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Educational Games and Learning Management Quality as Predictors of Digital Literacy in Mathematics

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ABSTRACT

This study aims to analyze the influence of educational game integration and learning management quality on students' digital literacy competence in mathematics at SMK Bina Mandiri. The research is motivated by the growing need to strengthen digital literacy skills in technology-based learning, particularly in mathematics, which many students perceive as abstract and challenging. The study adopts a quantitative approach with an explanatory correlational design involving 60 eleventh-grade students. Data were collected using a closed-ended Likert-scale questionnaire (1–5) that had been tested for validity and reliability. Data were analyzed using SPSS with multiple regression, supported by classical assumption tests to ensure the suitability of the model. The results show that all measurement instruments meet the required validity and reliability criteria. The regression model fulfills the assumptions of normality, linearity, multicollinearity, and heteroscedasticity, indicating that the data are appropriate for further analysis. Both partially and simultaneously, educational game integration (X_1) and learning management quality (X_2) positively and significantly affect digital literacy competence in mathematics (Y). The coefficient of determination (R^2) of 0.611 indicates that 61.1% of the variance in students' digital literacy competence is explained by the two independent variables, while the remaining 38.9% is influenced by other factors such as student motivation, technological infrastructure, and the broader learning environment. These findings highlight the importance of structured game-based learning and effective learning management in supporting students' digital skills. Findings suggest that integrating educational games with strong learning management enhances vocational students' digital literacy.

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INTRODUCTION

The development of digital technology has fundamentally transformed how students learn, interact, and acquire information. In the context of education, digital transformation presents significant opportunities to enhance learning quality through various technology-based platforms. One of the central challenges in 21st-century education is developing students' digital literacy competence, particularly in mathematics, which is often perceived as abstract and difficult by many learners [1]-[2]. Digital literacy not only involves the ability to operate technological tools but also encompasses skills in accessing, evaluating, managing, and creating digital information responsibly. Strengthening these competencies requires innovative pedagogical approaches, including the integration of educational games into mathematics learning as an engaging and effective learning medium [3].

The integration of educational games represents a student-centered strategy designed to increase motivation, engagement, and conceptual understanding [4]. For vocational students at SMK Bina Mandiri who generally exhibit active, visual, and practice-oriented learning characteristics game-based learning can offer interactive and challenging experiences that support the development of logical reasoning and problem-solving abilities [5]. Beyond the use of media, the quality of learning management also plays a crucial role in ensuring that technology is implemented effectively within the classroom. Digital-based learning management supported by LMS platforms such as Google Classroom or Moodle enables teachers to plan, organize, and monitor learning processes more efficiently. At the same time, these platforms facilitate productive teacher–student interaction that contributes to successful learning outcomes [6].

However, the digital literacy level of vocational students remains relatively low, as many still tend to use digital devices primarily for entertainment rather than academic purposes. The use of educational games is often limited to supplementary roles, and teachers continue to face various challenges related to infrastructure readiness and digital pedagogical competence [7]-[9]. In addition, only a limited number of studies in Indonesia have examined the integration of educational games and the quality of learning management simultaneously as predictors of digital literacy in vocational mathematics learning. This situation highlights a clear research gap that needs to be addressed to support better pedagogical innovations. Consequently, exploring these two variables becomes increasingly important to strengthen digital learning practices in vocational education.

Under these conditions, this study aims to examine how educational game integration and learning management quality predict students' digital literacy competence in mathematics at SMK Bina Mandiri. The research specifically addresses three questions: (1) How does the integration of educational games influence digital literacy competence? (2) What is the effect of learning management quality on digital literacy? and (3) Do both variables jointly predict vocational students' digital literacy competence? The findings of this study are expected to provide evidence-based insights for improving school policies and instructional practices. Moreover, the results may contribute to supporting national initiatives related to digital transformation in vocational education and the enhancement of 21st-century skills among students.

