



Innovative strategies for strengthening learning process management in high schools in the digital era

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ABSTRACT

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Teachers must be able to plan, prepare, manage, and implement the learning process effectively. However, in practice, teachers still face difficulties in the learning process, even with the assistance of digital technology. Research is urgently needed to create an effective and efficient learning process that improves learning management and motivates students to achieve digital learning outcomes. The novelty of this research lies in the integration of technology-based learning, digital collaborative learning, and personalized learning within a single learning framework. The research aims to analyze the role of digital technology, the role of teachers, supporting factors for implementation, and evaluate student perceptions. The research approach uses a mixed methods approach. The research sample consisted of 5,000 students and 500 teachers who were surveyed, and 120 students and 30 teachers who were interviewed. Data collection techniques used questionnaires, interviews, and documents. Data analysis techniques used linear regression and thematic analysis. The results showed that the technology-assisted learning process significantly influenced the effectiveness of learning management ($\beta = 0.41$; $p < 0.001$), digital collaborative learning ($\beta = 0.38$; $p < 0.001$), and personalized learning ($\beta = 0.36$; $p < 0.001$), with an average effectiveness score of 3.92. The role of teachers in training students in digital learning is very significant. In conclusion, digital technology improves learning effectiveness but requires continuous training for teachers. Practical implementation encourages policy strengthening, teacher and student training, and additional digital facilities in schools.

Contribution/Originality: This study contributes to the learning management literature. It uses a new mixed methods estimation methodology and produces a new learning formula. It is among the few to investigate learning integration and provides a logical analysis of implementation factors. Key contributions increase effectiveness, and the study documents roles and implementation.

1. INTRODUCTION

1.1. Research Background

The development of digital technology today has brought significant changes to aspects of the sustainability of people's lives, including in education (Burbules, Fan, & Repp, 2020). In today's digital era, technology is driving transformation in the management of the learning process, which requires educators and students to adapt to

technological innovations in understanding learning and achieving results (Abulibdeh, Baya Chatti, Alkhereibi, & El Menshaw, 2025; Strielkowski, Grebennikova, Lisovski, Rakhimova, & Vasileva, 2025). With digital technology, it becomes easier to access learning resources and opens opportunities for teachers to develop models and strategies for more innovative, effective, and meaningful learning processes (Honcharuk, Bugaenko, Shevchuk, Liubchenko, & Bezlatnia, 2024). UNESCO data shows that 90% of countries in the world have integrated digital technology into the education process (Alam, Stoica, Sharma, & Özgöbek, 2025). A World Bank report invests in educational technology for the purpose of improving the quality of education by facilitating access to learning resources (Aslam et al., 2024; Samala et al., 2025). In developed countries such as the United States and European countries, the implementation of learning methods that rely on technology has proven successful in increasing students' enthusiasm for learning and improving their academic results (McGee et al., 2024; Tareke, Oo, & Jozsa, 2025). Research at Stanford University shows that using digital learning platforms can improve student learning outcomes by up to 20% (Sun et al., 2024). However, in Indonesia, the challenges and obstacles educators face in the digital age are increasingly complex. According to data from the Central Statistics Agency, digital literacy in Indonesia is below 30%, highlighting the need to improve digital skills, especially among students (Andayani et al., 2026).

Through the program of the Indonesian Ministry of Education, Culture, Research, and Technology, it has developed a Deep Learning program to facilitate access and improve the educational process (Luckyardi et al., 2024). However, there are still various problems, obstacles, and challenges that must be faced in this field, such as the lack of technological facilities in remote areas, minimal digital skills among teachers, and differences in access to technology between urban and rural areas (Kwashi, Uleanya, & Chitsauko, 2025). At the high school student level, innovative learning management strategies are urgently needed (Amirudin, Muzaki, & Nurhayati, 2025). Efficient learning management requires integrating digital technology in the right way to strengthen students' understanding in interactive and personalized teaching and learning activities (Lagos-Castillo, Chiappe, Ramirez-Montoya, & Becerra Rodríguez, 2025). Innovative learning strategies are urgently needed, such as blended learning with interactive digital assistance and obtaining learning reference sources to help and encourage student progress (Alonso, Velez, Diego Mantecón, & Heredia Oliva, 2025). However, in the field, teachers and students still have difficulty accepting effective learning models during digital learning.

