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Analysis the Role of Learning Analytics and Digital Literacy in Enhancing the Effectiveness of Competency Based Sustainable Education for the 21st Century

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Abstract

The Fourth Industrial Revolution has profoundly transformed the educational paradigm through the integration of digital technologies, artificial intelligence, and data-driven learning systems. This study examines the influence of Learning Analytics (LA) and digital literacy on the effectiveness of sustainable education oriented toward 21st-century competencies critical thinking, creativity, collaboration, and communication. A quantitative research design was employed involving 95 students from grades IV to VI at SDN Sudimoro 1 Magelang. Data were collected through Likert-scale questionnaires measuring three variables: Learning Analytics (X_1), Digital Literacy (X_2), and Sustainable Education Effectiveness (Y). The data were analyzed using multiple linear regression with SPSS version 28. The results revealed that both Learning Analytics and digital literacy have a positive and significant effect on the effectiveness of sustainable education ($p < 0.05$). Learning Analytics demonstrated a stronger influence ($\beta = 0.476$, $t = 3.710$, $p = 0.000$) compared to digital literacy ($\beta = 0.342$, $t = 2.669$, $p = 0.010$). The coefficient of determination ($R^2 = 0.588$) indicates that 58.8% of the variance in sustainable education effectiveness is explained by these two predictors. These findings underscore that integrating data-driven learning through Learning Analytics and fostering students' digital literacy can enhance adaptive, innovative, and continuous learning processes aligned with 21st-century skill development.

Keywords: *learning analytics, digital literacy, sustainable education, 21st-century competencies, educational innovation*

INTRODUCTION

The Fourth Industrial Revolution has fundamentally transformed the landscape of education. Advances in digital technology, artificial intelligence, and automation have triggered a global shift in educational paradigms, demanding learning systems that are more adaptive to technological developments (Fitriani, 2024; Dito & Pujiastuti, 2023). This transformation not only influences instructional methods but also creates new demands for human resource competencies capable of thriving in a digitally driven work environment (Schwab, 2016). Twenty-first-century education emphasizes mastery of four key competencies-critical thinking, creativity, collaboration, and communication (4C) which serve as essential skills for students to navigate increasingly complex social, economic, and technological dynamics (Asri, Lasmawan, & Suharta, 2024). Conventional instructional models relying on one-way information delivery are no longer considered effective. Therefore, educational institutions must integrate technology and data-driven

approaches to create learning environments that are more efficient, adaptive, and sustainable (UNESCO, 2015; Trilling & Fadel, 2009).

One approach developed to support this educational transformation is Learning Analytics (LA). LA is used to analyze learning activity data to understand student behavior, monitor academic performance, and provide evidence-based interventions (Siemens & Long, 2011). Pan et al. (2024) found that the implementation of LA within Learning Management Systems (LMS) over the past decade has positively influenced student participation, collaboration, and academic achievement. Similarly, Cerro Martínez, Guitert Catasús, and Romeu Fontanillas (2020) demonstrated that LA can map online interaction patterns, improve discussion quality, and foster active engagement in learning activities. However, most LA studies have concentrated on big data and predictive algorithm applications, while quantitative investigations of its direct impact on 21st-century competency development at the elementary level remain limited (Guzmán-Valenzuela et al., 2021).

Digital literacy also plays a crucial role, as it determines students' ability to access, manage, and utilize technology-based information effectively (Ilomäki, Paavola, Lakkala, & Kantosalo, 2016). Students with higher levels of digital literacy tend to demonstrate stronger critical thinking, data-driven decision-making, and superior performance in online learning environments (Ng, 2012; Frontiers, 2025). Nevertheless, digital literacy has rarely been systematically examined in relation to data-driven learning effectiveness, particularly in elementary education settings (MDPI, 2023). Guzmán-Valenzuela et al. (2021) also highlighted that while most LA research focuses on big data and predictive analytics, few studies have investigated its direct role in fostering 21st-century competencies. Furthermore, a systematic review published by MDPI (2023) emphasized that LA contributes positively to student engagement and academic performance, yet the integration of digital literacy in enhancing data-based learning effectiveness remains underexplored.

Field observations conducted at SD Sidomulyo Magelang reveal that digital-based learning has been implemented, particularly in grades IV, V, and VI. The learning process utilizes simple digital platforms to facilitate teacher-student interaction. However, the use of digital learning data remains limited to recording grades and attendance. Valuable learning indicators-such as material access frequency, participation levels, and task completion rates have not been fully utilized to improve instructional effectiveness. In addition, students' digital literacy levels vary widely, indicating that technology integration has not yet optimally supported the achievement of 21st-century competencies.

