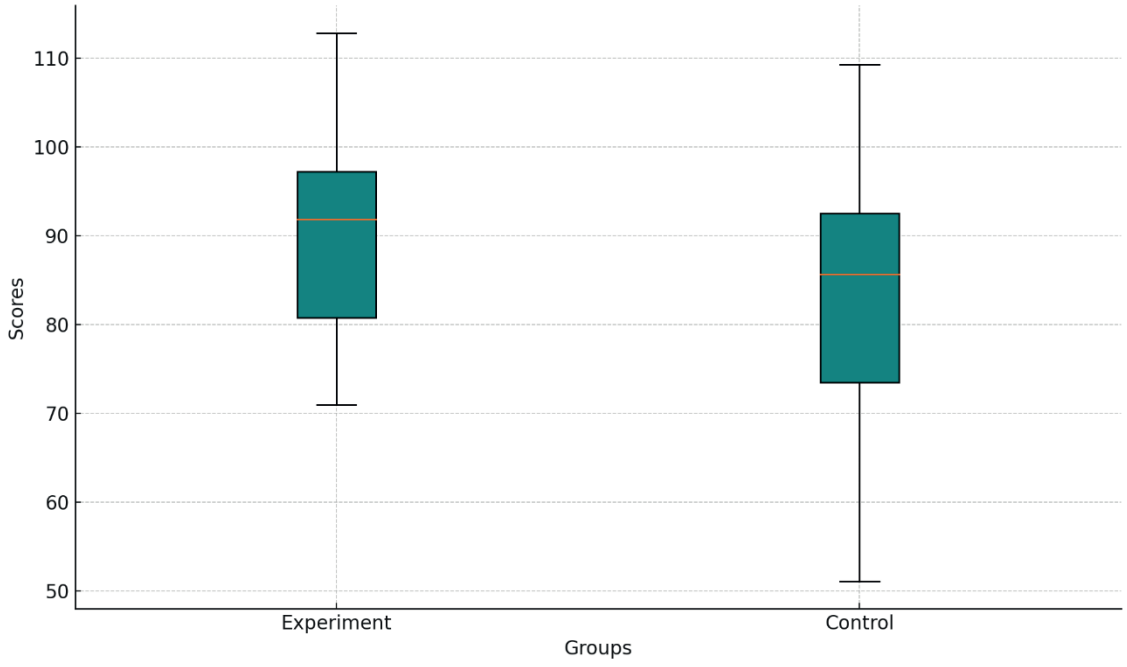

Figure 3. Box Plot Pre-Test and Post-Test Scores

DISCUSSION

This study aimed to assess the effectiveness of Blended Project-Based Learning (PBL) in improving Computer Network Education, with a focus on student learning outcomes. The results show a significant enhancement in the academic performance of the experimental group, which participated in the blended PBL approach, compared to the control group, which followed traditional teaching methods. Specifically, the experimental group exhibited a more considerable increase in their post-test scores, particularly in their ability to apply

theoretical knowledge to practical networking tasks. This finding aligns with previous research Jalinus and Servant-Miklos,[13,14] which has demonstrated that project-based and collaborative learning models greatly improve students' problem-solving skills and technical competencies in practical fields, such as computer network education.

The results from this study are consistent with other studies that have evaluated blended learning and project-based learning in technical education. For instance, Fan [6] found that the integration of digital learning components with traditional classroom instruction improves both cognitive understanding and practical application of complex subjects, such as computer networking. Additionally, research by Husamah[8] emphasized that active learning strategies like PBL foster critical thinking and collaborative problem-solving skills, which are crucial in the ever-evolving field of computer network management. These findings suggest that blending PBL with traditional methods not only enhances student engagement but also prepares students more effectively for professional challenges.

