Indonesian Journal of Educational Development (IJED)
Volume 7, Issue 1, 2026, pp. 49-64
ISSN: 2722-1059 (Online); ISSN: 2722-3671 (Print)
DOI: https://doi.org/10.59672/ijed.v7i1.6145

The effect of AI-Optimized project-based learning on digital pedagogical readiness

Hariyono*)[1], Umi Hidayati[2], Suharto[3]
[1]Universitas Nusantara PGRI Kediri, Kediri, Indonesia; hariyono@unpkdr.ac.id
[2]Universitas PGRI Mpu Sindok, Nganjuk, Indonesia; umihidayati@upms.ac.id
[3]Universitas PGRI Mpu Sindok, Nganjuk, Indonesia; suharto@upms.ac.id
*)Corresponding author: Hariyono; E-mail addresses: hariyono@unpkdr.ac.id

Article Info

Article history:
Received February 09, 2026
Revised March 28, 2026
Accepted April 06, 2026
Available online May 20, 2026

Keywords: Artificial intelligence in education, Digital pedagogical readiness, Higher education learning innovation, Project-based learning

Abstract. The integration of artificial intelligence (AI) in higher education has increased the demand for students' digital pedagogical readiness, particularly in economics education. This study examines the effect of AI-Optimized Project-Based Learning (AI-PjBL) on Digital Pedagogical Readiness (DPR) among undergraduate students. A quantitative approach was employed, involving 102 undergraduate students from the Economics Education and Management programs at Universitas Nusantara PGRI Kediri, using a purposive sampling technique. Data were collected using validated instruments and analyzed using Structural Equation Modeling–Partial Least Squares (SEM-PLS). The measurement model demonstrated strong reliability and validity, with factor loadings ranging from 0.77 to 0.90, Composite reliability values above 0.96, and Average Variance Extracted exceeding 0.67. Structural model analysis revealed that AI-PjBL had a strong and significant effect on DPR, indicated by a path coefficient of $\beta = 0.79$. The coefficient of determination ($R^2 = 0.63$) indicates that 63% of the variance in digital pedagogical readiness is explained by AI-PjBL, while the effect size ($f^2 = 1.52$) indicates a very large effect. These findings indicate that AI-PjBL effectively enhances students' technological readiness, pedagogical design ability, and reflective digital competence. The study highlights AI-PjBL as a promising instructional approach for strengthening digital pedagogy in economics education.

Introduction

The rapid expansion of artificial intelligence (AI) in higher education has reshaped how students learn; however, recent empirical evidence indicates that many students still demonstrate limited digital pedagogical readiness in applying technology for meaningful learning processes (Ghnemat et al., 2022). This transformation is particularly evident in pedagogical models that rely on active and inquiry-centered learning, such as Project-Based Learning (Marta et al., 2024). The swift advancement of digital technology has profoundly transformed educational methods in higher education worldwide. Among the most impactful technological breakthroughs in recent times is artificial intelligence (AI), which has been increasingly incorporated into educational settings to enhance instructional design, adaptive learning systems, and personalized feedback mechanisms (Xia, 2022). Technologies in artificial intelligence, including machine learning, intelligent tutoring systems, and generative AI applications, are being extensively investigated to enhance learning effectiveness and support data-driven decisions in education (Zawacki-Richter et al., 2019). Recent

advancements in technology have prompted universities to revamp their learning environments, allowing students to acquire not only subject-specific knowledge but also the digital skills necessary to thrive in technology-enhanced educational settings (Haryanto et al., 2026; Widana, 2020).

The incorporation of artificial intelligence into higher education has opened new opportunities to enhance teaching quality and boost student engagement in learning activities. AI-driven educational systems can offer personalized learning paths, intelligent feedback, and automated assessment tools that facilitate more efficient learning processes (Chen et al., 2020). Research indicates that AI-powered educational systems can boost students' cognitive engagement, support self-directed learning, and enhance knowledge retention through adaptive learning technologies (Kasneci et al., 2023). Moreover, incorporating artificial intelligence into education facilitates the development of learning environments that adapt to students' needs, thereby enhancing the effectiveness of their learning experiences (Sumandya et al., 2026).

While artificial intelligence holds great promise for education, the effective use of AI-enhanced learning environments is largely contingent on students' proficiency with digital technologies in educational settings. Consequently, the notion of digital pedagogical readiness has gained significant traction in modern educational research. This concept pertains to learners' capacity to incorporate digital tools into instructional design, learning facilitation, and knowledge construction (Wilson et al., 2020). Students with a high level of digital pedagogical readiness are better equipped to create digital learning resources, lead collaborative online learning sessions, and employ digital tools to enhance meaningful knowledge building.

Nonetheless, studies have shown that many university students continue to encounter difficulties integrating digital technologies into educational settings. Even though they are often well-acquainted with digital devices and online platforms, their proficiency in using these technologies for learning remains somewhat limited (García-Rico et al., 2021). Research has shown that students' digital skills often focus more on operational abilities than on their application in teaching, highlighting a disconnect between being technologically adept and being prepared for pedagogical use (Schmid et al., 2020; Gulo et al., 2026). This scenario indicates that institutions of higher learning should create educational strategies that not only introduce students to digital technologies but also equip them with the teaching skills necessary to effectively apply these technologies in educational settings.

Project-Based Learning (PBL) is an instructional method that has gained widespread recognition for fostering active learning and student involvement. This approach focuses on student-centered learning, in which participants explore real-world issues and devise solutions through collaborative project work (Kokotsaki et al., 2016). This teaching method promotes inquiry-based learning, encouraging students to examine issues, devise innovative solutions, and achieve significant educational outcomes. Studies have shown that project-based learning can significantly improve students' critical thinking, problem-solving, and collaborative learning skills (Jaleniauskienė & Venckienė, 2025).

Project-based learning is regarded as an effective approach to enhancing students' digital skills, as it involves using digital tools to collect information, analyze data, and present knowledge (Cespedes, 2025). When students engage in intricate projects, they are required to incorporate a range of digital tools to complete their tasks, which naturally fosters the development of digital literacy and technological skills. Additionally, project-based learning settings offer students the opportunity to collaborate via digital platforms, thereby enhancing their proficiency in using digital technologies for communication and knowledge exchange (Mosquera-Gende, 2025).

