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Project-Based Learning in the Digital Era: The Role of Self-Directed Learning and Artificial Intelligence Utilization by Students in Optimizing Learning in the Business Administration Department of Politeknik Negeri Semarang

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Abstract

The rapid advancement of digital technology has driven significant transformation in higher education, particularly through the adoption of Project-Based Learning (PBL). The effectiveness of PBL in the digital era is substantially shaped by students' levels of self-directed learning and their utilization of Artificial Intelligence (AI) as a learning support tool. This study aims to analyze the influence of self-directed learning and AI utilization on the optimization of project-based learning among students in the Business Administration Department of Politeknik Negeri Semarang. Using a quantitative approach with a survey method, data were collected from 100 students who had participated in PBL-based courses. The data were analyzed using multiple linear regression with SPSS. Results indicate that both self-directed learning and AI utilization, simultaneously and partially, exert a positive and significant influence on PBL optimization. Self-directed learning proved to be the most dominant factor, demonstrating that students' ability to plan, monitor, and evaluate their own learning process is critical to PBL success. AI utilization functions as a supporting tool that enhances efficiency, productivity, and access to information in learning. This study provides important implications for the development of adaptive PBL strategies, emphasizing the reinforcement of self-directed learning and the critical, ethical use of AI in vocational education contexts..

Keywords:Project-Based Learning, Self-Directed Learning, Artificial Intelligence, Digital Learning, Vocational Education.

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INTRODUCTION

Higher education in the digital era is undergoing significant transformation, particularly in learning methods and technology utilization. Project-Based Learning (PBL) has been recognized as an effective pedagogical approach for enhancing students' collaboration, creativity, and problem-solving competencies. In the context of vocational higher education such as Politeknik Negeri Semarang, where practical learning components carry a 60% weight, PBL enables students to acquire practical skills through real-world projects relevant to the industrial sector.

Several prior studies have highlighted the effectiveness of PBL in higher education. Bell (2010) found that PBL significantly enhances students' critical thinking and collaborative skills, while Hmelo-Silver (2004) demonstrated that PBL contributes to improved conceptual understanding and problem-solving abilities. However, the implementation of PBL in the digital era demands adaptation, particularly with regard to students' self-directed learning capacities and the utilization of digital technologies, including Artificial Intelligence (AI).

Self-directed learning is crucial to PBL success because students are required to actively search, manage, and integrate information from diverse digital sources. According to Zimmerman (2002), self-directed learning involves students' ability to regulate, monitor, and evaluate their own learning process. In the digital era, this capacity becomes increasingly vital as students are confronted with an abundance of information and learning resources available online. Broadbent and Poon (2015) confirmed that self-directed learning significantly influences students' academic success in online learning environments.

Concurrently, AI has emerged as a revolutionary tool in education, enabling personalized learning, data analysis, and task automation. AI can assist students in optimizing their learning process through material recommendations, project management, and more efficient data analysis. According to Holmes et al. (2019), AI holds great potential to enhance both the efficiency and effectiveness of learning, particularly within project-based contexts.

Surveys conducted in Indonesia indicate that approximately 45% of workers and entrepreneurs had already utilized AI applications in 2023, with ChatGPT being the most widely used, reaching 52% of users (Databoks/Katadata, 2023). Despite this growth, the adoption of AI in education still faces challenges such as a lack of understanding and skills in applying the technology effectively (Luckin et al., 2016).

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Within the Business Administration Department of Politeknik Negeri Semarang, PBL has been actively implemented since the odd semester of 2024/2025, following a curriculum revision requiring every study program to establish a composition of PBL- and case-method-based courses. However, research examining the roles of both self-directed learning and AI utilization in this specific context remains limited. Therefore, this study examines whether and to what degree self-directed learning and AI utilization influence the optimization of PBL in this department.

LITERATURE REVIEW

Project-Based Learning (PBL)

PBL is a learning model that emphasizes project-based assignments as the primary instructional tool. Thomas (2000) defines PBL as involving students in in-depth investigation of complex problems, requiring integration of knowledge and skills from multiple disciplines. PBL is designed to develop 21st-century skills such as critical thinking, collaboration, communication, and creativity (Bell, 2010).

Grounded in constructivist grand theory—which holds that knowledge is actively constructed by individuals through experience and interaction—PBL aligns with Dewey's (1938, in Henson, 2003) concept of experience-based learning that centers on students and connects learning to real life. According to Larmer et al. (2015), PBL is characterized by student-centeredness, real-world problem orientation, collaborative work, and interdisciplinary integration.

In the digital era, PBL becomes increasingly relevant as it enables students to access broad learning resources and collaborate virtually. However, Hidayati et al. (2020) noted that challenges remain, including students' uneven readiness for self-management and time management, as well as unequal access to and understanding of digital technologies.

