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Smart Learning in a Smart Era: The Use of Digital Literacy, Artificial Intelligence (AI), and Learning Styles as Predictors of Students' Learning Outcomes

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Abstract

Purpose – The focus or main purpose of this study emphasizes appropriate collaboration between the roles of digital literacy, AI platforms, and learning styles in learners so that it provides a significant impact on learning effectiveness, particularly on learners' learning outcomes.

Methods/Design/Approach – This study uses a quantitative approach, with a multiple linear regression method. The population and sample are students of Vocational High School (SMK) in East Java, with a research sample of 384 respondents using random sampling and Cochran calculation. Data collection uses a questionnaire (survey) method with a 7-point Likert scale. Validity and reliability tests are used to test the feasibility of the instrument, and continued with model feasibility testing using the classical assumption test, while hypothesis testing uses multiple linear regression test analysis.

Findings – The results show that partially and simultaneously the variables of digital literacy, artificial inttelegence, and learning styles have a significant effect on learning outcomes. This is seen from the t-count value > t-table [DL: 6.020 > 1.966; AI: 4.408 > 1.966; 14.166 > 1.966], and also the F-count value > F-table [250.106 > 2.268], in addition the R-Square value also shows 0.664.

Originality/Value – This study has strong originality because it simultaneously examines the roles of digital literacy, the use of artificial intelligence (AI)-based platforms, and learners' learning styles in influencing learning effectiveness. This study has not been widely conducted comprehensively, thus providing a new contribution in understanding how these three aspects interact with each other and impact the quality of the teaching and learning process in the digital era.

Practical Implications – These findings emphasize more on how all actors in education (students, teachers, and educational institutions) are able to integrate digital literacy into the curriculum, utilize artificial intelligence (AI)-based learning platforms that support personalization, and map students' learning styles early to adjust teaching strategies.

Keywords AI, learning effectiveness, learning styles, learning outcomes, digital literacy
Paper type Research paper

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1. Introduction

The increasing complexity in modern education has a significant influence on the effectiveness of existing learning (Akour & Alenezi, 2022; Halytska-Didukh et al., 2023; Walter, 2024), both from the internal side of learners, such as learners' motivation and learning styles, and from the external side of learners, such as teaching methods, the technological support provided, to the availability of adequate technology-based learning resources (Alzboun et al., 2023). Therefore, it is important to understand how the paradigm shift of the learning process influenced by technology is able to play an important role in the classroom learning process, and to find appropriate strategies in understanding the material comprehensively. Furthermore, the transformation brought by technological developments, particularly the use of artificial intelligence (AI) in higher education, not only revolutionizes how to access information, but also how to present that information (Cope et al., 2021).

This is consistent with research findings revealing that the use of technology in the learning process is able to improve the quality of material delivery (Mahmud, 2022), providing space for a more personalized approach and being able to provide closer engagement between lecturers and learners in the learning process (Major et al., 2021). On the other hand, research findings also show that the implementation of AI combined with a material recommendation system according to students' needs can improve learning efficiency (Holmes et al., 2023). Therefore, amid this fairly significant flow of change, learners are required to be able to adapt intelligently and strategically in the learning process while still using relevant technology (Hashim et al., 2022). This means that this adaptation not only emphasizes individuals' technical ability to operate devices or digital applications, but also emphasizes information literacy related to technology, critical thinking skills related to the positive benefits of technology, and digital ethics in using technology wisely.

Furthermore, one essential competency that learners must have in facing the dynamics of technological development in the world of education is digital literacy (Falloon, 2020). This provides an understanding that digital literacy itself is an indication that individuals have the ability, attitudes, and awareness in using digital devices and resources in creating a certain understanding, and are able to have a significant impact in communication on social actions (Biezā, 2020). However, several research results reveal that mastery of digital literacy alone is not sufficient, but it is also necessary to be equipped with various other skills, such as appropriate learning styles, critical thinking skills, time management, and collaborative abilities (Arono et al., 2022; Khan et al., 2022; Kwiatkowska & Wiśniewska-Nogaj, 2022). This is in line with research findings showing that appropriate learning styles can increase information retention and learners' learning motivation (Pashler et al., 2008).