In recent times, the incorporation of artificial intelligence into project-based learning settings has become a novel educational strategy in higher education. AI-Enhanced Project-Based Learning is a model in which AI tools are embedded within the project-based learning framework to aid in generating ideas, analyzing information, offering feedback, and reflecting on learning (Su et al., 2022). AI technologies can help students locate relevant educational resources, generate innovative project concepts, and assess learning outcomes through smart feedback mechanisms (Zawacki-Richter et al., 2019). By incorporating this approach, students can engage in a livelier, more interactive educational setting, fostering deeper engagement with their learning activities.

Studies on artificial intelligence in education have indicated that AI-assisted learning environments can enhance students' higher-order thinking abilities and improve learning outcomes when implemented effectively (Zawacki-Richter et al., 2019). AI-driven educational systems enable students to receive tailored feedback, analyze learning data, and adjust their learning approaches based on their performance. These features make artificial intelligence an effective tool for facilitating intricate learning processes, such as project-based learning, which demands ongoing feedback and iterative enhancements throughout project development (Botsieva et al., 2024).

Moreover, a number of recent studies have emphasized the impact of artificial intelligence on enhancing collaborative learning and fostering creative problem-solving in educational settings (Hariyono, 2023; Koper & Burgos, 2005). Collaborative learning environments supported by AI enable students to exchange knowledge, work together to analyze information, and develop innovative solutions to complex challenges. These environments are especially important in project-based learning contexts, where teamwork and the joint construction of knowledge are crucial elements of the educational experience.

While both artificial intelligence and project-based learning have been extensively explored, empirical studies have examined the integration of AI-optimized project-based learning to enhance students' digital pedagogical readiness. Most prior research has either examined artificial intelligence as a standalone educational tool or focused on project-based learning as an independent teaching method (Azizan et al., 2025). As a result, empirical data on the impact of incorporating artificial intelligence into project-based learning settings on students' readiness for digital pedagogy are scarce.

The identified research gap underscores the need to explore AI-optimized Project-Based Learning as a novel pedagogical approach that integrates adaptive AI capabilities into project-based learning to enhance digital pedagogical readiness. Grasping the connection between AI-Optimized Project-Based Learning and Digital Pedagogical Readiness is especially crucial for higher education institutions that aim to equip students for the digital transformation in education (Ruiz Viruel et al., 2025). There is a growing expectation that universities produce graduates who can effectively integrate digital technologies into both professional and educational settings, particularly in areas related to education and knowledge dissemination.

Within Indonesian higher education, efforts toward digital transformation have prompted universities to incorporate digital technologies into their teaching. This integration aims to elevate educational quality and bolster students' digital skills (Mejeh et al., 2024; Prosen & Ličen, 2025). For digital learning innovations to be implemented successfully, it is essential for students to have sufficient digital pedagogical readiness. Lacking this readiness, students might struggle to effectively use digital technologies for both learning and teaching.

The model assumes that students participating in AI-PjBL will demonstrate higher levels of digital competence due to AI's affordances for adaptive learning, knowledge construction, and reflective

improvement. This aligns with contemporary theoretical discussions suggesting that AI-enabled learning environments foster deeper cognitive engagement, personalized scaffolding, and improved decision-making in digital learning design (Chandrasekera et al., 2024).

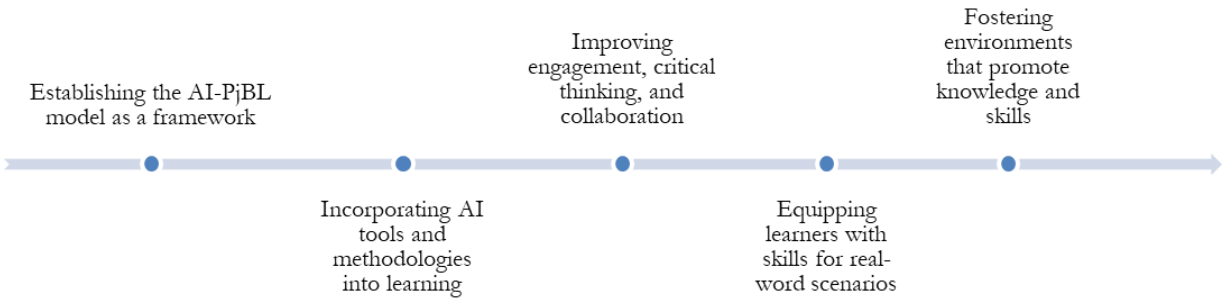

Image 1. Conceptual Framework AI-Optimized Project-Based Learning Model

This research investigates how AI-Optimized Project-Based Learning impacts students' Digital Pedagogical Readiness. It aims to examine the causal relationship between these variables, with the hypothesis that AI-optimized Project-Based Learning significantly enhances students' digital pedagogical readiness. The study targets students from the Faculty of Economics and Business at Universitas Nusantara PGRI Kediri who engage in technology-enhanced learning settings. Utilizing a quantitative research methodology with Structural Equation Modelling through the Partial Least Squares approach, this study aims to offer empirical insights into the influence of AI-supported project-based learning environments on students' preparedness to incorporate digital technologies into teaching practices (Kurniawan et al., 2025; Ruiz Viruel et al., 2025).

This study's outcomes are expected to inform the development of novel learning strategies that incorporate artificial intelligence into higher education settings. Additionally, the study's results might offer valuable insights for educators and academic institutions in crafting learning models that enhance students' digital teaching skills amid the digital transformation.

Method

This research employed a quantitative survey design to explore the relationship between AI-Optimized Project-Based Learning and Digital Pedagogical Readiness among university students. Quantitative methods are commonly employed in educational research to explore the relationships between variables and to validate theoretical models through statistical analysis (Joseph et al., 2024; Ruiz Viruel et al., 2025). By employing a quantitative design, this study enables the researcher to investigate the cause-and-effect relationship between the independent and dependent variables by analyzing empirical data gathered from participants.

Research Design

This study employs an explanatory research design to clarify causal relationships among variables by testing hypotheses. This type of research is typically used to evaluate theoretical models and assess the extent of influence among variables within a structured analytical framework (Vázquez-Parra et al., 2024; Wayan Santyasa et al., 2021). In this study, AI-Optimized Project-Based Learning was the independent variable, whereas Digital Pedagogical Readiness was the dependent variable. The research framework suggests that incorporating AI-enhanced project-based learning activities enhances students' preparedness to use digital technologies in educational settings.