Self-Directed Learning

Self-directed learning refers to an individual's capacity to regulate, control, and evaluate their own learning process (Zimmerman, 2002). It encompasses skills such as goal-setting, planning, progress monitoring, and self-reflection. According to Zimmerman (2002), students with high self-directed learning are better equipped to address academic challenges and develop effective learning strategies.

The three core components of self-directed learning as identified by Zimmerman (2002) are: (1) Planning—setting learning goals and devising strategies to achieve them;

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(2) Monitoring—tracking learning progress and adjusting strategies as needed; and (3) Reflection—evaluating learning outcomes and identifying areas for improvement.

Factors influencing self-directed learning include intrinsic motivation, environmental support (from lecturers, peers, and family), and technological skills that enable students to access and manage learning resources effectively (Artino & Stephens, 2009).

Artificial Intelligence in Education

Artificial Intelligence (AI) is defined as the capacity of computer systems to perform tasks that typically require human intelligence, such as learning, decision-making, problem-solving, and natural language understanding (Russell & Norvig, 2020). AI encompasses technologies including machine learning, natural language processing (NLP), and computer vision.

In higher education, AI has been applied across various domains. Holmes et al. (2019) identify three key transformations: (1) Personalized Learning—AI delivers materials adapted to individual students' learning styles, pace, and preferences; (2) Automated Assessment—AI evaluates assignments and examinations automatically, providing instant feedback; and (3) Intelligent Tutoring Systems—AI-powered tutors offer individualized guidance with flexible availability.

Additional applications include academic data analysis to identify student performance patterns (Luckin et al., 2016), writing assistance tools such as Grammarly and Turnitin, and virtual assistants like ChatGPT that help students search for information, answer questions, and receive academic guidance.

Despite these benefits, AI in education also presents challenges: risk of over-dependence that may reduce critical thinking and creativity (Selwyn, 2019), privacy and ethical concerns related to data collection, and digital divide issues where unequal access to technology may widen educational inequity.

Theoretical Framework and Hypotheses

Based on the literature review, the theoretical framework of this study posits that self-directed learning (X1) and AI utilization (X2) independently and jointly influence the optimization of PBL (Y). This framework is grounded in Zimmerman's (2002) Self-Regulated Learning theory and constructivist learning principles. The study advances the following hypotheses:

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1. H1: Self-directed learning positively and significantly influences PBL optimization in the Business Administration Department of Politeknik Negeri Semarang.
2. H2: AI utilization positively and significantly influences PBL optimization in the Business Administration Department of Politeknik Negeri Semarang.
3. H3: Self-directed learning and AI utilization simultaneously and positively influence PBL optimization in the Business Administration Department of Politeknik Negeri Semarang.

RESEARCH METHODOLOGY

Research Design and Sample

This study employs a quantitative approach with a survey method. Data were collected from 100 students in the Business Administration Department of Politeknik Negeri Semarang who had participated in PBL-based courses. Sampling was conducted using non-probability purposive sampling to ensure respondents met the criterion of having taken PBL courses. The sample size satisfies the minimum threshold of 100 recommended by Hair et al. (1995, in Ferdinand, 2006). Data collection was carried out between April and October 2025.

Measurement Instrument

Data were collected via a questionnaire containing statement items for each variable, measured on a Likert scale of 1 to 10. The questionnaire comprised three variable constructs: (1) Self-Directed Learning (X1) — 12 items covering planning, monitoring, use of learning strategies, and reflection; (2) AI Utilization (X2) — 12 items covering frequency of use, perceived benefit, and ease of use; and (3) PBL Optimization (Y) — 12 items covering student engagement, collaboration and teamwork, and quality of project outcomes.

Data Analysis

Data were analyzed using SPSS software. The analytical procedure comprised: (1) validity testing using Pearson Product Moment correlation, with a validity criterion of r-count > r-table (0.195) at a significance level of 0.05; (2) reliability testing using Cronbach's Alpha coefficient, with a reliability criterion of α > 0.70; (3) descriptive statistical analysis; (4) classical assumption tests including normality (Kolmogorov-Smirnov), multicollinearity (Tolerance and VIF), and heteroscedasticity (Scatterplot); and

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(5) multiple linear regression analysis, followed by simultaneous F-test, partial t-test, and coefficient of determination (R^2).

RESULTS AND FINDINGS

Validity and Reliability

The results of the validity test revealed that all questionnaire items for each variable had r-count values ranging from 0.425 to 0.812, exceeding the r-table value of 0.1966. This confirms that all items are valid. Reliability testing yielded Cronbach's Alpha values of 0.941 for Self-Directed Learning (X1), 0.950 for AI Utilization (X2), and 0.954 for PBL Optimization (Y)—all substantially above the threshold of 0.70. These results confirm that the measurement instrument is reliable and that the data collected are trustworthy and suitable for further analysis.