In addition to digital literacy, another factor that can influence learning effectiveness in the digital era is the wise use of AI-based platforms (Raza, 2016). AI platforms such as academic chatbots, chatGPT, adaptive learning systems, and learning analytics have become one potential solution as tools to improve learning effectiveness (Qazi et al., 2024), because they can provide immediate feedback, and provide answer adjustments to the intended learning material. This is consistent with research findings that integration of AI not only increases the efficiency of the learning process, but also makes a significant contribution to the creation of a learning experience that is more personal, interactive, and based on measurable data (Mahmoud & Sørensen, 2024). However, this is inversely related to research findings that find that the use of AI has risks to academic integrity, the loss of critical thinking skills, and creates the potential for excessive dependence (Guilherme, 2019). This provides an understanding to us that there is a need for the same understanding between teachers and students related to the use of AI in improving learning outcomes.

However, we also cannot deny that the success of using technology in education is also strongly influenced by the learning preferences possessed by students. Because preferences for learning styles owned by each student are very different, whether they tend toward visual, auditory, or kinesthetic (Dzulkalnine et al., 2024), and with appropriate

mapping of learning styles it will have a significant impact on the success of learning (Robinson, 2022). However, there are still many studies revealing that the implementation of appropriate learning styles in the learning process is still often ignored, so that learning tends to be uniform and less adaptive (Azizah et al., 2023; Sanjani, 2021). With technological developments reaching the world of education, teachers and related parties still need to identify and explore further so that the use of this technology can be accommodated to the learning style of each student, so that it will support the improvement of learning outcomes optimally (El-Sabagh, 2021).

On the other hand, several studies also mention that the use of AI is still limited to certain fields (Fahrurozi et al., 2024), the lack of digital literacy especially in the understanding and use of AI influenced by socioeconomic factors, technological access, and curriculum (Sulistyono et al., 2024), and the lack of adequate infrastructure and human resource readiness (Fransisca & Saputri, 2025). Therefore, there needs to be integrative research related to testing the roles of digital literacy, AI, and learning styles simultaneously as predictors of learning outcomes, especially in vocational high school (SMK) students. Therefore, the problem of this study is more about how the roles of digital literacy, the use of AI platforms, and the learning styles possessed by learners are able to influence the effectiveness of existing learning. Thus, the focus or main purpose of this study emphasizes that appropriate collaboration between the roles of digital literacy, AI platforms, and learning styles in learners can have a significant impact on learning effectiveness, particularly on learners' learning outcomes. Furthermore, the impact or potential of the findings of this study emphasizes a more comprehensive understanding of learners and lecturers regarding the importance of digital literacy and learners' learning styles, as well as the use of AI platforms in learning effectively, efficiently, and wisely, in order to support a more maximal learning pattern for learners.

2. Methods

2.1. Design

We used a quantitative research approach, with a multiple linear regression method. This allows the study to measure the extent to which digital literacy, the use of AI platforms in learning, and learners' learning styles can predict or explain changes that occur in learning effectiveness. In addition, with this method, it allows us to develop a predictive model that is useful in decision making based on empirical data (Iain, 2021).

2.2. Sample/Participants

The population and sample to be used in this study are students of Vocational High School (SMK) in East Java with a Marketing concentration. This selection, besides being based on the pilot project conducted by the researchers before conducting broader modeling, is based on the direct relevance between their field of expertise and the development of digital technology, especially in the application of digital literacy, artificial intelligence (AI), and adaptive learning styles. We used multistage sampling, where by combining two sampling techniques, namely cluster sampling (urban and rural) and simple random sampling as sampling techniques with calculations using the Cochran (1977) formula to obtain the sample size, it can be seen that the research sample was 384 respondents taken from 770,230 respondents as the population (BPS, 2023). Furthermore, the limitation we used for respondents is students in public vocational high schools (SMK Negeri) and private vocational high schools (SMK Swasta) in the East Java region, especially in the areas of Probolinggo, Trenggalek, Kediri, Blitar, and Malang. The selection of these areas is because these areas represent differences in geographic and socioeconomic conditions between

urban and rural areas in East Java, so it is expected to provide a more comprehensive overview related to the roles of digital literacy, AI, and learning styles in influencing the learning outcomes of vocational high school students in East Java.