Population and Sample

The study's participants were undergraduate students from the Faculty of Economics and Business at Universitas Nusantara PGRI Kediri who were enrolled in courses that incorporated digital learning activities. These students were chosen due to their active participation in educational settings that employ digital technologies and project-based learning as integral components of their academic experience.

In this study, 102 students participated. The sample was selected using purposive sampling, in which individuals were selected based on specific criteria relevant to the study's aims. The selection criteria included students who had completed coursework integrating digital technology and project-based learning. Purposive sampling is frequently used in educational research to select participants who are relevant to the research goals and have experience with the phenomena under investigation.

Utilizing 102 participants is deemed sufficient for conducting analysis with Structural Equation Modelling using the Partial Least Squares method. PLS-SEM is particularly appropriate for research with smaller sample sizes and exploratory models, as it aims to maximize explained variance and does not require stringent assumptions about data distribution (Zhan et al., 2024).

Research Instrument

In this study, data were gathered using a structured questionnaire to assess students' views on AI-Optimized Project-Based Learning and their Digital Pedagogical Readiness. The questionnaire employed a five-point Likert scale, with options ranging from 1 (strongly disagree) to 5 (strongly agree). Likert scales are commonly used in educational and social science research because they enable researchers to systematically and quantitatively assess respondents' attitudes and perceptions toward specific constructs.

The study employed an instrument comprising various indicators that represent the two primary variables. The AI-Optimized Project-Based Learning variable assesses the extent to which artificial intelligence tools are incorporated into project-based learning activities to support idea generation, information analysis, teamwork, and reflection. On the other hand, the Digital Pedagogical Readiness variable evaluates students' capability to create digital learning strategies, use digital learning tools, and incorporate technology into teaching practices.

Prior to performing the primary analysis, the research tool underwent validity and reliability assessments to confirm that the measurement indicators accurately reflect the constructs under investigation. In PLS-SEM analysis, construct validity and reliability are typically evaluated using indicators such as factor loadings, composite reliability, and average variance extracted (AVE) (Khosasih & Lisana, 2023).

Measurement Indicators

This study's measurement indicators were derived from earlier research on digital learning environments and technology-enhanced teaching methods. The indicators for the AI-Optimized Project-Based Learning variable encompass various aspects of AI integration in project-based learning settings, such as using AI tools to generate ideas, explore information, support collaborative learning, and evaluate projects. These indicators demonstrate how artificial intelligence can improve student engagement and learning during project-based activities.

The Digital Pedagogical Readiness variable comprises indicators that assess students' preparedness to use digital technologies in educational settings. These indicators encompass students' skills in creating digital learning activities, using digital learning platforms, assessing digital learning

resources, and effectively incorporating technology into learning processes. Evaluating digital pedagogical readiness demonstrates students' ability to use digital technologies not just for accessing information but also for significant pedagogical applications in educational environments.

Data Analysis Technique

The study's data were examined using Structural Equation Modeling with Partial Least Squares (PLS-SEM) in SmartPLS. PLS-SEM is a popular choice in social science research because it enables the analysis of intricate relationships between latent variables while also assessing both measurement and structural models simultaneously (Chinnaraju, 2025; Herwin et al., 2022; Yanuarto et al., 2024). This method of analysis is especially suitable for exploratory studies and predictive modeling, where the main goal is to account for variations in dependent variables.

The analysis process in this study involved two primary phases: assessing the measurement model (outer model) and evaluating the structural model (inner model). The purpose of evaluating the measurement model was to determine the validity and reliability of the measurement indicators. Indicators were deemed valid if their factor loadings exceeded the recommended threshold of 0.70, indicating that the indicators effectively represent the latent constructs being measured (Musyaffi et al., 2024). To confirm that the constructs exhibit internal consistency, reliability was evaluated using Composite reliability and Average Variance Extracted (AVE) metrics.

The assessment of the structural model examined the relationships between the independent and dependent variables within the research framework. This assessment included analyses of the path coefficient, the coefficient of determination (R^2), and the significance values derived from bootstrapping. The path coefficient reveals the strength and direction of the relationship between the variables, while the R^2 value indicates the proportion of variance in the dependent variable that the independent variable can account for. Hypothesis testing was performed by evaluating the t-statistics and p-values from the bootstrapping results, with a p-value below 0.05 signifying a statistically significant relationship between the variables (Ekayana et al., 2025).

By employing this analytical method, the research seeks to provide empirical evidence of the impact of AI-Optimized Project-Based Learning on students' readiness for digital pedagogy. Utilizing PLS-SEM enables the researcher to examine intricate relationships among constructs and gain a thorough understanding of how AI-enhanced learning settings support the development of digital pedagogical skills among university students.

Results and Discussion

Descriptive Statistics of Respondents

A total of 102 students participated in the study, consisting of Economics Education and Management majors from the Faculty of Economics and Business at Universitas Nusantara PGRI Kediri. Table 1 presents the respondents' characteristics.

Table 1. Respondent Characteristics

Variable	Category	Frequency	Percentage
Study Program	Economics Education	54	52.9%
	Management	48	47.1%
Gender	Female	63	61.8%
	Male	39	38.2%
Age	18–19	44	43.1%
	20–22	58	56.9%

These distributions reflect a balanced representation of both programs, allowing for appropriate generalization to undergraduate students within the same faculty.

Descriptive Statistics of Constructs and Indicators

Table 2 presents the descriptive statistics for the latent constructs, AI-optimized PjBL, and Digital Pedagogical Readiness (DPR). Both constructs fell within the "good to outstanding" category.

Table 2. Descriptive Statistics of Constructs

Construct	Mean	SD	Min	Max
AI-PjBL	3.94	0.55	2.27	5.00
DPR	3.97	0.58	2.75	5.00

Individual item scores also showed strong central tendencies, with most values concentrated in the 4–5 range, confirming that the implementation of AI-PjBL was perceived as highly positive.

Measurement Model Evaluation (Outer Model)

The measurement model was evaluated to determine the reliability and validity of the constructs within the research framework. SmartPLS software was utilized to analyze the connections between indicators and their corresponding latent variables. The findings reveal that all indicators employed in this study exhibit satisfactory measurement characteristics.