However, it is essential to recognize the challenges that come with implementing blended PBL in computer network education. One of the key obstacles highlighted by this study is the need for effective instructional design that integrates both online and in-person learning activities. As noted by Krismadinata,[10] the successful implementation of blended learning requires careful alignment between digital content and face-to-face interactions, ensuring that students can move seamlessly between the two learning environments. Additionally, the variability in post-test scores for the control group suggests that traditional teaching methods may not offer the same level of engagement and skill development, a limitation often highlighted in educational research.[4]

The study also suggests that the success of blended PBL is not solely dependent on the instructional model itself but also on how well it is implemented. The experimental group showed consistent improvements in both theoretical and practical aspects of computer network education, indicating that active engagement is crucial to learning outcomes. These findings support the argument put forth by Lin[11] that self-regulated learning facilitated by collaborative tasks can significantly enhance students' understanding and application of technical concepts. However, further research is needed to explore how different blended learning models might impact specific areas of computer network education, such as network security or advanced network configurations.

In comparison to other studies in the field of technical education, this research highlights the potential of Blended PBL to foster a deeper and more integrated understanding of complex subjects. Similar studies, such as those by Mielikäinen and Wani,[5,9] have emphasized that blended and project-based learning methods enable students to engage with content in a more authentic, meaningful way, which leads to improved learning outcomes. Moreover, the study supports findings by Servant-Miklos and Kolmos,[14] who assert that collaborative learning environments, where students collaborate on real-world problems, foster the development of key professional skills such as communication, teamwork, and problem-solving, which are crucial for success in the computer network industry.

Despite the promising findings, this study has several limitations that define the boundaries of its conclusions. The research was conducted with a relatively small sample size at a single institution, which may limit the generalizability of the results to a broader population of informatics students. Additionally, the short duration of the intervention (seven sessions) does not provide insight into the long-term retention of knowledge and skills. A stronger discussion uses limitations to define the boundaries of the study's conclusions and suggest future research.

These limitations also pave the way for future research. Subsequent studies should aim to replicate this design with larger and more diverse samples from multiple institutions to confirm the findings' external validity. A longitudinal study could also be conducted to assess the long-term impact of blended PBL on student performance and career readiness. Researchers could also explore the effects of varying the "blending" ratio and investigate the specific types of online tools or collaborative tasks that yield the most significant learning gains.

The implications of these findings for both educators and researchers are substantial. For educators in vocational and higher education, this study provides a clear and actionable framework. They should design curricula to center around authentic, real-world projects that encourage active learning rather than passive reception of information. This includes leveraging online platforms for theory and reserving classroom time for practical, collaborative problem-solving. For researchers, these results underscore the need for further investigation into the specific mechanisms of blended learning, particularly in technical and hands-on fields. Future research should also focus on developing validated instruments that specifically measure collaborative and problem-solving competencies within the context of blended learning models.

CONCLUSION

This study provides compelling evidence that the Blended Project-Based Learning model is a highly effective pedagogical approach for vocational and technical education, specifically within the field of computer networks. The findings demonstrate that by integrating authentic, real-world projects with a flexible blended format,

educators can achieve significantly superior learning outcomes and foster a deeper, more enduring understanding of complex concepts. The model not only enhances technical proficiency but also cultivates vital soft skills—such as teamwork, critical thinking, and problem-solving—that are indispensable for success in the modern workforce. This research advocates for a fundamental paradigm shift in educational practice, urging educators to move away from passive, lecture-based instruction toward active, student-centered methodologies that truly prepare graduates for a dynamic and constantly evolving professional landscape. The future of technical education lies not in what is taught, but in how we empower students to learn.

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FINANCING

The authors did not receive financing for the development of this research.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHORSHIP CONTRIBUTION

Conceptualization: Samsir, M. Giatman, Riki Mukhaiyar.
Data curation: Samsir.
Research: Samsir.
Methodology: M. Giatman, Riki Mukhaiyar.
Software: Samsir.
Validation: M. Giatman, Riki Mukhaiyar.
Drafting - original draft: Samsir, M. Giatman.
Writing - proofreading and editing: Samsir, Riki Mukhaiyar.