1.2. Research Questions

The research questions are: 1) How can the use of digital technology improve the efficiency of learning management in secondary schools? 2) Which creative strategies are most successful in combining digital platforms and interactive learning tools to increase student participation? 3) What roles do teachers and educators have in adopting and implementing innovative digital learning strategies? 4) What factors influence the successful implementation of innovative strategies in learning management in the digital age? 5) How do students view the application of digital technology in teaching and learning, and how does it impact their motivation and learning outcomes? 6) What are the main challenges faced by schools when implementing innovative digital strategies, and what are the possible solutions?

1.3. Research Significance

With the development of technology in education experiencing significant changes, appropriate strategies are needed to improve the management of the learning process. This research aims to find new approaches that can improve the quality of teaching, learning management, and adaptation to the latest technological advances, so that education can face challenges. This research contributes to the development of science in the field of educational management and technology in education. By identifying and evaluating effective and innovative approaches, this research can serve as a reference for educators, decision-makers, and others in designing and implementing more flexible and efficient learning management to face the complexities of the future of education. This research also has

the potential to improve the performance of teachers and educational staff by using appropriate digital technology in the management and design of the learning process, from materials and assessment to evaluation, so that learning becomes more interesting, interactive, and meaningful for students. The process of managing and designing learning can encourage student motivation and participation in learning activities (Balalle, 2024; Zhang, Dewitt, & Cheah, 2025). The use of innovative digital strategies can contribute to creating a more engaging and relevant learning environment, improving students' learning outcomes and academic achievement (Ammar, Al-Thani, & Ahmad, 2024). By conducting research, it becomes a new breakthrough for rural schools in helping schools implement learning with technology-based learning management that is innovative, effective and sustainable.

1.4. Novelty and Questions in Research

In today's technological developments, educators face challenges in managing learning management (Raza & Akhter, 2024). Balancing traditional learning methods with the needs of technology is essential to ensure the continuity of students' education in effective learning (Emma, 2026). Unfortunately, many schools in developing countries still rely on traditional management methods and do not utilize digital-based learning processes (Farisia, Santoso, Suyono, & Kusumaningrum, 2025). One of the challenges in improving teaching quality and student learning outcomes is having innovative, appropriate, and adaptable strategies to help manage the learning process. The need to formulate such innovative strategies is urgent. The world of education must adapt to technological advances, including the use of new learning platforms, educational apps, and other interactive tools (García-Holgado, Moreira, & Fonseca, 2024). The uniqueness of this approach lies in the comprehensive integration of technology into learning management at the secondary school level. This innovative strategy not only makes technology an additional element but also significantly transforms the management of the learning process. By developing a personalized learning platform that leverages digital technologies such as artificial intelligence, data analysis can directly demonstrate student progress and leverage the capabilities of technology. This approach contributes to creating a more responsive, efficient, and effective learning environment in the digital age and bridges the educational gap for the younger generation.

1.5. Research Purposes

The main objective of this study is to investigate the role of digital technology in enhancing the effectiveness of learning management in high schools in the digital age. The specific objectives of this study are: 1) to identify innovative strategies for integrating digital platforms, interactive media, and data-driven approaches to improve student engagement, motivation, and learning outcomes. 2) to investigate the role of teachers in designing, implementing, and assessing digital learning, along with the competencies needed to support these changes. 3) to identify factors that influence successful implementation, including infrastructure, school policies, and human resource preparation. 4) to analyze students' views on the use of digital technology and its effects on their learning experiences.

2. LITERATURE REVIEW

2.1. Technology-Enhanced Learning Theory

This theory encompasses the use of technology, such as online learning platforms, educational applications, and interactive multimedia, in teaching and learning activities. Schools can implement a Learning Process Management System (LMS) to support digital planning, material distribution, assignments, assessment, and evaluation (Herniawati, Holifah, & Syakur, 2025). Teachers can also utilize learning videos, online tests, and virtual discussions to increase student participation (Balalle, 2024). Digital models provide opportunities for more dynamic and adaptable learning, reaching learners with diverse backgrounds and residences in different locations (Price & Winchester, 2025). Technology can be used to measure student learning progress in real-time, enabling teachers to

provide quick and targeted feedback (Picasso, 2024). However, in the use of digital in learning management, effective implementation is needed through technical training for teachers and equipped with adequate supporting infrastructure.