These challenges indicate that elementary-level educational technology implementation still faces barriers in both data utilization and digital literacy development. This raises a critical question: How can Learning Analytics and digital literacy contribute to enhancing the effectiveness of competency-based sustainable education for the 21st century in elementary schools?

In light of these issues and the identified research gaps, this study aims to analyze the extent to which Learning Analytics and digital literacy contribute to the effectiveness of competency-based sustainable education among fourth-, fifth-, and sixth-grade students at SD Sidomulyo Magelang. The findings are expected to provide theoretical contributions to the development of data-driven education and practical recommendations for elementary schools in designing adaptive, innovative, and sustainable learning strategies..

METHOD

This study employed a quantitative approach with a survey design involving all students from grades IV, V, and VI at SDN Sudimoro 1 during the 2025/2026 academic year, totaling 95 participants. A saturated sampling technique was applied, whereby the entire population was included as respondents (Sugiyono, 2019). The research instrument consisted of a five-point Likert-scale questionnaire measuring three variables: Learning Analytics (X_1), Digital Literacy (X_2), and the Effectiveness of Competency-Based Sustainable Education (Y). Instrument validity was assessed using Pearson's correlation, where items were considered valid if $p < 0.05$, while reliability was tested using Cronbach's Alpha, with a minimum acceptable coefficient of $\alpha > 0.70$ (Ghozali, 2018). Data were analyzed using SPSS version 28, employing multiple linear regression to examine the effects of X_1 and X_2 on Y. The t-test was applied to evaluate the partial influence of each independent variable, while the F-test assessed the simultaneous influence of both variables, using a 5% significance level ($p < 0.05$). The relatively large number of respondents across three grade levels enhanced the representativeness and statistical power of the analysis.

RESULTS AND DISCUSSION

This section describes the results of statistical analyses, including validity and reliability testing, as well as hypothesis testing. The discussion further interprets these findings in relation to existing literature to explain the theoretical and practical implications of the study.

Table 1.
Validity Test Results

Variable	Item	Pearson's r	Sig. (p)	Remark
Learning Analytics	X1.1	0.804	0.000	Valid
	X1.2	0.744	0.000	Valid
	X1.3	0.824	0.000	Valid
	X1.4	0.800	0.000	Valid
Digital Literacy	X2.1	0.792	0.000	Valid
	X2.2	0.768	0.000	Valid
	X2.3	0.710	0.000	Valid
	X2.4	0.739	0.000	Valid
Sustainable Education Effectiveness	Y1.1	0.544	0.000	Valid
	Y1.2	0.618	0.000	Valid
	Y1.3	0.679	0.000	Valid
	Y1.4	0.517	0.000	Valid

Source: Processed data (2025)

All items for the variables Learning Analytics, Digital Literacy, and Sustainable Education Effectiveness have significance values below 0.05, indicating that each item is statistically valid. The highest correlation coefficient ($r = 0.824$) is found in item X1.3, suggesting a strong correlation with the total Learning Analytics score, while the lowest correlation ($r = 0.517$) in item Y1.4 still meets the validity criteria.

Reliability Test. Reliability was assessed using Cronbach's Alpha, as shown in Table 2.

Table 2.
Reliability Test Results

Variable	Cronbach's Alpha	Standard	Remark
Learning Analytics	0.800	≥ 0.70	Reliable
Digital Literacy	0.739	≥ 0.70	Reliable
Sustainable Education Effectiveness	0.814	≥ 0.70	Reliable

Source: Processed data (2025)

All variables exceed the reliability threshold (α > 0.70), confirming that the research instruments are consistent and reliable. Learning Analytics (α = 0.800) demonstrates good internal consistency, while Sustainable Education Effectiveness (α = 0.814) shows excellent reliability.

Multiple Linear Regression Analysis. The results of the multiple linear regression analysis are presented in Table 3.