Table 3. Outer Model (Loadings, CR, AVE, Alpha)

Construct	Loadings Range	CR	AVE	Cronbach's α
AI-PjBL	0.77–0.87	0.969	0.679	0.966
DPR	0.79–0.90	0.968	0.716	0.963

The HTMT value was 0.806, which is well below the conservative threshold of 0.85, indicating good discriminant validity between AI-PjBL and DPR.

The SmartPLS analysis reveals that all indicators have loading factor values surpassing the recommended threshold of 0.70. This finding suggests a strong correlation between the indicators and their respective latent constructs within the measurement model. The high loading factor values imply that the indicators effectively represent the constructs and play a significant role in elucidating the theoretical concepts underlying this study.

The assessment of the measurement model reveals that the indicators employed for each construct exhibit strong consistency in representing their respective latent variables. Indicators with high loading values confirm that the measurement items effectively capture the conceptual essence of the constructs under investigation. As a result, the measurement model robustly supports the validity of the indicators used to assess AI-Optimized Project-Based Learning and Digital Pedagogical Readiness.

To further assess convergent validity, the Average Variance Extracted (AVE) was utilized. The findings reveal that the AVE values for all constructs surpass the suggested minimum threshold of 0.50. This result suggests that the constructs in the research model can account for more than half of the variance in their respective indicators. Elevated AVE values indicate that the indicators share substantial variance in their representation of the constructs, confirming sufficient convergent validity of the measurement model.

In addition to evaluating convergent validity, construct reliability was assessed using Composite reliability values derived from the SmartPLS analysis. The findings reveal that all constructs possess composite reliability values exceeding the recommended threshold of 0.70. This demonstrates that the indicators employed in the measurement model exhibit high internal consistency in assessing the latent constructs. High composite reliability values imply that the measurement items consistently reflect the theoretical constructs included in the research model.

The evaluation of the measurement model indicates that the constructs utilized in this study satisfy the suggested standards for both validity and reliability. Consequently, the measurement model is deemed suitable for further examination of the structural relationships among the constructs featured in the research model.

Structural Model Evaluation (Inner Model)

Once the measurement model's adequacy was confirmed, the next step was to assess the structural model to examine the relationships among the latent constructs. The purpose of analyzing the structural model is to evaluate the extent to which AI-Optimized Project-Based Learning affects students' readiness for digital pedagogy.

Structural model evaluation revealed that AI-optimized PjBL had a strong, positive, and substantial effect on Digital Pedagogical Readiness.

Table 4. Structural Model Results

Path	β	R^2	f^2
AI-PjBL → DPR	0.79	0.63	1.52

The coefficient of determination ($R^2 = 0.63$) indicates that AI-PjBL explains 63% of the variance in DPR, which is considered strong in social science research. The effect size ($f^2 = 1.52$) far exceeded the threshold for a "large" effect (Cohen, 0.35), demonstrating the extreme predictive power of AI-PjBL on DPR. Bootstrapping with 5,000 subsamples confirmed the statistical significance of path coefficients ($p < 0.001$).

The SmartPLS analysis results reveal a positive and statistically significant path coefficient between AI-Optimized Project-Based Learning and Digital Pedagogical Readiness. With a path coefficient of 0.791, there is a strong positive correlation between these two constructs. This indicates that implementing AI-Optimized Project-Based Learning is crucial for enhancing students' preparedness to use digital technologies in educational settings.

The assessment of the structural model reveals substantial statistical support for the relationship between AI-Optimized Project-Based Learning and Digital Pedagogical Readiness. The importance of the path coefficient underscores that incorporating artificial intelligence tools into project-based learning can significantly enhance students' digital pedagogical skills.

The findings also suggest that students engaged in AI-enhanced project-based learning activities are more prepared to create digital learning strategies, incorporate digital technologies into educational tasks, and assess digital learning outcomes effectively. These results underscore the significant role of innovative teaching models in fostering the development of digital skills in higher education.

Structural Model Visualization

To strengthen the interpretation, the structural model is visualized in Image 2, which shows the direct effect of AI-optimized PjBL on DPR.

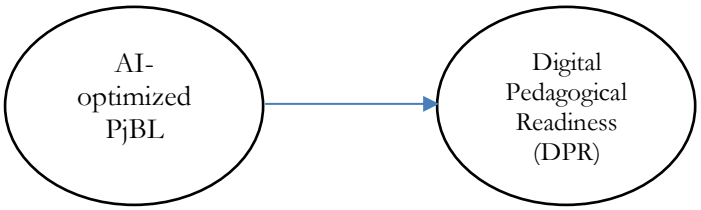

Image 2. Structural Model (AI-PjBL → DPR)

This image shows the single direct path with β = 0.79 and R^2 = 0.63 within the endogenous construct, consistent with conventional SEM-PLS notation.

Structural Model with Indicators

For complete clarity, image 3 presents an expanded SEM model with constructs and their respective dimensions.

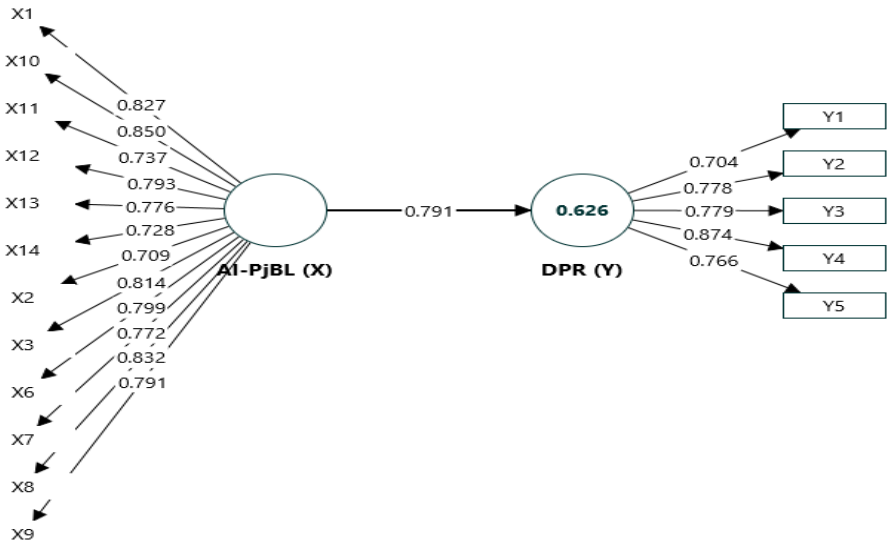

Image 3. SEM with Indicators (ASP, AGF, AEC, ASC, ARA → DPR Dimensions)

This visualization illustrates how each dimension contributes to the formation of the latent constructs of AI-PjBL and DPR, supporting the interpretation of the measurement model.