2.3. Data Collection

Data collection in this study used a questionnaire (survey) method as the main instrument. The questionnaire was prepared based on indicators of each research variable, namely digital literacy/DL (Ginting et al., 2021) with a total of seven statement items, artificial intelligence/AI (Razilu, 2025) with a total of eight statement items, learning styles/LS (Simatupang, 2019) with a total of four statement items, and learning outcomes/LO (Soegeng Tsh & Maryadi, 2015) with a total of five statement items, so the total items used in answering the research problem are 24 statement items. Each item prepared in the questionnaire will use the Likert scale method (Coolican, 2018) with 7-point (Hair et al., 2020) in measuring respondents' perceptions and attitudes, starting from strongly disagree [STS], disagree [TS], somewhat disagree [ATS], neutral [N], somewhat agree [AS], agree [S], and strongly agree [SS]. The questionnaire distribution was conducted twice, namely in April 2025 which was used for validity and reliability testing (100 respondents) and in May to June 2025 which was used for model feasibility testing and multiple linear regression testing (384 respondents).

2.4. Data Analysis

Data tabulation was carried out before conducting data analysis. Validity and reliability tests are the initial steps that we will take to validate the research instrument before being used as a data collection tool, with the decision of validity values Sig. < 0.05 and r-count > r-table, while for the reliability decision value, namely Cronbach's Alpha > 0.70. The next step is to conduct the classical assumption test, which consists of the normality test [normally distributed if Sig > 0.05], multicollinearity test [VIF value < 10], linearity test [Sig. Deviation from Linearity/dL > 0.05], and heteroskedasticity test [scatterplot evenly distributed]. Finally, after all pre-analysis values are met, then we will use multiple linear regression analysis testing to answer the research problem, which consists of the F test, t test, and the coefficient of determination (R2).

2.5. Ethics

This study was conducted in accordance with the research code of ethics established by Universitas Negeri Malang, which refers to the principles of informed concent, data confidentiality, and protection of the rights of participants or respondents, with protocol number 0149233573111242025072900131. Furthermore, this approval is required because we use living beings (humans) to obtain research data in the form of perceptions. Therefore, to protect respondents' rights, the data were collected and analyzed anonymously without including respondents' identities.

3. Results

3.1 Instrument Feasibility Test

The results of the pilot test analysis show that all instruments to be used have met the criteria for validity and reliability testing. This is seen from the validity test having an r-count value > r-table with a significance value < 0.05 (Table 1), so the data are declared valid.

Table 1. Summary of Instrument Validity and Reliability

No.	Statement Item (Code)	r-count	r-table	Sig. < 0.05	Remarks r-count > r-table
1.	DL_1	.510	.361	.004	Valid
2.	DL_2	.803	.361	.000	Valid
3.	DL_3	.658	.361	.000	Valid
4.	DL_4	.830	.361	.000	Valid
5.	DL_5	.747	.361	.000	Valid
6.	DL_6	.637	.361	.000	Valid
7.	DL_7	.822	.361	.000	Valid
8.	AI_1	.814	.361	.000	Valid
9.	AI_2	.794	.361	.000	Valid
10.	AI_3	.695	.361	.000	Valid
11.	AI_4	.410	.361	.024	Valid
12.	AI_5	.367	.361	.046	Valid
13.	AI_6	.753	.361	.000	Valid
14.	AI_7	.817	.361	.000	Valid
15.	AI_8	.850	.361	.000	Valid
16.	LS_1	.838	.361	.000	Valid
17.	LS_2	.869	.361	.000	Valid
18.	LS_3	.925	.361	.000	Valid
19.	LS_4	.813	.361	.000	Valid
20.	LO_1	.817	.361	.000	Valid
21.	LO_2	.742	.361	.000	Valid
22.	LO_3	.736	.361	.000	Valid
23.	LO_4	.819	.361	.000	Valid
24.	LO_5	.868	.361	.000	Valid

