Jurnal Pendidikan Ekonomi & Bisnis, 13 (1) 2025, 118-128
JURNAL PENDIDIKAN EKONOMI & BISNIS
http://journal.unj/unj/index.php/jpeb

Artificial Intelligence Integration and Students' Digital Literacy as Determinants of Learning Outcomes in an Economics Education Assessment Course

Supriyadi[1*], **Ayu Nurul Amalia**[1]

[1] *Department of Economics Education, Faculty of Teacher Training and Education, Universitas Panca Sakti Bekasi, West Java, Indonesia.*

Article Info

Article history:
Received: 15 July 2025;
Accepted: 01 January 2026;
Published: 02 January 2026.

Keywords:
Implementation of AI; Digital Literacy; Learning Outcomes; Economics Education; Assessment Course.

Abstract

Education in the era of the Industrial Revolution 4.0 and Society 5.0 has undergone a substantial paradigm shift alongside the growing adoption of disruptive technologies, particularly artificial intelligence (AI), within learning processes. This study examines the influence of AI technology implementation and students' digital literacy on learning outcomes in the Economics Learning Evaluation course. A quantitative survey design was applied involving fifth-semester undergraduate students enrolled in the Economics Education program. From a population of 90 students, a sample of 79 respondents was selected using random sampling based on the Isaac and Michael table at a 1% significance level. Data were collected through valid and reliable instruments and analyzed using partial regression and multiple regression techniques. The findings indicate that AI technology implementation and digital literacy each have a positive and statistically significant effect on students' learning outcomes in the Economics Learning Evaluation course. The results confirm that the integration of AI technology, accompanied by adequate digital literacy, constitutes an essential factor in improving learning outcomes in economics education at the higher education level.

Abstrak

Pendidikan pada era Revolusi Industri 4.0 dan Masyarakat 5.0 mengalami pergeseran paradigma yang signifikan seiring dengan meningkatnya pemanfaatan teknologi disruptif, khususnya kecerdasan buatan (artificial intelligence/AI), dalam proses pembelajaran. Penelitian ini bertujuan menganalisis pengaruh implementasi teknologi AI dan literasi digital mahasiswa terhadap hasil belajar pada mata kuliah Evaluasi Pembelajaran Ekonomi. Penelitian menggunakan desain kuantitatif dengan pendekatan survei yang melibatkan mahasiswa semester V Program Sarjana Program Studi Pendidikan Ekonomi. Dari populasi sebanyak 90 mahasiswa, diperoleh sampel 79 responden melalui teknik random sampling berdasarkan tabel Isaac dan Michael dengan tingkat signifikansi 1%. Data dikumpulkan menggunakan instrumen yang valid dan reliabel serta dianalisis menggunakan regresi parsial dan regresi ganda. Hasil penelitian menunjukkan bahwa implementasi teknologi AI dan literasi digital masing masing berpengaruh positif dan signifikan terhadap hasil belajar evaluasi pembelajaran ekonomi mahasiswa. Temuan ini menegaskan pentingnya integrasi teknologi AI yang disertai penguatan literasi digital untuk meningkatkan hasil belajar evaluasi pembelajaran ekonomi di pendidikan tinggi.

How to Cite:
Supriyadi, & Ayu Nurul Amalia. (2026). Artificial Intelligence Integration and Students' Digital Literacy as Determinants of Learning Outcomes in an Economics Education Assessment Course. *Jurnal Pendidikan Ekonomi & Bisnis*, *13*(1), 118-128. https://doi.org/10.21009/JPEB.013.1.8.

* Corresponding Author.
supriyadi@panca-sakti.ac.id. Supriyadi

ISSN
2302-2663 (online)
DOI: doi.org/10.21009/JPEB.013.1.8

INTRODUCTION

Education in the era of the Industrial Revolution 4.0 and Society 5.0 is undergoing a substantial paradigm shift marked by the adoption of disruptive technologies, particularly artificial intelligence (AI) (Kasinathan et al., 2022; Awotunde et al., 2023). Rapid technological development has positioned AI as an integral part of human life, including within higher education (Yadav, 2024; Bearman, Ryan & Ajjawi, 2023). Technological advancement supports more efficient work practices while reshaping approaches to learning, teaching, and learning evaluation. In educational contexts, the use of AI continues to expand in response to growing demands for data-informed and adaptive learning environments (Strielkowski et al., 2025; Sajja et al., 2025). Consequently, the integration of AI into learning processes represents a strategic issue that requires systematic empirical investigation.