The results of this study demonstrate that AI-Optimized Project-Based Learning has a strong influence on Digital Pedagogical Readiness, which is consistent with previous studies indicating that AI-supported learning enhances engagement and digital competence. The structural model showed a path coefficient of β = 0.79, indicating that AI-PjBL plays a substantial role in shaping students' technological, cognitive, and pedagogical capabilities in digital learning environments. This finding aligns with recent work by Mustafa, who emphasized that AI-supported learning systems provide personalized scaffolding, automated feedback, and adaptive guidance that significantly improve student performance and digital confidence.

The high R^2 value of 0.63 further confirms that AI-PjBL accounts for a substantial proportion of the variance in students' DPR, suggesting that AI-enriched learning activities help students engage more deeply in digital learning processes. This is consistent with the argument by Suraworachet et al., who found that digital learning analytics and AI-generated guidance foster students' reflective

and self-regulated digital-learning behaviors. In this study, the strong contribution of the AI-based Reflection & Analytics (ARA) dimension reinforces the assertion that reflective digital competence is strengthened when students can analyze their learning data through dashboards and AI-generated insights.

Moreover, the large effect size ($f^2 = 1.52$) underscores the substantial impact of AI-PjBL, exceeding the typical effect sizes reported in digital pedagogy research. This demonstrates that AI integration is not merely supportive but transformative, enhancing students' ability to utilize digital tools, analyze digital content, and design pedagogically meaningful digital learning experiences. This finding builds on Akinnagbe's conceptual discussions, which argued that AI-based tools can stimulate creativity, support decision-making, and refine project outputs. In our context, indicators linked to AI-Enhanced Creativity (AEC) and AI-Supported Collaboration (ASC) were consistently strong, indicating that AI enabled students to create more innovative economic learning projects and collaborate more efficiently.

Coefficient of Determination (R^2)

The structural model's explanatory power was assessed through the coefficient of determination (R^2). The findings reveal that the R^2 value for the Digital Pedagogical Readiness construct stands at 0.626. This suggests that the AI-Optimized Project-Based Learning variable in the research model accounts for about 62.6% of the variance in students' Digital Pedagogical Readiness.

The R^2 value derived from this research indicates that the proposed model effectively explains students' digital pedagogical readiness. This result highlights the significant impact of implementing AI-supported project-based learning strategies on students' preparedness to participate in technology-enhanced teaching practices.

The analysis's coefficient of determination indicates that the proposed model effectively captures the impact of instructional innovation on students' preparedness to incorporate digital technologies into educational settings. The findings affirm that AI-Optimized Project-Based Learning is a crucial instructional strategy that fosters the development of digital skills among students in higher education.

Discussion

The results of this research indicate that AI-Optimized Project-Based Learning significantly impacts students' readiness for digital pedagogy. Unlike prior studies, this research emphasizes integrating AI optimization into project-based learning to enable adaptive, data-driven, and personalized learning experiences. The positive correlation found in the structural model suggests that incorporating artificial intelligence tools into project-based learning activities offers valuable opportunities for students to acquire the skills necessary to use digital technologies in educational settings. The findings reveal that students who engage in AI-enhanced project-based learning activities are better equipped to develop digital learning strategies, incorporate digital tools into their teaching, and assess digital learning outcomes effectively. These results underscore the importance of merging innovative learning models with new technologies to enhance students' digital pedagogical skills in higher education.

The beneficial link between AI-enhanced learning settings and digital teaching preparedness aligns with growing research highlighting the transformative impact of artificial intelligence on education. AI technologies are increasingly acknowledged as tools that can boost educational processes by offering adaptive learning assistance, intelligent tutoring systems, and personalized feedback mechanisms, all of which enhance learning efficiency (Asnawi, 2023; Jose & Binu, 2025). AI systems' ability to analyze learner data and provide immediate suggestions enables students to

immerse themselves more deeply in educational activities while also acquiring the digital skills essential for contemporary learning environments.

This study's results further highlight the educational advantages of project-based learning in higher education settings. This approach motivates students to investigate real-world issues, work together with classmates, and build knowledge through genuine learning experiences. Such environments foster active learning and inspire students to take charge of their educational journey. Prior research has consistently shown that project-based learning improves students' critical thinking, problem-solving skills, and ability to work collaboratively (Li et al., 2025; Patel & Lim, 2025). To achieve digital pedagogical readiness, it is crucial to possess these skills, as successfully incorporating digital technologies into education demands both technological expertise and a solid grasp of pedagogical principles.

Beyond the educational benefits of project-based learning, incorporating artificial intelligence tools enhances the learning experience by supporting students throughout the various phases of project creation. AI technologies can help students brainstorm ideas, locate pertinent information, analyze project data, and assess learning outcomes. Additionally, AI-driven systems can offer automated feedback, enabling students to refine their work and elevate the quality of their project results (Hamid et al., 2024; Qodariah & Arifin, 2023). This ongoing feedback system allows students to participate in repeated learning cycles, which are crucial for fostering deeper comprehension and encouraging reflective learning habits.

One significant takeaway from this research is that AI-enhanced project-based learning environments foster students' digital literacy and technological problem-solving abilities. Engaging with artificial intelligence tools during project creation requires students to assess digital information sources, interpret algorithm-generated outputs, and make informed decisions about the use of digital tools in educational activities. These experiences enable students to critically evaluate digital resources and apply technology in pedagogically meaningful ways. This process plays a crucial role in building digital pedagogical readiness, as students not only learn to use digital technologies but also how to implement them effectively in educational settings.

Moreover, the relatively high coefficient of determination found in this study demonstrates that AI-Optimized Project-Based Learning accounts for a significant portion of the variation in students' digital pedagogical readiness. This implies that educational settings that incorporate artificial intelligence tools alongside student-focused teaching methods offer valuable opportunities for enhancing digital skills. The results of this study align with earlier research showing that technology-enhanced learning environments can greatly improve students' preparedness for digital learning activities (Karchmer-Klein et al., 2017; Sudarwati & Prianto, 2025).