Source: Primary Data Processed by Researchers, 2025

In addition, the results of the reliability test using the Cronbach's Alpha method show a coefficient value > 0.70, namely a total of 0.994, while if viewed per variable, it can be seen that the Cronbach's Alpha value for the DL variable is 0.884, AI is 0.857, LS is 0.866, LO is 0.909, this means that all statement items in the instrument indicate good internal consistency and can be relied upon for use in data collection. The findings in the instrument feasibility test results can be indicated that all statement items in the instrument have been feasible and ready to be used to measure the DL, AI, LS, and LO variables accurately and consistently.

3.2 Analysis Model Feasibility Test

Next, the results of the analysis model feasibility test using the classical assumption test show that all collected data have met the requirements of the multiple linear regression test. Where the normality test using the Kolmogorov-Smirnov test shows a significance value of 0.175 (p > 0.05), which means the residual data are normally distributed. Meanwhile, the multicollinearity test also shows that there is no indication of multicollinearity between variables, this is seen from the Variance Inflation Factor (VIF)

value < 10 and the tolerance value p > 0.10, namely the VIF value of 2.066 and the tolerance value of 0.484 for the digital literacy variable, the VIF value of 2.075 and the tolerance value of 0.482 for the artificial intellegence variable, and the VIF value of 1.461 and the tolerance value of 0.684 for the learning styles variable. Meanwhile, the linearity test shows that the deviation from linierity (dL) value is 0.831 which means it is greater than 0.05, so it can be interpreted that the relationship between each independent variable and the dependent variable is linear (Table 2).

Table 2. Summary of the Normality Test, Multicollinearity Test, and Linearity Test

		Normality			**Multicollinearity**		**Linearity**
		Kolmogorov-Smirnov[a]			**Tolerance and VIF**		**Deviation from Linearity (dL)**
		Statistic	df	Sig.	Tolerance	VIF	Sig.
Unstandardized Residual		.044	382	.175	-	-	-
Model							
1	Digital Literacy [DL]	-	-	-	.484	2.066	-
	Artificial Intelligence [AI]	-	-	-	.482	2.075	-
	Learning Styles [LS]	-	-	-	.684	1.461	-
	Between Groups	Deviation from Linierity					.831

Source: Primary Data Processed by Researchers, 2025

Furthermore, the heteroskedasticity test using a Scatterplot (Figure 1) shows that the residual points are randomly distributed and do not form a certain pattern, whether a curved, spreading, or narrowing pattern. This means that the error variance of the regression model is constant (homoskedasticity), so there is no heteroskedasticity problem.