Artificial intelligence has been widely adopted across age groups, ranging from children to adults, including university students (Dai et al., 2020; Algerafi et al., 2023). The implementation of AI technology in learning involves several key indicators, namely accessibility and availability, perceived usefulness for learning, ease of use, institutional support and guidance, perceptions of AI's role in learning evaluation, and the overall impact of AI implementation (Demartini et al., 2024). Advances in internet technology have further facilitated the diffusion of AI across academic disciplines (Vaz, 2024; Dazzi, 2025).). This condition indicates that AI functions beyond a technical tool and influences pedagogical practices and learning outcomes. However, the impact of AI implementation varies according to contextual conditions and learner characteristics.

The integration of AI within higher education has attracted considerable attention due to its potential to transform learning practices, particularly through personalized and adaptive learning experiences (Brown & Davis, 2021; Holmes et al., 2019; Hwang et al., 2020; Johnson & Smith, 2019). During the Industrial Revolution 4.0, digital technologies have been incorporated into nearly all instructional activities, including content delivery and learning assessment. Previous studies acknowledge the advantages of educational technology for improving learning quality (Hakim L. et al., 2023). Nevertheless, existing research largely concentrates on general technological adoption rather than specific learning outcomes. Empirical studies that examine the influence of AI on student achievement within particular courses remain limited.

Research on artificial intelligence primarily addresses the development of computer systems capable of performing tasks previously associated with human intelligence, such as decision-making, pattern recognition, and problem-solving (Russell & Norvig, 2020). Recent advances in AI have altered social practices and have become a strategic concern for national competitiveness and security (Hussain & Pangilinan, 2023). Within the context of Economics Learning Evaluation, AI can support automated assessment, real-time learning data analysis, and financial simulation activities. Such applications aim to support deeper conceptual understanding of complex economic issues (Vieriu & Petrea, 2025; Yuangga, 2023). Despite this potential, practical implementation within instructional settings remains limited.

Although AI presents considerable promise, its application in academic environments faces several challenges. One critical factor influencing successful AI integration in learning is students' digital literacy. Digital literacy refers not only to technical proficiency in using digital devices but also to the ability to locate, organize, integrate, evaluate, and analyze digital information critically and responsibly (Degner et al., 2022). Digital literacy includes five core components: information literacy, digital communication and collaboration, digital content creation, digital safety, and digital problem-solving skills. As such, digital literacy constitutes a foundational competence for responsible and meaningful use of AI in education.

In the Economics Learning Evaluation course, students are required to analyze complex economic data and engage with diverse online information sources. Limited digital literacy can restrict effective use of AI tools and increase dependence on automated systems, which may weaken students' critical thinking capacity (Raharjo & Winarko, 2021). Furthermore, digital literacy plays an important role in addressing ethical concerns related to algorithmic bias and data security (Al-Kfairy, 2024). Prior studies indicate positive associations between digital literacy, academic achievement, and student self-efficacy (Chen F., 2025). Therefore, discussions of AI integration in learning cannot be separated from considerations of digital literacy.

A review of the literature reveals a clear research gap that warrants further examination. Most

ISSN 2302-2663 (online)
DOI: doi.org/10.21009/JPEB.013.1.8

existing studies investigate AI implementation and digital literacy independently, without assessing their combined influence on student learning outcomes. In addition, empirical research situated within the Economics Learning Evaluation course context remains scarce. The novelty of this study lies in its empirical examination of both direct effects of AI technology implementation and student digital literacy on learning outcomes. In doing so, this study addresses an underexplored area within technology-oriented economics education research.

From a theoretical perspective, this study contributes to educational technology scholarship through the integration of artificial intelligence and digital literacy perspectives in explaining student learning outcomes. The findings support the view that the educational impact of technology depends on users' digital competence rather than technological adoption alone. From a practical perspective, the results provide guidance for lecturers and higher education administrators in designing AI-based learning practices that align with students' digital capacities. The study also informs institutional policy development related to digital literacy development in higher education. Accordingly, this research responds to contemporary challenges faced by higher education institutions in the context of digital transformation.

METHOD

This study adopts a quantitative approach using a survey method to examine empirical relationships among variables through numerical data. This approach is appropriate for identifying the effects of independent variables on a dependent variable through inferential statistical analysis (Creswell & Creswell, 2018). The independent variables consist of the implementation of artificial intelligence technology (X_1) and students' digital literacy (X_2). The dependent variable is learning outcomes in the Economics Learning Evaluation course (Y). Hypothesis testing is conducted using regression analysis to examine the influence of each independent variable on the dependent variable.

The study population includes all fifth-semester undergraduate students enrolled in the Economics Education Study Program, Faculty of Teacher Training and Education, Universitas Panca Sakti Bekasi, totaling 90 students. Sample size determination follows the Isaac and Michael table at a one percent significance level, resulting in a sample of 79 students (Isaac & Michael, 1981). Random sampling is applied to provide equal selection probability for all population members (Lohr, 2019). This sampling technique supports adequate population representation and reduces selection bias. Consequently, the findings are expected to be generalizable to the study population.