H₁: The implementation of technology-based learning through the use of LMS and interactive multimedia has a positive and significant impact on the effectiveness of learning management in high schools.

2.2. Digital Collaborative Learning Theory

This theory highlights the value of collaboration between students through digital media. Teachers can implement project-oriented learning methods and online forums that encourage students to collaborate online (Ahmed, Elenany, Albinali, El-Sayegh, & Anumba, 2025). Utilizing discussions through Google Classroom or collaboration tools such as Microsoft Teams supports good interaction and knowledge sharing (Yingxin et al., 2024). Students are trained to improve their communication, collaboration, and problem-solving skills through digital interactions. Teachers act as guides, directing conversations and assigning stimulating group assignments (Otto et al., 2024). This approach equips students to train for an increasingly digital and international workplace and enhances their enthusiasm and independence in the learning process.

H₂: The implementation of digital collaborative learning through online discussions and group work based on digital platforms has a positive and significant impact on student engagement in the learning process.

2.3. Personalized Learning Theory

This theory focuses on developing learning methods that suit the needs, interests, and learning development of each student (Strielkowski et al., 2025). In the digital age, data analysis and artificial intelligence enable education systems to automatically change content and difficulty levels (Hariyanto, Kristianingsih, & Maharani, 2025). Schools can use systems that support personalized learning, where students receive materials tailored to their individual abilities (Duque et al., 2024). Teachers act as mentors, monitoring progress and providing individual guidance. This method increases learning success because students feel more engaged and less likely to give up when faced with difficult material (Li, Dai, Li, & Guan, 2025). The use of technology also allows early identification of students who need special assistance, thus enabling rapid and appropriate intervention.

H₃: The application of personalized learning based on data analysis and artificial intelligence has a positive and significant impact on students' learning motivation and learning outcomes.

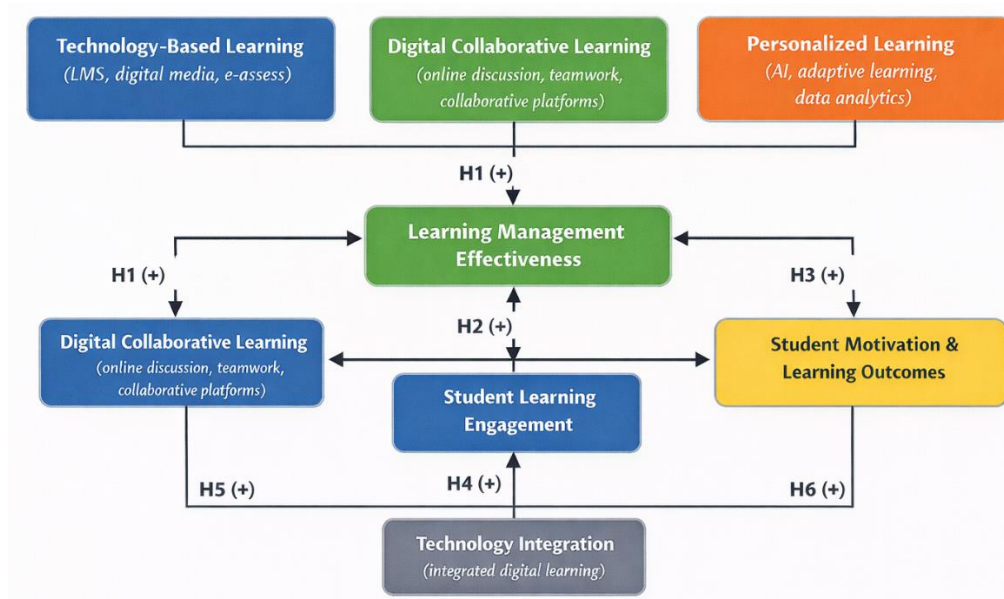


Figure 1. Research framework.