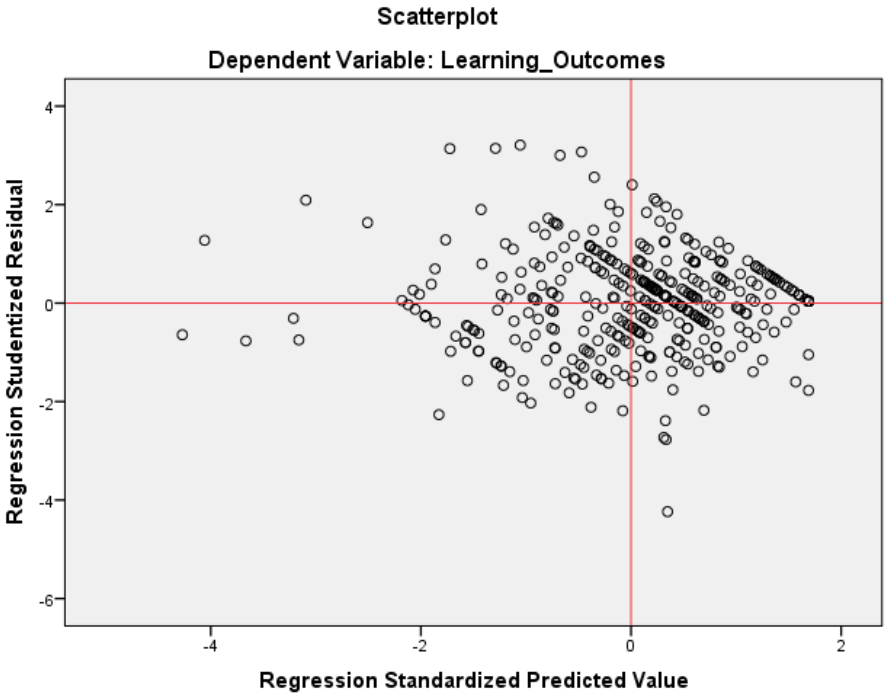

Figure 1. Heteroskedasticity Test Results

After the four classical assumption tests (Normality, Multicollinearity, Linearity, and Heteroskedasticity) are fulfilled, the multiple linear regression analysis can be continued to

test the effect of the digital literacy, artificial intellegence, and learning styles variables on learning outcomes, both partially and simultaneously.

3.3 Multiple Linear Regression Test

Based on the results of the multiple linear regression analysis, it was found that both partially and simultaneously the DL, AI, and LS variables have a significant effect on LO. This is seen from the partial significance values showing that each independent variable has a value < 0.05 and the t-count value > t-table, while simultaneously it is also seen that the F-count value > F-table with a significance level of 0.000 (Table 3).

Table 3. Summary of the Multiple Linear Regression Test (Partial and Simultaneous)

Model	Variabel	R-Square	F-count	F-table	Sig.	t-count	t-table	Sig.	Remarks
1		0.664	250.106	2.628	.000	-	-	-	Accepted
	DL	-	-		-	6.020	1.966	.000	Accepted
	AI	-	-		-	4.408	1.966	.000	Accepted
	LS	-	-		-	14.166	1.966	.000	Accepted

a. Dependent Variable: Learning Outcomes
b. Predictors: (Constant), Digital Literacy, Artificial Intellegence, Learning Styles

The results above also show that the R-Square value provides an illustration that 66.4% of the variation in changes in the dependent variable can be explained by the independent variables in this regression model, while the remaining 33.6% is influenced by other factors outside the model. Therefore, overall, the results of the study provide an understanding that students' learning success is influenced jointly by their ability to master digital literacy, the extent to which artificial intelligence technology is utilized in the learning process, and the suitability between learning methods and each individual's learning style. In other words, improving learning outcomes cannot be achieved only by focusing on one aspect, but requires an integrated approach between mastery of technology, the application of artificial intelligence in learning, and an understanding of students' learning preferences.

4. Discussion

The results of the analysis mention that both partially and simultaneously, digital literacy, the use of AI platforms, and learners' learning styles have an influence on students' learning outcomes, where these learning outcomes are an indicator of learning effectiveness. Therefore, these findings indicate that the higher the digital literacy possessed by students, the more optimal their ability will be in accessing, understanding, and utilizing technology-based learning resources. This is consistent with research findings revealing that students' ability to access, understand, and use digital technology directly contributes to improving the quality of education (Bachtiar et al., 2024). In addition, the results of this study also explicitly support research findings stating that increasing digital literacy will have a positive effect on digital competence, informal learning, and students' self-efficacy which will ultimately support academic achievement (Zakir et al., 2025). This means that strengthening digital literacy in the educational environment is not only relevant in the context of mastering technology, but also becomes an important foundation in shaping independent learning, increasing self-confidence, and encouraging students' active involvement in the learning process.

In addition, the use of AI platforms in learning is proven to be able to increase efficiency, personalization, and engagement in the learning process, which directly impacts

improving learning outcomes. This is in line with other research findings showing that the use of AI in learning increases students' active participation and creates a more dynamic learning experience, as well as facilitating personalization of materials according to individual needs (Fajriati et al., 2024). Furthermore, other research also confirms that AI provides personalized learning pathways, real time feedback, 24/7 tutoring, and gamification, which collectively improve efficiency and student engagement (Major et al., 2021). Thus, the use of AI not only provides benefits in the technical aspects of learning, but is also able to create a learning environment that is more adaptive and responsive to differences in students' needs. This ultimately has a positive impact on increasing learning motivation, understanding of the material, and the achievement of overall learning outcomes. Thus, the integration of AI in learning strategies can be one relevant innovative approach in responding to educational challenges in the digital era.