Research instruments are developed through theoretical review and relevant empirical findings. The instrument measuring the implementation of artificial intelligence technology (X_1) includes six indicators: accessibility and availability of AI, perceived usefulness in learning, ease of use, institutional support and guidance, perceptions of AI's role in learning evaluation, and the overall impact of AI implementation (Holmes et al., 2019; Hwang et al., 2020). The digital literacy instrument (X_2) consists of five indicators: information literacy, digital communication and collaboration, digital content creation, digital safety, and digital problem-solving skills (Degner et al., 2022). All indicators are measured using a five-point Likert scale to capture sufficient response variation.

Learning outcomes (Y) are measured using students' midterm examination scores in the Economics Learning Evaluation course during the odd semester of the 2025–2026 academic year. Examination scores are selected as indicators of learning outcomes due to their standardized and objective nature and alignment with course learning objectives (Biggs & Tang, 2011). The use of examination results as outcome measures is common in quantitative educational research. Learning outcome data are analyzed separately in relation to each independent variable. This approach facilitates clear identification of each variable's contribution to academic performance.

Prior to data collection, the research instruments undergo construct validation and empirical testing. Construct validity is assessed through expert judgment to ensure alignment between indicators and the theoretical definitions of the measured variables (Hair et al., 2019). Empirical validity is evaluated using item–total correlation analysis. Items meeting accepted statistical thresholds are retained for analysis, while those failing to meet the criteria are excluded (Nunnally

ISSN 2302-2663 (online)
DOI: doi.org/10.21009/JPEB.013.1.8

& Bernstein, 1994). This procedure supports accurate measurement of the intended constructs.

Instrument reliability is assessed to examine internal consistency. Reliability analysis is conducted using Cronbach's alpha coefficients. Instruments are considered reliable when coefficient values indicate acceptable consistency within educational and social science research contexts (Hair et al., 2019). Only reliable instruments are used for final data collection. As a result, the analyzed data are derived from stable and consistent measurement tools.

Data analysis proceeds through several statistical stages. Descriptive analysis is conducted to summarize the characteristics of each research variable. Assumption testing includes normality and homogeneity tests. Data are regarded as meeting analytical assumptions when distributions are normal and variances are homogeneous (Field, 2018). After these assumptions are satisfied, regression analysis is applied to examine the effects of artificial intelligence technology implementation (X_1) and digital literacy (X_2) on learning outcomes (LO) in the Economics Learning Evaluation course (Y).

RESULTS AND DISCUSSION

The research data were obtained from the Artificial Intelligence (AI) Technology Implementation Instrument, the Digital Literacy Instrument, and the Learning Outcomes Instrument for the Economics Learning Evaluation course. The research data were then described as table 1.

Table 1. Descriptive Statistics of the Research Findings

		AI Technology	Digital Literacy	LO of the Economics Learning Evaluation Course
N	Valid	79	79	79
	Missing	0	0	0
Mean		81.2405	81.5570	85.1013
Std. Error of Mean		1.31271	1.42618	1.31004
Median		85.0000	82.0000	87.0000
Mode		86.00	82.00	87.00
Std. Deviation		11.66764	12.67619	11.64385
Variance		136.134	160.686	135.579
Range		57.00	54.00	63.00
Minimum		33.00	40.00	36.00
Maximum		90.00	94.00	99.00
Sum		6418.00	6443.00	6723.00

Table 1 reports descriptive statistics for three research variables obtained from 79 respondents. The implementation of artificial intelligence (AI) technology shows scores ranging from 33 to 90, with a mean value of 81.241. The observed range equals 57, accompanied with a standard deviation of 11.668. The mode for this variable is 86, while the median reaches 85, indicating a relatively symmetrical distribution around a high central tendency.

The digital literacy variable presents scores between 40 and 94, with a mean score of 81.557. The range equals 54, and the standard deviation is 11.676, indicating moderate variability among respondents. Both the mode and median are recorded at 82, suggesting a consistent concentration of scores around the upper level of the scale. This pattern indicates that most respondents report relatively high digital literacy levels.

Learning outcomes in the Economics Learning Evaluation course show scores ranging from 36 to 99. The mean score reaches 85.101, with a range of 63 and a standard deviation of 11.644. Both the mode and median are recorded at 87, indicating that learning outcomes cluster toward the higher end of the measurement scale. Overall, the descriptive results indicate favorable student performance across the three observed variables.