METHOD

This study employs a quantitative approach with an explanatory correlational design to analyze the influence of educational game integration (X_1) and learning management quality (X_2) on students' digital literacy competence in mathematics (Y) [11]. The research was conducted at SMK Bina Mandiri with a population of 11th-grade students, involving 60 respondents. A total sampling technique was used because the population size was relatively small, manageable, and fully accessible, allowing all students in the population to be included. All participants voluntarily participated, and data collection complied with institutional ethical standards.

Data were collected using a closed-ended questionnaire with a Likert scale of 1–5. Prior to distribution, the research instrument was tested for validity using item-total correlation (Pearson) and reliability using Cronbach's Alpha, with $\alpha \geq 0.70$ as the minimum acceptable threshold. After the instrument was confirmed to be valid and reliable, the questionnaires were administered directly in the classroom under the supervision of the researcher and subject teachers [12].

The collected data were processed using SPSS through descriptive and inferential analyses. Multiple linear regression was employed to examine the effects of X_1 and X_2 on Y. Before conducting the regression test, prerequisite assumption tests—normality, linearity, multicollinearity, and heteroscedasticity—were performed following standard statistical

guideline [26]-[27]. The regression outputs included the coefficient of determination (R^2) to show the explained variance, along with the t-test and F-test to determine the significance of partial and simultaneous effects at the 5% significance level.

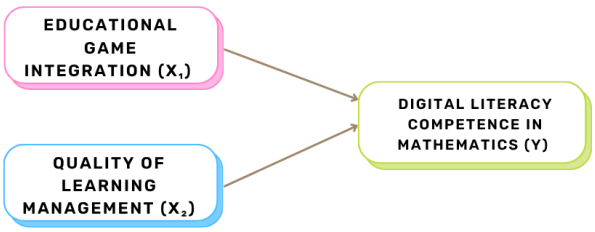


Figure 1. Conceptual Framework

Figure 1 presents the conceptual framework of this study, illustrating the directional relationships between the independent and dependent variables. The two independent variables—Educational Game Integration (X_1) and Quality of Learning Management (X_2)—are hypothesized to influence the dependent variable, Digital Literacy Competence in Mathematics (Y). This framework forms the basis for analyzing both partial and simultaneous effects of the predictors on students' digital literacy outcomes. It visually clarifies how each variable contributes to the development of digital literacy competence within the context of vocational mathematics learning.

RESULTS AND DISCUSSION

Preliminary Data Analysis

This study aims to analyze the influence of Educational Game Integration (X_1) and Quality of Learning Management (X_2) on Digital Literacy Competence in Mathematics (Y) among 60 eleventh-grade students of SMK Bina Mandiri. Data were collected through questionnaires using a 5-point Likert scale, which were then analyzed to describe the characteristics of the respondents, examine the validity and reliability of the instruments, and identify the relationships and effects among the variables. Descriptive analysis was conducted to provide an overview of the data for each research variable. This analysis includes the minimum, maximum, mean, and standard deviation values of the respondents' scores. The descriptive results for each variable are presented in table 1 below.

Table 1. Descriptive Statistics of Research Variables

No	Variable	Mean	STD	Min	Max	Assumption Test
1	Educational game integration (X_1)	40.35	5.12	28	50	Normality p > 0.05; Tolerance > 0.10; VIF < 10
2	Learning management quality (X_2)	31.87	4.56	22	40	Normality p > 0.05;

						Tolerance > 0.10; VIF < 10
3	Mathematics Competence (Y)	43.20	5.74	30	55	Normality p > 0.05; Durbin–Watson = 1.87

Source: Author (2025)

Based on the descriptive analysis results presented in table 1, the Educational Game Integration (X_1) variable has a minimum score of 28 and a maximum score of 50, with a mean of 40.35 and a standard deviation of 5.12 from a total of 10 items. The Quality of Learning Management (X_2) variable has a minimum score of 22 and a maximum score of 40, with a mean of 31.87 and a standard deviation of 4.56 from 8 items. Meanwhile, the Digital Literacy Competence in Mathematics (Y) variable has a minimum score of 30 and a maximum score of 55, with a mean of 43.20 and a standard deviation of 5.74 from 11 items. Overall, the average scores of the three variables fall into the high category, indicating that the integration of educational games and the quality of learning management are well implemented, and students' digital literacy competence is at a good level and relatively consistent among respondents. After conducting the validity test and confirming that all questionnaire items are valid, the next step is to perform a reliability test to determine the internal consistency level of the research instrument. The reliability test was carried out using the Cronbach's Alpha coefficient for each variable.

