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The Influence of Project Based Learning Strategy on Learning Outcomes in Computer Science Subjects at Vocational High School

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ABSTRACT

Technological developments in the Industrial Revolution 4.0 era require the world of education to implement learning strategies that can improve critical thinking skills and student creativity, especially in Informatics subjects in Vocational High Schools (SMK), but the dominance of conventional strategies causes student learning outcomes to be less than optimal. This study aims to examine the improvement, differences, and the effect of implementing Project Based Learning (PjBL) strategies on Informatics learning outcomes of class X Health Services students at SMK Negeri 1 Banyudono. This study used a quantitative approach with a quasi-experimental design, involving class X LK 1 as the experimental class receiving the PjBL strategy and class X LK 2 as the control class using conventional learning. Data collection used a pre-test and post-test, then analyzed using paired sample t-tests, independent sample t-tests, and the N-Gain test. The results indicated a significant increase in learning outcomes in the experimental class with a calculated t-value of 23.610, and a significant difference between the experimental and control classes with a calculated t-value of 10.915. The average N-Gain value of 0.55 is in the moderate category. Based on these findings, it is concluded that the Project Based Learning strategy has been proven to have a significant influence on student learning outcomes through collaborative activities and project completion, thus potentially being an effective alternative learning strategy in informatics subjects.

Keywords: Project Based Learning, learning outcomes, Informatics, quasi-experiment, vocational high school

INTRODUCTION

The rapid development of technology in the era of the Fourth Industrial Revolution has accelerated digitalization and the integration of intelligent systems across various sectors. This transformation requires a workforce equipped with adaptive, analytical, and innovative competencies to meet the demands of the modern industry (Yanti et al., 2024). Consequently, educational institutions are expected to adopt learning approaches that align graduates' competencies with the needs of technology-driven and future-oriented industries (Kasili et al., 2025). Setyaningsih (2023) highlights that contemporary digital multimedia developments have evolved beyond basic audio and text to encompass highly integrated formats of graphics, animations, images, and audio/video, creating an extraordinary impact on learning resources

across international boundaries. Furthermore, future innovations such as the metaverse are emerging as 3D shared virtual spaces that promise highly immersive and interactive experiences for global education (Alhakimi, 2023). This digital transformation marks a significant turning point in pedagogy, where the shift to screen-to-screen interactions places educational technology in a crucial role to facilitate flexible and meaningful environments (Peramtasari, 2023). This adaptation is further supported by cloud computing technologies such as Google Forms, Quizizz, and Wordwall, which enhance the fundamental efficiency, engagement, and outcome quality within informatics education at vocational schools (Purnama et al., 2024).

Vocational High Schools (SMK) play a strategic role in preparing skilled graduates who are not only proficient in technical competencies but also possess essential 21st-century skills, including communication, collaboration, creativity, and critical thinking (Rahmi et al., 2023). Career development and entrepreneurial intentions among vocational graduates in this digital era are heavily determined by their capacity to solve complex technical problems, handle advanced applications, and navigate digital services effectively (Vitariyanti et al., 2024). To establish this high-level adaptive capacity, proper control, guidance, and exposure to technological toolsets should ideally serve as a foundational anchor during early childhood development and informal education phases (Pinilih, 2023). In secondary education environments, teachers must act not only as instructional transmittors but also as crucial role models who instill emotional intelligence, responsibility, and core ethical values to help students establish healthy peer relationships and navigate conflicts constructively (Septyventia et al., 2024). However, despite improvements in national educational indicators, learning outcomes in vocational education remain a concern. Previous reports indicated that vocational students demonstrated relatively low academic achievement in both general and vocational subjects, highlighting the need for more effective instructional strategies (Puspendik, 2019). This learning deficiency is often exacerbated by conventional, unvaried teaching habits that result in student disengagement (Fitriani & Ridhani, 2025). To overcome classroom boredom and accommodate highly diverse learning styles in the post-pandemic era, creative teaching variations combining novel methods, digital media, and adaptive interactions are vital to building inclusive classrooms (Arifin et al., 2025).

Similar conditions were identified at SMK Negeri 1 Banyudono. Preliminary data from Informatics classes revealed that a considerable proportion of students had not achieved the Minimum Completeness Criteria (KKM). Classroom observations further indicated that learning activities were predominantly teacher-centered, relying heavily on lecture-based instruction. Such conventional practices tend to limit students' active participation, reduce learning motivation, and hinder the development of deeper conceptual understanding. Real-world challenges indicate that formative computational thinking assessments remain in their infancy, revealing deep conceptual gaps regarding how digital tools are leveraged, while learning management systems are frequently underutilized as metacognitive scaffolding instruments (Buwono et al., 2025). These challenges emphasize the importance of implementing innovative learning strategies that promote active and meaningful learning experiences. One relevant direction involves systemically developed multimedia tools, such as digital flipbooks mapped to the Dick & Carey instructional design model, which have proven highly valid and capable of boosting creative problem-solving fluency and engagement (Yasni et al., 2025). Similarly, structured digital management systems such as the Nearpod platform, when structured through systematic instructional design, have demonstrated significant success in supporting high-order cognitive processes and critical thinking (Sasongko et al., 2025). On an experiential level, holistic instructional frameworks like the BERAKSI model (Playing, Creating, Discussing, and Cheerful) confirm that multi-activity engagement fosters a pleasant, dynamic atmosphere that significantly optimizes student immersion (Nongko et al., 2025).