The findings of this research emphasize the significance of artificial intelligence in facilitating self-directed learning among students. AI-driven educational systems can provide immediate performance feedback and tailored suggestions, enabling students to track their learning progress and adjust their strategies as needed. These learning environments promote greater student accountability for their educational journey and foster reflective learning practices (DeCoito & Briona, 2023; DeFillippi, 2001). Self-regulated learning plays a crucial role in preparing for digital education, as it requires students to independently assess the effectiveness of digital tools and learning methods (Widana & Ratnaya, 2021).

This study highlights another crucial aspect concerning the collaborative construction of knowledge in technology-enhanced learning settings. In project-based learning, students are required to collaborate to design solutions, analyze issues, and generate project results. Digital

technologies and AI tools facilitate these collaborative efforts by allowing students to exchange information, communicate ideas, and jointly analyze data on digital platforms. Learning environments that incorporate digital technologies for collaboration have been shown to boost student engagement and foster deeper learning outcomes (Cosentino et al., 2025).

Beyond fostering collaboration, AI-assisted project-based learning significantly enhances students' higher-order cognitive abilities. Engaging with AI tools often requires students to interpret complex data, assess algorithm-generated suggestions, and make well-informed decisions about using digital resources. These cognitive tasks promote analytical thinking and critical reasoning, which are crucial for managing complex educational settings. Studies have indicated that technology-enhanced learning environments can cultivate higher-order thinking skills by prompting students to analyze data, integrate knowledge, and assess various solutions (Ali et al., 2023; Hsu & Wu, 2023).

These findings underscore the value of integrating AI tools into project-based learning to create adaptive, data-informed, and creativity-rich learning experiences. In economics education, such integration prepares future educators to navigate and design digital learning ecosystems with confidence and pedagogical insight. This model is a promising instructional approach for fostering digital competence in teacher education programmes. This study is limited by the use of a single institutional context and a relatively moderate sample size, which may affect the generalizability of the findings. Future research may extend this work by examining the model across different courses, incorporating mediating or moderating variables, and employing richer learning analytics data to deepen insights into students' digital readiness.

Moreover, incorporating artificial intelligence into project-based learning settings fosters student creativity and innovation. AI technologies enable students to tap into a variety of information sources, generate fresh ideas, and explore different methods for tackling complex issues. When these technological tools are paired with collaborative project-based learning activities, they motivate students to explore innovative solutions and enhance their creative thinking. These skills are becoming increasingly vital in today's professional settings, where digital innovation is a key factor in organizational growth.

This study also highlights the significant role educators play in creating AI-enhanced learning environments. While artificial intelligence technologies offer powerful learning tools, educators are crucial in guiding students through their educational journey. They need to design learning activities that incorporate AI tools in ways that align with educational goals and ensure that meaningful human interaction is maintained.

Conclusion

This study concludes that AI-optimized Project-Based Learning significantly enhances students' digital pedagogical readiness, particularly in economics education. The findings emphasize the importance of integrating adaptive and technology-based learning models in higher education to help students navigate increasingly digital learning environments. The analysis demonstrates that AI-enhanced project-based learning fosters students' ability to effectively utilize digital technologies in instructional contexts, while also strengthening their capacity to design, implement, and evaluate technology-integrated learning. Through AI-assisted project activities, students actively engage in collaborative problem-solving, explore digital learning resources more deeply, and develop essential competencies related to digital pedagogy. These experiences contribute to the formation of critical digital skills, including the ability to apply digital tools, construct digital learning strategies, and integrate technology meaningfully into teaching practices. Furthermore, the study highlights the

broader pedagogical value of AI integration in creating adaptive, data-informed, and creativity-driven learning environments that prepare future educators with confidence and professional insight. However, this study is limited by its focus on a single institutional context and a moderate sample scope, which may influence the generalizability of the findings. Therefore, future research is encouraged to explore broader educational contexts, incorporate additional variables, and examine the application of AI-enhanced learning models across diverse settings.

Acknowledgements

The authors gratefully acknowledge the support of the Research and Community Service Institute (LPPM) of Universitas Nusantara PGRI Kediri through the 2025 Institutional Research Stimulus Program. This support enabled the successful completion of the study. The authors also thank the participating students and colleagues for their valuable contributions and constructive academic feedback.

Bibliography

Ali, N., Santos, I. M., AlHakmani, R., Abu Khurma, O. A., Khine, M. S., & Kassem, U. (2023). Exploring technology acceptance: Teachers' perspectives on robotics in teaching and learning in the UAE. *Contemporary Educational Technology*, 15(4). https://doi.org/10.30935/cedtech/13646

Asnawi, A. (2023). Development of digital diagnostic test instruments for differentiated learning process in elementary schools. *Jurnal Penelitian Pendidikan IPA*. https://doi.org/10.29303/jppipa.v9ispecialissue.6125

Azizan, M. F., Mohd Matore, M. E. E., & Omar, M. (2025). A bibliometric analysis of complex problem-solving approaches in engineering education. *Journal of Applied Science, Engineering, Technology, and Education*, 7(1), 17–28. https://doi.org/10.35877/454RI.asci3846

Botsieva, N., Semenova, L., Khabekirova, Z., & Dzodzikova, F. (2024). Adaptive educational technologies for the formation of environmental awareness. *Reliability: Theory and Applications*, 19(Special issue 6), 1457–1463. https://doi.org/10.24412/1932-2321-2024-681-1457-1463

Cespedes, A. A. (2025). Teachers in transition: A qualitative exploration into the impact of emergency remote teaching on professional development. *International Journal of Educational Research*, 130. https://doi.org/10.1016/j.ijer.2025.102548

Chandrasekera, T., Hosseini, Z., Perera, U., & Bazhaw Hyscher, A. (2024). Generative artificial intelligence tools for diverse learning styles in design education. International Journal of Architectural Computing, 23(2), 358–369. https://doi.org/10.1177/14780771241287345

Chen, L., Chen, P., & Lin, Z. (2020). Artificial intelligence in education: A Review. *IEEE Access*, 8, 75264–75278. https://doi.org/10.1109/ACCESS.2020.2988510

Chinnaraju, A. (2025). Partial least squares structural equation modeling (PLS-SEM) in the AI Era: Innovative methodological guide and framework for business research. *Magna Scientia Advanced Research and Reviews*, 13(2), 62–108. https://doi.org/10.30574/msarr.2025.13.2.0048