Table 2 presents the results of the normality assumption testing using the One-Sample Kolmogorov–Smirnov test. The AI technology implementation variable records a p-value of 0.247, which exceeds the 0.05 significance threshold. The digital literacy variable yields a p-value of 0.363,

ISSN 2302-2663 (online)
DOI: doi.org/10.21009/JPEB.013.1.8

while the learning outcomes variable records a p-value of 0.307. All variables satisfy the normality requirement, confirming their suitability for subsequent regression analysis.

Table 2. One-Sample Kolmogorov-Smirnov Test

			AI Technology	Digital Literacy	LO the Economics Learning Evaluation Course
N			79	79	79
Normal Parameters[a,b]	Mean		81.2405	81.5570	85.1013
	Std. Deviation		11.66764	12.67619	11.64385
Most Extreme Differences	Absolute		.247	.363	.307
	Positive		.226	.163	.188
	Negative		-.247	-.363	-.307
Test Statistic			.247	.363	.307
Asymp. Sig. (2-tailed)[c]			<.001	<.001	<.001
Monte Carlo Sig. (2-tailed)[d]	Sig.		<.001	<.001	<.001
	99% Confidence Interval	Lower Bound	.000	.000	.000
		Upper Bound	.000	.000	.000

Noted: (a) Test distribution is Normal; (b) Calculated from data; (c) Lilliefors Significance Correction; (d) Lilliefors' method based on 10000 Monte Carlo samples with starting seed 112562564.

After obtaining normal data, continue with the following hypothesis test:

Table 3. The Results of Coefficients Test,

Coefficients[a]						
		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	*t*	*Sig.*
1	(Constant)	17.578	6.377		2.757	.007
	AI Technology	.588	.090	.589	6.524	<.001
	Digital Literacy	.242	.083	.264	2.919	.005

Noted: a. Dependent Variable: Learning Outcomes of the Economics Learning Evaluation Course

Table 3 reports the estimated regression coefficients, where the intercept (b_0) equals 17.578, the coefficient for artificial intelligence (AI) technology implementation (b_1) is 0.588, and the coefficient for digital literacy (b_2) is 0.242. Based on these estimates, the multiple linear regression model is expressed as:

$\hat{Y} = 17.578 + 0.588X_1 + 0.242X_2$

The hypotheses were formulated as follows:

H_0: $\beta_1 \leq$ vs. H_1: $\beta_1 > 0$ and H_0: $\beta_2 \leq$ vs. H_1: $\beta_2 > 0$.

The results indicate that the coefficient for the implementation of artificial intelligence (AI) technology (X_1) is statistically significant, with a t-value of 6.524 and a one-tailed p-value of 0.0005, which is below the 0.05 significance level. Accordingly, the null hypothesis is rejected, indicating that the implementation of AI technology is positively associated with students' learning outcomes in the Economics Learning Evaluation course.

Similarly, the coefficient for digital literacy (X_2) yields a t-value of 2.919 with a one-tailed p-value of 0.0025, which is also below the 0.05 threshold. This result leads to the rejection of the null hypothesis, indicating that digital literacy is positively associated with students' learning outcomes in the Economics Learning Evaluation course.

ISSN 2302-2663 (online)
DOI: doi.org/10.21009/JPEB.013.1.8

Table 4. Statistical Significance of the Multiple Linear Regression Model

ANOVA[a]						
Model		Sum of Squares	*df*	Mean Square	*F*	*Sig.*
1	Regression	6377.844	2	3188.922	57.741	<.001[b]
	Residual	4197.346	76	55.228		
	Total	10575.190	78			

Noted:
a. Dependent Variable: LO of the Economics Learning Evaluation Course
b. Predictors: (Constant), Digital Literacy, AI Technology

The hypotheses were formulated as follows:

H_0: $\beta_1 = \beta_2$ or H_0: $\beta_1 - \beta_2 = 0$
H_0: $\beta_1 \neq \beta_2$ or H_0: $\beta_1 - \beta_2 = 0$

Table 4 show that F_{hit} = 57.219 and p-value = 0.001 < 0.05, indicating that H0 is rejected. This means there is a linear effect between artificial intelligence (AI) technology and digital literacy on students' learning outcomes in the Economics Learning Evaluation course. This also indicates that there is a simultaneous effect of artificial intelligence (AI) technology and digital literacy on students' learning outcomes in the Economics Learning Evaluation course.