On the other hand, learning styles that are in accordance with individual characteristics also strengthen the effectiveness of the learning strategies applied. This is in accordance with research findings highlighting the need to identify and adjust learning strategies according to students' learning styles to improve effectiveness, efficiency, and learning comfort (Andriani & Nugraheni, 2024). Therefore, while accommodating learning styles can enrich teaching strategies, true effectiveness emerges when the approach is combined with active and varied methods, one of which is by utilizing technology in the learning process (El-Sabagh, 2021). This means that technology enables learning personalization more accurately and dynamically according to the needs and preferences of each student, and in this way the integration of learning styles and technology not only increases participation and learning motivation, but also strengthens concept understanding and overall academic outcomes.

Thus, these three factors support each other in creating a learning environment that is more adaptive, interactive, and productive, which ultimately contributes positively to the achievement of learners' learning outcomes. Thus, this study has several limitations that need to be considered and can be used as consideration material for further research. First, the approach used is quantitative with a survey method, so it is not fully able to explore in depth the context and subjective dynamics behind the influence of digital literacy, the use of artificial intelligence (AI), and learning styles on learning outcomes. Therefore, it is suggested to continue this research using a mixed methods approach so that it can explore more deeply students' experiences and learning dynamics holistically. Second, the limitation of this study is related to being limited to the student population from only one level, namely in vocational high school (SMK), so the generalization of the findings to other educational contexts (for example different levels of education or diverse cultural and geographic backgrounds) needs to be done with caution. Therefore, the recommendation is more directed toward expanding the sample coverage by involving various levels of education and school backgrounds to increase the generalizability of the results.

Therefore, the implications or practical application of these findings emphasize more on how all actors in education (students, teachers, and educational institutions) are able to integrate digital literacy into the curriculum, utilize artificial intelligence (AI)-based learning platforms that support personalization, and map students' learning styles early to adjust teaching strategies. Teachers also need to be provided with continuous training on the use of learning technology and differentiation approaches based on learners' characteristics. In addition, educational institutions are advised to provide adequate digital infrastructure and create a learning culture that is open to innovation and collaboration.

5. Conclusion

By using multiple linear regression analysis, the problems in this study have been answered comprehensively. This is seen from the results of the study which confirm that digital literacy, the use of AI platforms during the learning process, and the learning styles possessed by learners, are seen to make a significant contribution as predictors of the achievement of learners' learning outcomes, especially in the era of learning that uses

technology media. However, this study still has limitations that need special attention, especially in the scope of the sample which is still limited and also the other forming variables have not been accommodated, such as digital infrastructure and the readiness of educators. Furthermore, this study provides theoretical implications for contemporary learning theory, where the emphasis of the learning process is more directed toward personalization and the development of skills needed in the 21st century. In addition, the practical implications emphasize the importance of improving learners' digital literacy competence, supporting the strengthening of teachers' capacity in implementing AI-based technology in the learning process, and applying several strategic learning methods that are adapted to learners' learning styles. Therefore, there is a need for further research development, by paying attention to several factors, including expanding the population and research sample, and including other variables that can be used to predict the improvement of learning effectiveness comprehensively.

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Declarations

Author contribution statement
Andy Prasetyo Wati: Conceptualization; Methodology; Investigation; Writing - Original Draft.
Rachmat Hidayat: Formal analysis; Validation; Visualization; Writing - Review & Editing.
Jefry Aulia Martha: Supervision; Project administration; Resources; Writing - Review & Editing.
Aryati Binti Abd Rahman: Data Curation; Writing - Review & Editing.

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Data availability statement
The data that support the findings of this study are available from the corresponding author upon reasonable request.

Ethical Approval and Informed Consent
Ethical approval was obtained from Universitas Negeri Malang (Protocol No. 01492335731112420250729001 31). Informed consent was obtained from all participants. Data were collected and analysed anonymously.

Declaration of interest statement
No potential conflict of interest was reported by the authors.

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