In line with national educational goals, students are expected to develop critical thinking, creativity, collaboration, and communication skills through student-centered learning approaches. One strategy that supports these objectives is Project-Based Learning (PjBL). PjBL engages students in authentic projects, encouraging active participation, collaboration, and problem-solving throughout the learning process (Hera Erisa et al., 2021). The educational value of action-based innovations is mirrored in Game-Based Learning (GBL) models that merge ADDIE principles with discovery learning to simulate authentic vocational scenarios, significantly maximizing logical thinking and preparing graduates for real job markets (Raziana & Wibawanto, 2025). By targeting concrete project outcomes, PjBL fosters a parallel constructivist environment. Previous studies have demonstrated that PjBL can improve critical thinking skills, creativity, learning motivation, and academic achievement compared to conventional instructional methods (Salman et al., 2020). Although numerous studies have examined the implementation of PjBL in vocational education, most have employed Classroom Action Research designs, which provide findings limited to specific contexts. Experimental studies investigating the effectiveness of PjBL in improving Informatics learning outcomes remain limited. Therefore, this study aims to examine the effect of Project-Based Learning on students' learning outcomes in Informatics through a quasi-experimental design, providing stronger empirical evidence regarding the effectiveness of PjBL in vocational education settings.

METHODS

This study was conducted at SMK Negeri 1 Banyudono, located at Jl. Kuwiran No. 3, Banyudono, Boyolali Regency, Central Java, Indonesia. The school was selected as the research site because the learning strategies implemented in Informatics classes were considered less optimal, resulting in suboptimal student learning outcomes.

This study employed a quasi-experimental design involving 68 tenth-grade students, consisting of 35 students in the control class and 33 students in the experimental class. The participants were selected using purposive sampling. Data were collected through pre-tests and post-tests to examine the effects of the implemented learning strategies on students' learning outcomes. The research instruments were validated through validity and reliability testing prior to data collection.

Data analysis included normality and homogeneity tests, followed by hypothesis testing using paired sample t-tests, independent sample t-tests, and N-gain analysis. The research procedure consisted of four stages: preparation, implementation of the intervention, data analysis, and conclusion drawing.

RESULTS AND DISCUSSION

Results

This study aimed to examine the effect of the Project-Based Learning (PjBL) strategy on students' learning outcomes in Informatics at SMK Negeri 1 Banyudono. The effectiveness of PjBL was analyzed using paired sample t-tests, independent sample t-tests, and N-Gain analysis.

Table 1. Results of Paired Sample t-Test

Analysis Component	Value
Mean Difference (Pre–post-test)	21.143
Standard Deviation	5.298
t-value	23.610
df	34
Sig. (2-tailed)	0.001

The paired sample t-test revealed a mean difference of 21.143 between pre-test and post-test scores, indicating a substantial improvement in students' learning outcomes after the implementation of PjBL. The obtained t-value was 23.610 with a significance value of 0.001 ($p < 0.05$), demonstrating a statistically significant difference between pre-test and post-test scores. These findings indicate that the PjBL strategy effectively improved students' Informatics learning outcomes in the experimental class.

To compare learning outcomes between students taught using PjBL and those receiving conventional instruction, an independent sample t-test was conducted.

Table 2. Results of Independent Sample t-Test

Analysis Component	**Value**
Levene's Test (F)	0.032
Levene's Sig.	0.859
t-value	10.915
df	66
Sig. (2-tailed)	0.001

The Levene's test significance value of 0.859 ($p > 0.05$) indicated homogeneity of variance between the two groups. Therefore, the equal variances assumed criterion was applied. The independent sample t-test yielded a t-value of 10.915 with a significance value of 0.001 ($p < 0.05$), indicating a significant difference in learning outcomes between the experimental and control groups. Students who learned through the PjBL strategy achieved significantly better learning outcomes than those who experienced conventional learning.

Furthermore, N-Gain analysis was performed to determine the effectiveness of PjBL in improving students' learning outcomes. The analysis involved 35 students in the experimental class. The N-Gain scores ranged from 0.25 to 0.75, with a mean score of 0.5548 and a standard deviation of 0.09875. Based on the N-Gain interpretation criteria, this result falls within the moderate category, suggesting that PjBL was moderately effective in enhancing students' Informatics learning outcomes.

Discussion

The descriptive analysis revealed a substantial improvement in students' learning outcomes following the implementation of Project-Based Learning (PjBL). The mean score increased from 62.29 on the pre-test to 83.43 on the post-test, indicating an improvement of 21.14 points. Similar improvements were observed in other descriptive statistics, including increases in the minimum score (50 to 80), maximum score (80 to 90), median (65 to 85), and mode (65 to 80–85). These findings suggest that PjBL promotes active student engagement and enhances understanding of Informatics concepts through meaningful learning experiences.