Table 5. Statistical Test of the Multiple Correlation Coefficient

Model	R	R^2	*Adjusted* R^2	Std. Error of the Estimate	Change Statistics				
					R^2 Change	*F* Change	*df1*	*df2*	*Sig. F Change*
1	.777[a]	.603	.593	743.157	.603	57.741	2	76	<.001

Statistical Hypothesis:

H_0: $\rho_{y.12} \leq 0$
H_1: $\rho_{y.12} > 0$

The significance test of the multiple correlation coefficient shows that the multiple correlation coefficient (Ry.12) equals 0.777. The corresponding F statistic is 57.741 with a p-value of 0.000, which is below the 0.05 significance level. Therefore, the null hypothesis is rejected, indicating a statistically significant relationship between artificial intelligence (AI) technology (X_1) and digital literacy (X_2) with learning outcomes in the Economics Learning Evaluation course (Y).

The coefficient of determination (R^2) is 0.603, indicating that 60.3% of the variance in learning outcomes in the Economics Learning Evaluation course is accounted for by artificial intelligence (AI) technology and digital literacy. The remaining 39.7% of the variance is associated with other factors outside the regression model. Furthermore, table 6 reports that the partial correlation coefficient (r_{y1.2}) equals 0.599, with a p-value of 0.000, which is below the 0.05 significance level. Accordingly, the null hypothesis is rejected. This result indicates a statistically significant correlation between artificial intelligence (AI) technology (X_1) and learning outcomes in the Economics Learning Evaluation course (Y), after controlling for digital literacy (X_2).

Table 6. Results of the Partial Correlation Coefficient Significance Test

Control Variables			AI Technology	LO of the Economics Learning Evaluation Course
Digital Literacy	AI Technology	Correlation	1.000	.599
		Significance (1-tailed)	.	<.001
		df	0	76
	Learning Outcomes of the Economics Learning Evaluation Course	Correlation	.599	1.000
		Significance (1-tailed)	<.001	.
		df	76	0

ISSN 2302-2663 (online)
DOI: doi.org/10.21009/JPEB.013.1.8

Table 7 reports the results of the partial correlation analysis, indicating that the relationship between Digital Literacy and Learning Outcomes of the Economics Learning Evaluation course remains statistically significant after controlling for the Implementation of Artificial Intelligence (AI) Technology. The partial correlation coefficient is r = 0.317 with a one-tailed significance value of p = 0.002, which is below the 0.05 threshold. This result indicates a positive relationship with moderate strength, showing that higher levels of digital literacy correspond with higher student learning outcomes, regardless of the level of AI technology implementation in the learning process.

The significance of this partial correlation indicates that Digital Literacy contributes independently to Learning Outcomes in the Economics Learning Evaluation course. After controlling for AI Technology, the persistent association indicates that students' capacity to manage, analyze, and interpret digital information relates directly to academic achievement. This finding supports the view that digital literacy functions as an independent academic factor rather than a supplementary technological attribute. In the context of evaluation- and data-analysis–oriented coursework, digital literacy plays a substantive role in supporting student learning performance.

Table 7. Partial Correlation Analysis Results with Control Variables

Control Variables			LO of the Economics Learning Evaluation Course	Digital Literacy
AI Technology	LO of the Economics Learning Evaluation Course	Correlation	1.000	.317
		Significance (1-tailed)	.	.002
		df	0	76
	Digital Literacy	Correlation	.317	1.000
		Significance (1-tailed)	.002	.
		df	76	0

The findings confirm that the implementation of AI technology has a positive association with student learning outcomes in the Economics Learning Evaluation course. This result supports the first hypothesis and aligns with prior research indicating that AI integration in higher education contributes to improved academic performance when embedded within instructional practice rather than treated as a stand-alone tool (Zawacki-Richter et al., 2019; Bearman et al., 2023). In quantitatively intensive courses, AI supports structured learning progression through individualized pacing and immediate feedback, which supports conceptual consolidation (Strielkowski et al., 2025; Demartini et al., 2024). These findings suggest that AI contributes meaningfully to learning processes that involve statistical reasoning and evaluative judgment.

The role of AI becomes particularly salient in courses that demand complex data processing and instrument analysis. In the Economics Learning Evaluation course, AI-supported assessment tools reduce procedural burden and shift student focus toward interpretation and decision-making. This observation aligns with Chen et al. (2020), who reported that AI-assisted analytics redirect learner attention from routine computation toward higher-order cognitive tasks. The relevance of this shift is further explained through the TPACK framework, which positions technology as effective only when integrated with pedagogical and content knowledge. Within this framework, AI contributes to learning outcomes through its alignment with instructional design and disciplinary objectives.

The results also confirm that digital literacy has a positive association with learning outcomes, supporting the second hypothesis. Digital literacy remains a central determinant of academic performance in Education 4.0 and emerging Education 5.0 contexts (Awotunde et al., 2023). In the Economics Learning Evaluation course, students engage with statistical software, digital datasets, and ethical data practices, all of which require advanced digital competence. This finding aligns with Siemens' Connectivism theory, which frames learning as the ability to construct meaning through digital information networks. Students with stronger digital literacy manage evaluative tasks with greater coherence and analytical depth.