Cosentino, G., Anton, J., Sharma, K., Gelsomini, M., Giannakos, M., & Abrahamson, D. (2025). Generative AI and multimodal data for educational feedback: Insights from embodied math learning. *British Journal of Educational Technology*, 56(5), 1686–1709. https://doi.org/10.1111/bjet.13587

DeCoito, I., & Briona, L. K. (2023). Fostering an entrepreneurial mindset through project-based learning and digital technologies in STEM teacher education. In Integrated Science (Vol. 15, pp. 195–222). *Springer Nature*. https://doi.org/10.1007/978-3-031-17816-0_9

DeFillippi, R. J. (2001). Introduction: Project-based learning, reflective practices, and learning. *In Management learning* (Vol. 32, Issue 1, pp. 5–10). Sage Publications Sage CA: Thousand Oaks, CA.

Ekayana, A. A. G., Parwati, N. N., Agustini, K., & Gede Ratnaya, I. G. (2025). Project-based learning framework with steam methodology assessed based on self-efficacy: Does it affect creative thinking skills and learning achievement in studying fundamental computers? *Journal of Technology and Science Education*, 15(1), 107–128. https://doi.org/10.3926/JOTSE.2751

García-Rico, L., Santos-Pastor, M. L., Martínez-Muñoz, L. F., & Ruiz-Montero, P. J. (2021). The development of professional aptitudes through university service-learning methodology in the sciences of physical activity and sports. *Teaching and Teacher Education*, 105. https://doi.org/10.1016/j.tate.2021.103402

Ghnemat, R., Al-Sowi, A. M., & Shaout, A. (2022). Higher education transformation for artificial intelligence revolution: Transformation framework. *International Journal of Emerging Technologies in Learning (IJET)*, 17(19), 224–241. https://doi.org/10.3991/ijet.v17i19.33309

Gulo, R. S., Niswanto, Ismail, & Handayani, N. (2026). Coaching-based academic supervision to enhance teachers' pedagogical competence. *Indonesian Journal of Educational Development (IJED)*, *6*(4), 1294–1305. https://doi.org/10.59672/ijed.v6i4.5683

Hamid, H., Muchsin, S. B., Maifa, T. S., & Wardani, A. K. (2024). Learning design: Hypothetical Learning Trajectory (HLT) for the concept of ratio to improve numeracy and creative thinking skills. In R. I. I. Putri, Hartono, R. Bos, K. Trundle, M. Shahrill, Meilinda, & D. Kurniawan (Eds.), *AIP Conference Proceedings*, *3052*(1). American Institute of Physics. https://doi.org/10.1063/5.0200997

Hariyono, H. (2023). Implementation of digital technology-based learning model to enhance student engagement and motivation in economics subject learning at high school. *EDUTEC : Journal of Education And Technology*, 7(2), 388–396. https://doi.org/10.29062/edu.v7i2.710

Haryanto, E., Hendra, R., Sembiring, D.A.E.P., Mukminin, A., Sadikin, A., Yusuf, M., Widana, I.W. Factors influencing technology integration of high school English teachers in Indonesia. *Discov Educ* (2026). https://doi.org/10.1007/s44217-026-01413-0

Herwin, H., Fathurrohman, F., Wuryandani, W., Dahalan, S. C., Suparlan, S., Firmansyah, F., & Kurniawati, K. (2022). Evaluation of structural and measurement models of student satisfaction in online learning. *International Journal of Evaluation and Research in Education*, 11(1), 152–160. https://doi.org/10.11591/ijere.v11i1.22115

Hsu, C.-Y., & Wu, T.-T. (2023). Application of business simulation games in flipped classrooms to facilitate student engagement and higher-order thinking skills for sustainable learning practices. *Sustainability (Switzerland)*, 15(24). https://doi.org/10.3390/su152416867

Jaleniauskienė, E., & Venckienė, D. (2025). Project-based language learning in higher education: A scoping review. *Interdisciplinary Journal of Problem-Based Learning*, 19(1). https://doi.org/10.14434/ijpbl.v19i1.35846

Jose, J., & Binu, B. P. (2025). Information technology students' perspectives on differentiated instruction and its impact on their learning approaches. *Journal of Education and Learning*, 19(4), 2033–2041. https://doi.org/10.11591/edulearn.v19i4.23085

Joseph, J., Jose, J., Jose, A. S., Ettaniyil, G. G., Cyriac, J., Sebastian, S. K., & Joseph, A. P. (2024). Quantitative insights into outcome-based education: A bibliometric exploration. *International Journal of Evaluation and Research in Education*, 13(6), 4030–4045. https://doi.org/10.11591/ijere.v13i6.29272

Karchmer-Klein, R., Mouza, C., Harlow Shinas, V., & Park, S. (2017). Patterns in teachers' instructional design when integrating apps in middle school content-area teaching. *Journal of Digital Learning in Teacher Education*, 33(3), 91–102. https://doi.org/10.1080/21532974.2017.1305305

Kasneci, E., Sessler, K., Küchemann, S., Bannert, M., Dementieva, D., Fischer, F., Gasser, U., Groh, G., Günnemann, S., Hüllermeier, E., Krusche, S., Kutyniok, G., Michaeli, T., Nerdel, C., Pfeffer, J., Poquet, O., Sailer, M., Schmidt, A., Seidel, T., … Kasneci, G. (2023). Chat GPT for good? On opportunities and challenges of large language models for education. *Learning and Individual Differences*, 103, 102274. https://doi.org/10.1016/j.lindif.2023.102274

Khosasih, M. M., & Lisana, L. (2023). Intention to adopt online food delivery using augmented reality mobile apps: A perspective of the SOR framework. *International Journal on Advanced Science, Engineering and Information Technology*, 13(2), 618–624. https://doi.org/10.18517/ijaseit.13.2.17245

Kokotsaki, D., Menzies, V., & Wiggins, A. (2016). Project-based learning: A review of the literature. *Improving Schools*, 19(3), 267–277.