Table 1. Validity and Reliability Test Results

Variable	Cronbach's Alpha	No. of Items	r-count Range
Self-Directed Learning (X1)	0.941	12	0.618 – 0.771
AI Utilization (X2)	0.950	12	0.617 – 0.753
PBL Optimization (Y)	0.954	12	0.645 – 0.802

Source: Primary Data (SPSS, 2025)

Descriptive Statistics

Descriptive statistical analysis of the 100 respondents yielded the following results: Self-Directed Learning (X1) had a minimum score of 25, a maximum of 120, a mean of 97.88, and a standard deviation of 16.41; AI Utilization (X2) had a minimum of 13, a maximum of 120, a mean of 99.08, and a standard deviation of 17.46; and PBL Optimization (Y) had a minimum of 24, a maximum of 120, a mean of 105.72, and a standard deviation of 14.14.

Table 2. Descriptive Statistics

Variable	N	Min	Max	Mean (SD)
Self-Directed Learning (X1)	100	25.00	120.00	97.88 (16.41)
AI Utilization (X2)	100	13.00	120.00	99.08 (17.46)

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PBL Optimization (Y)	100	24.00	120.00	105.72 (14.14)

Source: Primary Data (SPSS, 2025)

The descriptive findings on self-directed learning indicate that students exhibit a high level of learning autonomy, with the highest scores observed in time management and self-reflection. Most respondents reported proactively preparing for lectures before class, reviewing materials, and creating structured study plans. In terms of AI utilization, students widely employ tools such as ChatGPT, Gemini, Grammarly, and Canva to support report writing, idea generation, and presentation design. However, approximately 25% of respondents acknowledged limited ability to use AI critically and ethically. Regarding PBL optimization, students generally engaged actively in every stage of projects—from planning through evaluation—and reported improvements in collaboration, communication, and problem-solving skills.

Classical Assumption Tests

The normality test using the One-Sample Kolmogorov-Smirnov method yielded an Asymp. Sig. (2-tailed) value of 0.200 (> 0.05), indicating that the data are normally distributed. The multicollinearity test revealed Tolerance values of 0.637 (> 0.10) and VIF values of 1.569 (< 10) for both independent variables, confirming the absence of multicollinearity. The heteroscedasticity test using the scatterplot method showed that residuals are randomly scattered above and below zero with no systematic pattern, confirming the absence of heteroscedasticity. All classical assumptions are satisfied, validating the use of multiple linear regression.

Table 3. Classical Assumption Test Results Summary

Test	Result	Conclusion
Normality (K-S)	Asymp. Sig. = 0.200 > 0.05	Data normally distributed
Multicollinearity	Tolerance = 0.637 > 0.10; VIF = 1.569 < 10	No multicollinearity
Heteroscedasticity	Random residual scatter (Scatterplot)	No heteroscedasticity

Source: Primary Data (SPSS, 2025)

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Multiple Linear Regression Analysis

The multiple linear regression equation obtained from the analysis is:

Y = 8926.076 + 0.554 X1 + 0.269 X2

The constant value of 8926.076 indicates that in the absence of changes in self-directed learning (X1) and AI utilization (X2), PBL optimization has a base value of 8926.076. The regression coefficient for self-directed learning of 0.554 signifies that a one-unit increase in self-directed learning will increase PBL optimization by 0.554 units, holding AI utilization constant. Similarly, the coefficient for AI utilization of 0.269 indicates that a one-unit increase in AI utilization will increase PBL optimization by 0.269 units, holding self-directed learning constant.

Table 4. Multiple Linear Regression, F-Test, t-Test, and R^2 Results

Variable / Test	Coefficient (B)	t / F value	Sig.	Conclusion
Constant	8926.076	2.706	0.008	—
Self-Directed Learning (X1)	0.554 (β = 0.544)	6.368	0.000	H1 Supported (positive & significant)
AI Utilization (X2)	0.269 (β = 0.272)	3.180	0.002	H2 Supported (positive & significant)
F-test (Simultaneous)	—	58.888	0.000	H3 Supported (simultaneous influence)
R^2 (Coefficient of Determination)	—	—	—	R^2 = 0.548; Adj. R^2 = 0.539

Source: Primary Data (SPSS, 2025)

Hypothesis Testing

The simultaneous F-test produced an F-count of 58.888 (> F-table of 3.090) with a significance value of 0.000 (< 0.05), confirming that self-directed learning and AI utilization jointly and significantly influence PBL optimization (H3 accepted).

For the partial t-test with a t-table value of 1.661 (df = 97, α = 0.05): (1) Self-directed learning (X1) yielded a t-count of 6.368 (> 1.661) with a significance of 0.000 (< 0.05), confirming a positive and significant partial influence on PBL optimization (H1 accepted);

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(2) AI utilization (X2) yielded a t-count of 3.180 (> 1.661) with a significance of 0.002 (< 0.05), also confirming a positive and significant partial influence (H2 accepted).