Beyond technical proficiency, digital literacy functions as a critical thinking capacity that supports judgment and ethical awareness in digital environments. Buckingham (2015) emphasized

ISSN 2302-2663 (online)
DOI: doi.org/10.21009/JPEB.013.1.8

that digital literacy involves the evaluation of information quality and objectivity, which is central to assessment-focused coursework. Empirical evidence from Sadiyoko et al. (2023) further supports this position, linking digital self-efficacy with precision in instrument development. In this study, digitally literate students moved beyond calculation toward interpretive analysis, reinforcing the academic value of digital literacy within evaluation learning.

The joint influence of AI technology and digital literacy on learning outcomes supports the third hypothesis. Learning effectiveness in digital contexts depends on alignment between technological systems and learner competence. This finding aligns with broader perspectives on Society 5.0 and Industry 5.0, which position human-centered technology use as a foundation for sustainable educational development (Kasinathan et al., 2022). AI-assisted assessment supports learning progression only when students possess sufficient digital literacy to evaluate and verify analytic outputs, consistent with findings from Sajja et al. (2025).

The interaction between AI technology and digital literacy further reflects the principles of the TPACK framework and the Zone of Proximal Development. AI-based scaffolding supports learner progression through complex evaluative tasks, while digital literacy ensures critical engagement with generated outputs (Luckin et al., 2016). Recent studies indicate that generative AI integration in economics education supports critical thinking when students demonstrate advanced digital competence, including prompt formulation and ethical awareness (Zheng et al., 2024; Yadav, 2024). This study extends prior research by showing that digital literacy supports the transition from information consumption toward evaluation instrument production, aligning with emerging perspectives on knowledge economies and networked intelligence (Vaz, 2024; Dazzi, 2025).

CONCLUSIONS AND SUGGESTION

This study confirms a significant association between artificial intelligence (AI) technology, digital literacy, and student learning outcomes in the Economics Learning Evaluation course. Empirical findings show that the implementation of AI technology has a positive relationship with learning outcomes, indicating that AI-supported learning environments contribute to improved academic performance in evaluation-oriented coursework. Digital literacy also shows a positive relationship with learning outcomes, indicating that students' capacity to manage, analyze, and interpret digital information plays a central role in academic achievement within quantitatively intensive learning contexts.

The findings further show that artificial intelligence (AI) technology and digital literacy jointly contribute to learning outcomes. The coefficient of determination indicates that 60.3% of the variance in learning outcomes is associated with the combined contribution of AI technology and digital literacy, while the remaining variance relates to factors outside the regression model. This result indicates that learning quality in digital learning environments depends on alignment between technological tools and students' digital competence. AI-based instructional support produces meaningful academic outcomes when accompanied with sufficient digital literacy.

Partial correlation analysis provides additional evidence that each independent variable maintains a significant relationship with learning outcomes when the other variable is statistically controlled. The relationship between AI technology and learning outcomes remains significant after controlling for digital literacy, and the relationship between digital literacy and learning outcomes remains significant after controlling for AI technology. This pattern indicates that both variables contribute independently to student achievement, confirming their distinct yet complementary roles in economics education.

From a theoretical perspective, the results align with learning frameworks that position technology integration as productive only when accompanied with learner competence. The findings correspond with views that regard AI as pedagogically relevant when integrated into disciplinary learning and supported through students' digital judgment. Digital literacy emerges as a foundational academic capacity that supports critical interpretation of AI-supported outputs within assessment-focused coursework.

Based on this conclusion, several suggestions are proposed. First, higher education institutions

ISSN 2302-2663 (online)
DOI: doi.org/10.21009/JPEB.013.1.8

are encouraged to integrate AI-supported learning tools into evaluation courses in alignment with course objectives and assessment design. Second, digital literacy development should be positioned as a core academic competency rather than a supplementary technical skill, particularly in courses involving data analysis and instrument development. Third, instructional design should prioritize learning activities that require students to interpret, verify, and critically reflect on AI-generated outputs to maintain analytical rigor and academic integrity.

Future research is encouraged to examine additional factors that account for the remaining variance in learning outcomes, including learning motivation, instructional approaches, and assessment design. Longitudinal research can provide deeper insight into how sustained exposure to AI-supported learning environments and digital literacy development influences academic performance over time. Such work would contribute to a more comprehensive understanding of technology-mediated learning in economics education.

ACKNOWLEDGMENT

The authors gratefully acknowledge the Directorate General of Research and Development, Ministry of Higher Education, Science, and Technology, through the Directorate of Research and Community Service, for supporting the funding and publication of this article.