The findings support Vygotsky's social constructivist theory, which emphasizes that knowledge is constructed through social interaction and collaborative learning processes (Rusman, 2020). The concept of the Zone of Proximal Development (ZPD) suggests that students achieve optimal learning outcomes when appropriate guidance and peer support are provided. In the implementation of PjBL, students actively engaged in discussions, collaboration, and project completion, enabling them to construct knowledge more effectively and apply concepts in authentic contexts. The profound impact of this structured scaffolding is mirrored when Problem-Based Learning is combined with differentiated instructions matching students' initial capacities and ZPD limits, showing an exceptional increase in active participation, independent task completion, and overall positive academic attitudes (Pawitra et al., 2025). The practical implications of such interactive adjustments match the success observed in cooperative

structures like the Numbered Head Together method, which utilizes targeted media to significantly improve classroom engagement, successfully lifting classic learning completeness from low thresholds to fully realized benchmarks (Fitriani & Ridhani, 2025).

The effectiveness of PjBL was further confirmed by the paired sample t-test results. The mean difference of 21.143 and the significant t-value ($t = 23.610$, $p < 0.001$) indicate that students' learning outcomes improved significantly after the intervention. Moreover, the 95% confidence interval did not cross zero, demonstrating the consistency of the observed improvement. These results indicate that PjBL not only facilitates theoretical understanding but also provides students with direct learning experiences through project-based activities related to Informatics content. This clear cognitive improvement satisfies the intense demands brought by modern digital multimedia shifts, which compel modern educators to design environments that naturally spark digital knowledge creation (Setyaningsih, 2023). Grounding PjBL instruction within authentic project workflows addresses the critical requirement for systematic, multimedia-supported learning environments that have been empirically shown to foster complex creative thinking skills in 21st-century classrooms (Yasni et al., 2025).

Comparative analysis between the experimental and control groups also demonstrated the superiority of PjBL over conventional instruction. The experimental group achieved a higher mean post-test score (83.43) compared to the control group (73.64). The independent sample t-test yielded a significant difference between the two groups ($t = 10.915$, $p < 0.001$), while Levene's test confirmed the homogeneity of variance ($p = 0.859$). In addition, the average N-Gain score of 0.5548 was categorized as moderate, indicating that PjBL was moderately effective in improving students' learning outcomes in Informatics. The fact that PjBL yields superior results compared to teacher-centered structures carries substantial implications for tactical curriculum changes in vocational schools. It emphasizes that incorporating highly adaptive, inclusive, and multi-method pedagogical frameworks is the primary mechanism to combat student boredom and harmonize instructions with highly varied student learning profiles (Arifin et al., 2025). By allowing students the freedom to navigate hands-on digital artifacts, the learning environment transforms into a dynamic space optimized for real-world competency growth.

These findings are consistent with previous studies reporting the positive impact of PjBL on students' academic achievement. Surbakti et al. (2023) found that the implementation of PjBL significantly improved Informatics learning outcomes, with students' average scores increasing from 52.63 to 83.40. Similar to the present study, their research employed PjBL as the instructional intervention and learning outcomes as the primary variable of interest. However, this study contributes additional empirical evidence by focusing on vocational education settings, specifically tenth-grade Health Services students at SMK Negeri 1 Banyudono. This provides an important theoretical bridging effect, aligning with modern digital instructional management approaches that establish a direct link between strategic design platforms and high-order cognitive development (Sasongko et al., 2025). Therefore, the findings strengthen existing evidence regarding the effectiveness of PjBL in enhancing learning outcomes within vocational Informatics education while offering concrete operational solutions to the structural limitations of conventional systems that limit student potential.

Overall, the results indicate significant differences in learning outcomes before and after the implementation of PjBL, as well as between students taught using PjBL and those receiving conventional instruction. These findings confirm that Project-Based Learning is both statistically and practically effective in improving Informatics learning outcomes among vocational high school students.

CONCLUSION

This study demonstrates that the implementation of Project-Based Learning (PjBL) has a positive and significant effect on students' learning outcomes in Informatics at SMK Negeri 1 Banyudono.

The paired sample t-test results revealed a significant improvement in learning outcomes after the implementation of PjBL, while the independent sample t-test indicated a significant difference between the experimental and control groups, with the experimental class achieving higher post-test scores. Furthermore, the N-Gain analysis yielded an average score of 0.5548, categorized as moderate, suggesting that PjBL was moderately effective in enhancing students' learning outcomes. The integration of current empirical literature indicates that this instructional success is driven by fulfilling the critical demands for multimodal learning tools, adaptive digital environments, and student-centered project execution. These findings confirm that Project-Based Learning can serve as an exceptionally robust and adaptive instructional strategy to enhance learning outcomes and cultivate core modern competencies within vocational high school informatics systems.

CONFLICT OF INTEREST

The authors declare no competing financial, professional, or personal interests that might have influenced the performance or presentation of the work described in this manuscript.

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