The results of the classical assumption tests presented in Table 1 show that all data meet the required criteria for multiple linear regression analysis. The normality test using the Kolmogorov–Smirnov method indicates that all variables have significance values greater than 0.05, which means that the data are normally distributed. The multicollinearity test shows that all tolerance values are greater than 0.10 and all VIF values are less than 10, indicating that there is no multicollinearity problem among the independent variables. The heteroscedasticity test results show significance values greater than 0.05 for all variables, meaning that there is no heteroscedasticity in the model. Lastly, the autocorrelation test shows a Durbin–Watson value of 1.87, which falls within the acceptable range, indicating no autocorrelation problem in the residuals.

Multiple Linear Regression Analysis

Table 2. Regression Coefficients

Variable	B	t-value	Sig.
Constant	12.345		
Educational Game Integration (X_1)	0.532	4.892	0.000
Quality of Learning Management (X_2)	0.412	4.322	0.000

Source: Author (2025)

Based on table 2 The results of the multiple linear regression analysis clearly indicate that Educational Game Integration (X_1) and Quality of Learning Management (X_2) exert a positive and statistically significant influence on students' Digital Literacy Competence in Mathematics (Y). The regression equation derived from the analysis can be expressed as follows : $Y = 12.345 + 0.532\ X_1 + 0.412\ X_2$.

This equation demonstrates that an increase of one unit in Educational Game Integration is predicted to enhance students' digital literacy competence by 0.523 units, while a one-unit increase in Quality of Learning Management is expected to raise students' digital literacy competence by 0.412 units, assuming other factors remain constant. These coefficients highlight the substantial contribution of both variables in promoting students' ability to utilize digital technologies effectively in mathematics learning.

Simultaneous Effect (F-Test) and Coefficient of Determination (R^2)

Table 3. ANOVA (F-test)

Type of Test	Result
46,892	0,000

Source: Author (2025)

The results of the ANOVA (F-test), as presented in table 3, indicate that the overall regression model is statistically significant. The F-value of 46.892 with a significance level of 0.000 (Sig. < 0.05) demonstrates that the independent variables, Educational Game Integration (X_1) and Quality of Learning Management (X_2), collectively have a significant effect on students' Digital Literacy Competence in Mathematics (Y). This means that the regression model reliably predicts the dependent variable, and the variation in digital literacy competence among students can be explained, at least in part, by the combined influence of the two independent variables.

Table 3. Coefficient of Determination

R	R^2
0.781	0.611

Based on table 6 The coefficient of determination (R^2 = 0.611) shows that 61,1% of the variation in students' digital literacy competence is explained by educational game integration and quality of learning management. This indicates that while these factors are dominant, other variables such as students' prior knowledge, self-regulated learning, or classroom culture also play a role in shaping digital literacy.

Effect of Educational Game Integration on Students' Digital Literacy

Educational games provide an interactive, engaging, and stimulating learning environment that encourages students to actively explore mathematical concepts, experiment with problem-solving strategies, and apply logical reasoning. According to constructivist learning theory), students acquire and construct knowledge through active engagement, social interaction, and experiential learning, all of which are facilitated when learning activities are gamified [13]-[14]. The positive coefficient of X_1 (0.523) empirically confirms that integrating educational games into mathematics lessons significantly enhances students' ability to operate digital tools, develop analytical thinking, and apply mathematical reasoning in a digital context. This finding is consistent with prior research that emphasizes the role of educational games in increasing students' motivation, engagement, and digital competence, thereby improving overall learning outcomes [15]-[17]. By incorporating elements such as challenges, instant feedback, rewards, and interactive problem-solving, educational games stimulate higher-order cognitive processes, including critical thinking and logical reasoning, which are fundamental for the development of digital literacy in mathematics. Furthermore, gamified learning enables students to learn

independently, encourages experimentation, and reduces anxiety associated with complex mathematical tasks, fostering a more meaningful and enjoyable learning experience [18]-[19].