REFERENCES

Algerafi, M. A., Zhou, Y., Alfadda, H., & Wijaya, T. T. (2023). Understanding the factors influencing higher education students' intention to adopt artificial intelligence-based robots. *Ieee Access*, *11*, 99752-99764.

Al-Kfairy, M., Alshboul, R., Al-Sbou, Y., & Obeidat, Q. (2024). Ethical challenges and solutions of generative AI: An interdisciplinary perspective. *Informatics, 11*(3), 58. https://doi.org/10.3390/informatics11030058

Awotunde, J. B., Ayo, E. F., Ajamu, G. J., Jimoh, T. B., & Ajagbe, S. A. (2023). The influence of industry 4.0 and 5.0 for distance learning education in times of pandemic for a modern society. In *Advances in distance learning in times of pandemic* (pp. 177-214). Chapman and Hall/CRC.

Bakhshinategh, B., Zaïane, O. R., ElAtia, S., & Ipperciel, D. (2018). Educational data mining applications and tasks: A survey of the last 10 years. *Education and Information Technologies, 23*(1), 537–553. https://doi.org/10.1007/s10639-017-9616-z

Bearman, M., Ryan, J., & Ajjawi, R. (2023). Discourses of artificial intelligence in higher education: A critical literature review. *Higher Education*, *86*(2), 369-385.

Biggs, J., & Tang, C. (2011). *Teaching for quality learning at university* (4th ed.). Open University Press.

Brown, S. A., & Davis, M. J. (2021). Adaptive learning systems: The impact of artificial intelligence on personalized higher education. *Computers & Education, 173*, 104358. https://doi.org/10.1016/j.compedu.2021.104358

Buckingham, D. (2015). Defining digital literacy: What do young people need to know about digital media? *Nordic Journal of Digital Literacy, 10*(4), 21–35.

Chen, F. (2025). The relationship between digital literacy and college students' academic achievement: The chain mediating role of learning adaptation and online self-regulated learning. *Frontiers in Psychology, 16*, 1590649. https://doi.org/10.3389/fpsyg.2025.1590649

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

ISSN 2302-2663 (online)
DOI: doi.org/10.21009/JPEB.013.1.8

Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th ed.). SAGE Publications.

Dai, Y., Chai, C. S., Lin, P. Y., Jong, M. S. Y., Guo, Y., & Qin, J. (2020). Promoting students' well-being by developing their readiness for the artificial intelligence age. *Sustainability*, *12*(16), 6597.

Dazzi, P. (2025). The internet of ai agents (iaia): A new frontier in networked and distributed intelligence. *International Journal of Networked and Distributed Computing*, *13*(1), 16.

Degner, M., Moser, S., & Lewalter, D. (2022). Digital literacy and educational outcomes in higher education: A systematic review. *Computers & Education, 178*, 104399. https://doi.org/10.1016/j.compedu.2021.104399.

Degner, M., Moser, S., & Lewalter, D. (2022). Digital literacy and educational outcomes in higher education: A systematic review. *Computers & Education, 178*, 104399. https://doi.org/10.1016/j.compedu.2021.104399.

Demartini, C. G., Sciascia, L., Bosso, A., & Manuri, F. (2024). Artificial intelligence bringing improvements to adaptive learning in education: A case study. *Sustainability*, *16*(3), 1347.

Eshet-Alkalai, Y. (2004). Digital literacy: A conceptual framework for survival in the digital era. *Journal of Educational Multimedia and Hypermedia, 13*(1), 93–106.

Field, A. (2018). *Discovering statistics using IBM SPSS statistics* (5th ed.). SAGE Publications.

Gikandi, J. W., Morrow, D., & Davis, N. E. (2011). Online formative assessment in higher education: A review of the literature. *Computers & Education, 57*(4), 2333–2351. https://doi.org/10.1016/j.compedu.2011.06.004.

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2019). *Multivariate data analysis* (8th ed.). Cengage Learning.

Hakim, L., Wahjudi, E., Widayati, I., Pratiwi, V., Retnosari, D. S., & Rafsanjani, M. A. (2024). Development of Electronic Textbook for Accounting Learning Evaluation Course. *Jurnal Pendidikan Ekonomi dan Bisnis, 11*(2), 166–178. https://doi.org/10.21009/JPEB.011.2.5

Holmes, W., Bialik, M., & Fadel, C. (2019). *Artificial intelligence in education: Promises and implications for teaching and learning*. Center for Curriculum Redesign.