Koper, R., & Burgos, D. (2005). Developing advanced units of learning using IMS learning design level b. advanced technology for learning. https://doi.org/10.2316/journal.208.2005.4.208-0868

Kurniawan, D., Masitoh, S., Bachri, B. S., Warman, W., Kamila, V. Z., Subastian, E., & Wahyuningsih, T. (2025). Integrating AI in digital project-based blended learning to enhance critical thinking and problem-solving skills. *Multidisciplinary Science Journal*, 7(12). https://doi.org/10.31893/multiscience.2025552

Li, F., Wu, J., Liu, J., Ma, Y., Liu, Y., & Zuo, T. (2025). A study of STEM teaching and learning in IT industry innovation and practice programs. 515–519. https://doi.org/10.1145/3711403.3711487

Marta, R., Riyanda, A. R., Samala, A. D., Dewi, I. P., & Adi, N. H. (2024). Innovative learning strategies: Project-based learning model for excelling in visual programming. *TEM Journal*, 13(1), 581–589. https://doi.org/10.18421/TEM131-61

Mejeh, M., Sarbach, L., & Hascher, T. (2024). Effects of adaptive feedback through a digital tool – a mixed-methods study on the course of self-regulated learning. *Education and Information Technologies*, 29(14), 1–43. https://doi.org/10.1007/s10639-024-12510-8

Mosquera-Gende, I. (2025). Synchronous and asynchronous collaborative dynamics and strategies in an online university using digital tools. *International Journal of Information and Education Technology*, 15(7), 1312–1321. https://doi.org/10.18178/ijiet.2025.15.7.2333

Musyaffi, A. M., Adha, M. A., Mukhibad, H., & Oli, M. C. (2024). Improving students' openness to artificial intelligence through risk awareness and digital literacy: Evidence form a developing country. *Social Sciences and Humanities Open*, 10. https://doi.org/10.1016/j.ssaho.2024.101168

Patel, N. S., & Lim, J. T.-H. (2025). Critical design futures thinking and generative AI: a Foresight 3.0 approach in higher education to design preferred futures for the industry. *Foresight*, 27(2), 380–402. https://doi.org/10.1108/FS-11-2023-0228

Prosen, M., & Ličen, S. (2025). Evaluating the digital transformation in health sciences education: A thematic analysis of higher education teachers' perspectives. *BMC Medical Education*, 25(1). https://doi.org/10.1186/s12909-025-07420-3

Qodariah, Q., & Arifin, Y. A. (2023). The influence of entrepreneurship knowledge, motivation, and family environment on entrepreneurship interest. *International Journal of Social Service and Research*, 3(3). https://doi.org/10.46799/ijssr.v3i3.293

Ruiz Viruel, S., Sánchez-Rivas, E., & Ruiz Palmero, J. (2025). The role of artificial intelligence in project-based learning: Teacher perceptions and pedagogical implications. *Education Sciences*, 15(2). https://doi.org/10.3390/educsci15020150

Schmid, M., Brianza, E., & Petko, D. (2020). Developing a short assessment instrument for Technological Pedagogical Content Knowledge (TPACK.xs) and comparing the factor structure of an integrative and a transformative model. *Computers & Education*, 157, 103967. https://doi.org/10.1016/j.compedu.2020.103967

Su, J., Zhong, Y., & Ng, D. T. K. (2022). A meta-review of literature on educational approaches for teaching AI at the K-12 levels in the Asia-Pacific region. *Computers and Education: Artificial Intelligence*, 3, 100065. https://doi.org/10.1016/j.caeai.2022.100065

Sudarwati, N., & Prianto, A. (2025). The effectiveness of marketing-oriented project-based mobile learning in improving students' critical thinking and collaboration skills in business education. *Educational Process: International Journal,* 16. https://doi.org/10.22521/edupij.2025.16.271

Sumandya, I.W., Widana, I.W, Dharmadewi, A.A.I., Setiawan, G.I., Habibi, A., and Robi, H. (2026). Extending the UTAUT Model with External Variables in Inclusive Schools: An Analysis of Teacher Satisfaction and AI-STEM Use Using SEM and ANN Models. *Open Education Studies, 8*(1), 20250126. https://doi.org/10.1515/edu-2025-0126

Vázquez-Parra, J. C., Alcantar-Nieblas, C., Glasserman-Morales, L. D., & Núñez-Rodríguez, X. (2024). Development of social entrepreneurship competencies and complex thinking in an intensive course of open educational innovation. *International Journal of Educational Psychology*, 13(1), 1–20. https://doi.org/10.17583/ijep.12187

Wayan Santyasa, I., Agustini, K., & Eka Pratiwi, N. W. (2021). Project-based e-learning and academic procrastination of students in learning chemistry. *International Journal of Instruction*, 14(3), 909–928. https://doi.org/10.29333/iji.2021.14353a

Widana, I. W. (2020). The effect of digital literacy on the ability of teachers to develop HOTS-based assessment. *Journal of Physics: Conference Series 1503* (2020) 012045. https://doi.org/10.1088/1742-6596/1503/1/012045

Widana, I. W. & Ratnaya, I. G. (2021). Relationship between divergent thinking and digital literacy on teacher ability to develop HOTS assessment. *Journal of Educational Research and Evaluation, 5*(4), 516-524. https://doi.org/10.23887/jere.v5i4.35128

Wilson, M. L., Ritzhaupt, A. D., & Cheng, L. (2020). The impact of teacher education courses for technology integration on pre-service teacher knowledge: A meta-analysis study. *Computers & Education*, 156, 103941. https://doi.org/10.1016/j.compedu.2020.103941

Xia, X. (2022). Diversion inference model of learning effectiveness supported by differential evolution strategy. *Computers and Education Artificial Intelligence*. https://doi.org/10.1016/j.caeai.2022.100071

Yanuarto, W. N., Hapsari, I., Galistiani, G. F., Jazuli, A., & Suanto, E. (2024). The structural model of students' sustainable professional for developing indonesia's higher education programs. *International Journal of Learning, Teaching and Educational Research*, 23(5), 21–40. https://doi.org/10.26803/ijlter.23.5.2

Zawacki-Richter, O., Marín, V. I., & Bond, M. (2019). Systematic review of research on artificial intelligence applications in higher education where are the educators ? Springer.

Zhan, Y., Sun, D., Kong, H. M., & Zeng, Y. (2024). Primary school teachers' classroom-based e-assessment practices: Insights from the theory of planned behaviour. *British Journal of Educational Technology*, 55(6), 2740–2759. https://doi.org/10.1111/bjet.13478