Table 3.
Multiple Linear Regression Coefficients

Model	Unstandardized Coefficients (B)	Std. Error	Standardized Coefficients (Beta)	t
(Constant)	1.644	1.773	—	0.927
Learning Analytics (X_1)	0.527	0.142	0.476	3.71
Digital Literacy (X_2)	0.362	0.136	0.342	2.669
Dependent Variable: Sustainable Education Effectiveness (Y)				

Source: Processed data (2025)

The regression equation derived from the analysis is expressed as follows:

$Y = 1.664 + 0{,}527X_1 + 0.362X_2 + e$

The constant (1.644) implies that even when Learning Analytics and Digital Literacy are zero, Sustainable Education Effectiveness remains at 1.644. Both Learning Analytics (p = 0.000) and Digital Literacy (p = 0.010) significantly and positively influence sustainable education effectiveness. Learning Analytics exerts a stronger effect (β = 0.476) than Digital Literacy (β = 0.342).

Simultaneous Test (ANOVA)

Table 4.
ANOVA Results

Source	Sum of Squares	df	Mean Square	F	Sig. (p)
Regression	115.647	2	57.824	40.647	0.000
Residual	81.086	57	1.423	—	—
Total	196.733	59	—	—	—

Dependent Variable: Sustainable Education Effectiveness (Y)
Predictors: (Constant), Learning Analytics (X_1), Digital Literacy (X_2)

Source: Processed data (2025)

The F-value of 40.647 with a significance level of $p < 0.001$ indicates that Learning Analytics and Digital Literacy jointly have a significant positive effect on the effectiveness of sustainable education. This confirms the overall fit of the regression model.

Coefficient of Determination

Table 5.
Model Summary

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate
1	0.767	0.588	0.573	1.193
Predictors: (Constant), Learning Analytics (X_1), Digital Literacy (X_2)				

Source: Processed data (2025)

The correlation coefficient ($R = 0.767$) shows a strong positive relationship between Learning Analytics and Digital Literacy with Sustainable Education Effectiveness. The R^2 value of 0.588 means that 58.8% of the variance in sustainable education effectiveness is explained by the two predictor variables, while the remaining 41.2% is influenced by other factors not included in this model, such as parental involvement, learning environment, or school technological readiness.

The regression analysis demonstrates that Learning Analytics (X_1) significantly influences Sustainable Education Effectiveness, with a coefficient of 0.527 and $t = 3.710$ ($p < 0.001$). This indicates that effective implementation of learning analytics enhances students' engagement, collaboration, and academic achievement consistent with previous findings emphasizing the role of data-driven insights in improving educational quality (Siemens & Long, 2011; Pan et al., 2024). Learning Analytics functions not only as a monitoring mechanism but also as a pedagogical tool that supports adaptive instruction and evidence-based decision-making, thereby fostering the 21st-century competencies of critical thinking, creativity, collaboration, and communication.

Similarly, Digital Literacy (X_2) has a positive and significant effect on Sustainable Education Effectiveness ($\beta = 0.362$, $t = 2.669$, $p = 0.010$). Students with higher digital literacy demonstrate stronger technological engagement and autonomy in digital learning contexts (Ilomäki et al., 2016; Ng, 2012). Hence, digital literacy acts as a cognitive competency that enables reflective, critical, and innovative use of digital resources to support sustainable learning outcomes.

The simultaneous test ($F = 40.647$, $p < 0.001$) confirms that both Learning Analytics and Digital Literacy jointly contribute to educational effectiveness, explaining 58.8% of its variance ($R^2 = 0.588$). Among these predictors, Learning Analytics exerts a greater influence ($\beta = 0.476$) than Digital Literacy ($\beta = 0.342$), underscoring the pivotal role of data-informed decision-making in sustaining effective, technology-integrated learning environments (Trilling & Fadel, 2009; UNESCO, 2015).

CONCLUSION AND RECOMMENDATIONS

This study concludes that both Learning Analytics (LA) and Digital Literacy significantly enhance the effectiveness of sustainable education within the framework of 21st-century competencies. Among the two, Learning Analytics exerts a stronger influence, emphasizing the crucial role of data-driven insights in improving instructional quality, promoting adaptive learning, and fostering student engagement. The integration of these two dimensions contributes to the creation of innovative, adaptive, and sustainable learning ecosystems that prepare students for the challenges of the digital era.

For practical application, it is recommended that educational institutions embed data-informed practices and digital competency development into school curricula and teacher training programs. Policymakers and educators should prioritize the use of learning analytics to support evidence-based decision-making while strengthening students' digital literacy to ensure equitable and sustainable learning outcomes. Future studies are encouraged to examine additional determinants such as teacher readiness, institutional digital infrastructure, and parental involvement to further advance the effectiveness of sustainable education.

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