The coefficient of determination revealed an R^2 value of 0.548, indicating that self-directed learning and AI utilization jointly explain 54.8% of the variance in PBL optimization. The remaining 45.2% is attributable to other variables not included in this model.

DISCUSSION

Influence of Self-Directed Learning on PBL Optimization

The finding that self-directed learning positively and significantly influences PBL optimization is consistent with Zimmerman's (2002) Self-Regulated Learning theory, which posits that students with high autonomy are more capable of regulating their learning strategies, managing time, and reflectively evaluating their learning outcomes. In the PBL context, self-directed students demonstrate greater proficiency in determining project completion strategies, managing roles within teams, and conducting independent research using digital resources. This result also aligns with Broadbent and Poon (2015), who confirmed that self-directed learning makes a substantial contribution to academic success, particularly in online and collaborative learning environments.

The qualitative evidence from open-ended questionnaire responses reveals that students with high self-directed learning tend to prepare materials before lectures, keep structured notes, and actively monitor their own learning progress. However, reflective practices tend to be shallow—students evaluate final outcomes rather than deeply reflecting on and improving their learning process. This suggests that while self-directed learning is relatively well-developed in terms of planning and monitoring, the reflective evaluation component still requires strengthening.

Influence of AI Utilization on PBL Optimization

The finding that AI utilization positively and significantly influences PBL optimization supports Holmes et al. (2019), who stated that AI has the potential to transform learning into a more personalized and adaptive experience. Luckin et al. (2016) also emphasized that AI can enhance students' metacognitive and reflective abilities through rapid and specific automated feedback.

In practice, students primarily utilize ChatGPT, Gemini, Grammarly, and Canva for report compilation, information retrieval, idea development, and presentation design. AI functions as an efficient learning assistant, accelerating project completion and

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broadening access to information. However, open-ended responses indicate that AI use tends to be instrumental rather than cognitively deep—students more often use AI to obtain quick answers rather than to stimulate critical thinking or independent idea exploration. This echoes Selwyn's (2019) concern about the risk of over-dependence on technology reducing students' critical and creative capacities.

Simultaneous Influence and Implications

The simultaneous influence of self-directed learning and AI utilization on PBL optimization reinforces the constructivist learning perspective, where effective learning occurs when students actively build their own knowledge by leveraging rich and adaptive digital learning resources. Students who are self-directed will use AI not as a substitute for thinking, but as a tool to expand knowledge, accelerate analysis, and enhance project quality.

These findings point to several key implications. For students, it is essential to use AI critically and ethically as a complement to independent thinking rather than a replacement for it, and to engage in deeper self-reflection beyond simply evaluating final outputs. For lecturers, the role of facilitator should be strengthened by integrating AI into teaching and providing ethical guidelines for its use—for instance, through AI-facilitated reflective journals or structured discussion activities. For institutional management, curriculum development should move toward an AI-supported PBL model, accompanied by the provision of digital infrastructure and literacy training to ensure equitable access and competent use of AI tools.

The study also identified key enablers and barriers to the integration of AI and self-directed learning in PBL. Enablers include students' existing motivation for self-directed learning, the user-friendliness and accessibility of AI platforms, the collaborative nature of PBL, and AI's ability to accelerate information retrieval and report writing. Barriers include over-dependence on AI as a shortcut, insufficient critical digital literacy among some students, superficial self-reflection practices, and coordination challenges within PBL teams resulting in unequal contribution.

CONCLUSION

This study concludes that both self-directed learning and AI utilization exert a positive and significant influence on PBL optimization—both partially and simultaneously—among students in the Business Administration Department of Politeknik Negeri Semarang. Self-directed learning is the more dominant factor,

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accounting for the greater portion of explained variance, while AI utilization plays a supportive role in enhancing learning efficiency and productivity.

Together, the two variables explain 54.8% of the variance in PBL optimization ($R^2 = 0.548$), with the remaining 45.2% attributable to other variables outside this model, such as the quality of lecturers' facilitation, digital infrastructure, institutional culture, and student characteristics.

The integration of self-directed learning and AI in a PBL environment creates a synergistic effect that fosters creativity, collaboration, and learning efficiency in the digital era. This model is recommended as an approach for vocational education curriculum development—emphasizing not only technological competency but also the metacognitive and ethical dimensions of learning in the digital age.

Future research is encouraged to expand the sample size to encompass multiple study programs or polytechnics, and to incorporate additional variables such as the quality of lecturers' facilitation, digital technology infrastructure, and organizational learning culture, in order to obtain a more comprehensive understanding of the factors shaping PBL effectiveness in vocational higher education.

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