In addition, the effectiveness of educational games in enhancing digital literacy can also be attributed to their ability to promote adaptive learning, where students receive personalized support based on their individual pace and skill level. Through digital game-based platforms, learners can repeatedly practice mathematical procedures, receive automated feedback, and adjust their strategies in response to performance indicators embedded in the game environment. This iterative learning process not only strengthens students' mastery of mathematical concepts but also deepens their familiarity with essential digital operations, such as navigating interfaces, interpreting visual information, and utilizing interactive tools. Such experiences cultivate a sense of digital confidence, which is a key component of digital literacy development. As students become more comfortable engaging with technology-rich learning tasks, they are better equipped to apply digital skills in broader academic and vocational contexts, demonstrating the long-term benefits of integrating educational games into mathematics instruction.

Effect of Learning Management Quality on Digital Literacy Competence

The quality of learning management encompasses several essential components, including lesson planning, instructional delivery, assessment strategies, and classroom management. High-quality learning management ensures that learning activities are systematic, well-organized, and effectively implemented, while simultaneously providing students with structured guidance and support to explore digital tools independently. The positive regression coefficient for X_2 (0.412) confirms that effective management of learning activities contributes significantly to the enhancement of students' digital literacy competence in mathematics.This outcome aligns with the principles of instructional design theory, which posits that careful planning, clear objectives, and well-structured instructional strategies are critical for achieving optimal learning outcomes [20]. When teachers organize learning efficiently, students receive clear explanations, timely feedback, and access to appropriate digital resources, enabling them to navigate complex digital environments and solve mathematical problems effectively. In essence, the combination of structured guidance and opportunities for independent exploration allows students to internalize digital literacy skills, which are crucial for both academic and vocational success in the 21st century.

Furthermore, the significance of learning management quality in enhancing digital literacy also reflects the broader shift toward learner-centered digital pedagogy, where teachers act not only as content providers but also as facilitators who guide students through complex problem-solving processes. Effective learning management enables teachers to create structured digital learning pathways, integrate multimedia resources strategically, and scaffold learning tasks to accommodate varying levels of student readiness. This structured yet flexible environment is particularly important in vocational education, where students often require clear procedural guidance while simultaneously being encouraged to develop autonomy and technological confidence. When teachers consistently apply these principles, classrooms become more conducive to active participation, collaborative learning, and adaptive use of digital tools—conditions that directly support the growth of digital literacy. As a result, high-quality learning management not only improves students' immediate engagement with mathematical tasks but also strengthens their capacity to transfer digital skills to real-world vocational contexts.

Joint Influence of Educational Game Integration and Learning Management on Digital Literacy

The F-test result (F = 46.892, Sig. = 0.000) demonstrates that X_1 and X_2 together have a significant impact on students' digital literacy competence. The coefficient of determination (R^2 = 0.611) indicates that approximately 61.1% of the variation in digital literacy competence among students can be explained by educational game integration and quality of learning management. The remaining 38,9% is influenced by other factors not included in this study, such as students' prior knowledge, individual motivation, self-regulated learning strategies, learning environment, and classroom culture. These findings suggest that while X_1 and X_2 are dominant predictors, a comprehensive understanding of digital literacy development requires attention to multiple interacting variables.

Moreover, the substantial unexplained variance reflected in the remaining 38.9% underscores the complexity of digital literacy as a multidimensional construct influenced by both internal and external factors. Future studies should therefore consider incorporating additional predictors such as technology attitudes, digital self-efficacy, parental support, and the availability of digital infrastructure to obtain a more comprehensive model of factors shaping students' digital competencies. Including these variables may help capture the broader ecological and psychological dimensions of digital literacy development that extend beyond classroom instruction and digital media integration. Furthermore, longitudinal research designs may provide deeper insights into how digital literacy evolves over time and how sustained exposure to technology-enhanced learning environments interacts with individual learner characteristics. By expanding the analytical framework, future research can contribute to a more holistic understanding of the pathways through which students develop the digital skills necessary for academic and vocational success.