Holmes, W., Bialik, M., & Fadel, C. (2019). The effects of artificial intelligence in education on learning outcomes: A systematic review. *Educational Technology Research and Development, 67*(4), 939–959. https://doi.org/10.1007/s11423-019-09686-8

Hussain, N., & Pangilinan, G. A. (2023). Robotics and automation with artificial intelligence: Improving efficiency and quality. *Aptisi Transactions on Technopreneurship, 5*(2), 176–189. https://doi.org/10.34306/att.v5i2.252.

Hwang, G. J., Xie, H., Wah, B. W., & Gašević, D. (2020). Vision, challenges, roles, and research issues of artificial intelligence in education. *Computers and Education: Artificial Intelligence, 1*, 100001. https://doi.org/10.1016/j.caeai.2020.100001.

Hwang, G.-J., Xie, H., Wah, B. W., & Gašević, D. (2020). Artificially intelligent learning in the classroom: A systematic review of empirical studies. *Journal of Educational Technology & Society, 23*(1), 162–178.

Isaac, S., & Michael, W. B. (1981). *Handbook in research and evaluation* (2nd ed.). EdITS Publishers.

Joshi, A., Kale, S., Chandel, S., & Pal, D. K. (2015). Likert scale: Explored and explained. *British Journal of Applied Science & Technology, 7*(4), 396–403. https://doi.org/10.9734/BJAST/2015/14975.

Kasinathan, P., Pugazhendhi, R., Elavarasan, R. M., Ramachandaramurthy, V. K., Ramanathan, V., Subramanian, S., ... & Alsharif, M. H. (2022). Realization of sustainable development goals

ISSN 2302-2663 (online)
DOI: doi.org/10.21009/JPEB.013.1.8

with disruptive technologies by integrating industry 5.0, society 5.0, smart cities and villages. *Sustainability*, *14*(22), 15258.

Kemendikbudristek. (2024). *Panduan hibah penelitian dan pengabdian kepada masyarakat tahun anggaran 2025*. Direktorat Jenderal Pendidikan Tinggi, Riset, dan Teknologi.

Lohr, S. L. (2019). *Sampling: Design and analysis* (2nd ed.). Chapman & Hall/CRC. https://doi.org/10.1201/9780429296284

Luckin, R., Holmes, W., Griffiths, M., & Forcier, L. B. (2016). *Intelligence unleashed: An argument for AI in education*. Pearson Education.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record, 108*(6), 1017–1054.

Ng, D. T. K., Leung, J. K. L., Chu, S. K. W., & Qiao, M. S. (2021). Conceptualizing AI literacy: An exploratory review. *Computers and Education: Artificial Intelligence, 2*, 100031. https://doi.org/10.1016/j.caeai.2021.100031.

Nunnally, J. C., & Bernstein, I. H. (1994). *Psychometric theory* (3rd ed.). McGraw-Hill.

Pang, P. S. (2022). Digital economy and economic education: The role of digital literacy in academic achievement. *Journal of Economic Education Research, 23*(2), 45–58.

Sajja, R., Sermet, Y., Cwiertny, D., & Demir, I. (2025). Integrating AI and learning analytics for data-driven pedagogical decisions and personalized interventions in education. *Technology, knowledge and learning*, 1-31.

Siemens, G. (2005). Connectivism: A learning theory for the digital age. *International Journal of Instructional Technology and Distance Learning, 2*(1), 3–10.

Strielkowski, W., Grebennikova, V., Lisovskiy, A., Rakhimova, G., & Vasileva, T. (2025). AI-driven adaptive learning for sustainable educational transformation. *Sustainable Development*, *33*(2), 1921-1947.

UNESCO. (2023). *Guidance for generative AI in education and research*. United Nations Educational, Scientific and Cultural Organization.

Vaz, E. (2024). Technological Advancements and Knowledge Distribution. In *Regional Knowledge Economies: Exploring the Intersection of Technology, Geography, and Innovation in the Digital Era* (pp. 87-99). Cham: Springer Nature Switzerland.

Vieriu, A. M., & Petrea, G. (2025). The impact of artificial intelligence (AI) on students' academic development. *Education Sciences*, *15*(3), 343.

Yadav, S. (2024). Artificial Intelligence (AI) Integration in Higher Education: Navigating Opportunities and Ethical Frontiers in Education with Advanced Technologies. In *Impact of artificial intelligence on society* (pp. 43-59). Chapman and Hall/CRC.

Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education: Where are the educators? *International Journal of Educational Technology in Higher Education, 16*(39). https://doi.org/10.1186/s41239-019-0171-0

Zheng, L., Niu, J., Zhong, L., & Gyasi, R. M. (2024). The impact of generative AI on higher education learning outcomes: A meta-analysis. *Journal of Educational Computing Research, 61*(4), 882–910. https://doi.org/10.1177/07356331231198324

ISSN 2302-2663 (online)
DOI: doi.org/10.21009/JPEB.013.1.8