Interpretation of Findings and Theoretical Implications

The results of this study provide strong support for integrating constructivist learning principles and digital pedagogy in vocational education settings, particularly in mathematics learning. Educational games function as active learning tools that stimulate engagement, motivation, and self-directed learning. Meanwhile, high-quality learning management ensures that digital learning activities are purposeful, structured, and goal-oriented, facilitating the effective acquisition of digital literacy skills [21]-[23]. Together, these factors enhance students' ability to use digital technologies competently, think critically, and solve mathematical problems efficiently skills that are essential for the 21st-century competency framework. In practical terms, teachers are encouraged to blend gamified learning experiences with well-structured instructional strategies, creating a classroom environment where students can explore, experiment, and learn collaboratively [24]-[25]. This approach not only strengthens digital literacy but also reinforces mathematical reasoning, problem-solving, critical thinking, and creativity. By applying these strategies consistently, vocational education institutions can prepare students to navigate increasingly digitalized professional and academic environments, thereby improving their readiness for future careers in technology-driven fields.

In addition, the findings of this study highlight the importance of continuous professional development for teachers as a key component of successful digital integration in vocational mathematics learning. Effective implementation of educational games and digital learning management requires not only technological proficiency but also pedagogical adaptability, enabling teachers to design meaningful learning experiences that align with students' needs and learning characteristics. Schools and policymakers should therefore prioritize training programs that strengthen teachers' digital competencies, encourage innovation in instructional design, and promote the use of data-driven decision-making to improve learning outcomes. When supported

by adequate infrastructure, institutional commitment, and a collaborative teaching culture, these efforts can significantly enhance the sustainability of digital literacy initiatives in vocational education. Ultimately, fostering a digitally competent teaching workforce will ensure that the integration of educational games and structured learning management continues to contribute to improved mathematics learning and better preparation of students for future technological challenges.

Limitations, Implications, and Future Research Directions

This study has several limitations. It was conducted in a single vocational school with 60 students, which restricts the generalizability of the results to broader educational contexts. The explanatory correlational design allows identification of relationships but cannot establish causality. Additionally, the study focused only on two predictors educational game integration and learning management quality while other relevant factors such as student motivation, technological infrastructure, teacher digital competence, or school policy support were not examined.

Despite these limitations, the findings offer important practical implications. Schools can use the results to strengthen digital learning practices by integrating structured educational games and improving the quality of learning management. Teachers are encouraged to enhance their digital pedagogical skills through training and continuous professional development. Institutions should also provide adequate technological infrastructure and supportive supervision to optimize the implementation of digital learning tools.

Future research should involve multiple vocational schools with larger and more diverse samples to increase external validity. Researchers are also encouraged to include additional variables, such as student engagement, self-regulated learning, or digital readiness, to obtain a more comprehensive model. Moreover, longitudinal or mixed-method approaches can be employed to capture deeper insights into how digital learning interventions influence the development of digital literacy competence over time.

CONCLUSIONS

Based on the results of the study, it can be concluded that the integration of educational games and the quality of learning management have a positive and significant effect on students' digital literacy competence in mathematics at SMK Bina Mandiri. The regression analysis shows that both variables contribute 61.1% ($R^2 = 0.611$) to the variation in digital literacy competence, while the remaining 38.9% is influenced by other factors beyond the scope of this study. Higher levels of educational game integration are associated with increased student ability to access, evaluate, and utilize digital resources, as the interactive nature of game-based learning supports engagement and understanding. Likewise, effective learning management enables teachers to organize and implement digital learning more systematically, creating an environment that supports the development of students' digital skills.

Overall, the study demonstrates that improving digital literacy in vocational mathematics learning requires both well-designed educational games and strong learning management practices. The success of digital-era mathematics instruction therefore depends not only on subject mastery but also on the strategic use of learning technologies supported by structured instructional management. Future research should include mediating variables such as motivation or self-regulated learning to provide a more comprehensive explanation of digital literacy development.

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