3. METHODOLOGY

3.1. Research Design

A mixed-methods research approach to investigate the contribution of digital technology in improving learning management at the senior high school level (Dahri et al., 2024) combines quantitative and qualitative data to observe measurable outcomes and gain a deeper understanding of the context. The quantitative element employs a correlational survey design to evaluate the relationship between technology-enabled learning, digital collaborative learning, and personalized learning, along with key outcomes such as learning management effectiveness, student engagement, motivation, and academic achievement. Data were collected through structured questionnaires distributed to students and teachers, then analyzed using statistical methods to test hypotheses. The qualitative element employs a descriptive approach, utilizing interviews, classroom observations, and document analysis to investigate teachers' roles, implementation practices, and barriers faced when adopting innovative digital strategies. Evidence from this qualitative data provides sufficient context to complement and strengthen the results from the quantitative data. A simultaneous triangulation strategy was applied, allowing for the concurrent collection and analysis of both data sets, which were then combined to ensure alignment and enhance the validity of the research findings. By integrating these two approaches, the research design offers a comprehensive understanding of digital learning management, enabling the experimental model to be supported by contextual interpretations. This design is considered ideal for formulating evidence-based recommendations that can achieve effective and sustainable digital transformation in upper secondary education.

3.2. Participants and Sample Size

The sample for this study consisted of students and teachers from several public and private high schools implementing digital learning methods in Makassar. Respondents were selected collaboratively to gain an in-depth understanding of digital learning management, including instructional design, implementation, and student learning experiences. Students served as the primary respondents to assess engagement, motivation, and learning outcomes, while teachers provided perspectives on teaching strategies, technology integration, and learning management practices. A stratified random sampling method ensured adequate representation across grade levels, academic tracks, and school types. This approach served to reduce bias in sample selection and increase the generalizability of the findings. Schools were first stratified by location (urban and semi-urban), and then classes and participants were randomly drawn from each group. For the qualitative aspect, a purposive sampling technique was applied to select teachers and principals with extensive experience in using digital learning, resulting in richer and more relevant data. The quantitative sample consisted of 5,000 students and 500 teachers. This sample size is sufficient for statistical analysis and hypothesis testing, particularly for multivariate techniques such as structural equation modeling. The sample size also allows for reliable estimates of the relationships between variables related to technology-assisted learning, digital collaboration, and face-to-face learning. In the qualitative phase, 120 students and 30 teachers and educational leaders participated in in-depth interviews, in addition to classroom observations. This number was deemed sufficient to achieve data saturation, as no new issues emerged. All participants were informed about the study's purpose and provided voluntary consent. Confidentiality and anonymity were strictly maintained. Overall, participant selection and sample size aimed to reach valid, reliable, and meaningful conclusions regarding the management of innovative digital learning in upper secondary education.

3.3. Measure Instruments

This study utilized integrated data collection methods to support the use of mixed methods. Quantitative data were obtained through a structured questionnaire survey administered to students and teachers in secondary schools that have implemented technology-based learning. The questionnaire aimed to assess respondents' views on the implementation of technology-supported learning, digital collaborative learning, and personalized learning, and their

impact on the effectiveness of learning management, student engagement, motivation, and academic outcomes. The questionnaire was distributed online through the school's digital platform to increase efficiency and response rates. The rating scale used was a Likert scale ranging from 1 to 5, from strongly disagree to strongly agree. Qualitative data were obtained through in-depth interviews, classroom observations, and document analysis. Semi-structured interviews were conducted with teachers and principals to explore their experiences, implementation strategies, and barriers in managing digital-based learning. Classroom observations were conducted to directly observe technology-based learning practices, interactions between teachers and students, and the use of digital platforms. Additionally, documents such as lesson plans, digital modules, and school policies were analyzed to strengthen understanding of the context and validate the data obtained from the interviews and observations.

Table 1. Instruments for measuring learning process management in high school in the digital era.

Variables	Indicators	Statement Items
Technology-Enhanced Learning (X1).	LMS Usage	1. LMS is used consistently in learning. 2. Learning materials are easily accessible through the LMS. 3. The LMS facilitates assignment submission. 4. The LMS supports learning evaluation. 5. Teachers actively utilize the LMS. 6. The LMS helps manage learning time. 7. The LMS enhances learning interaction. 8. The LMS is easy for students to use. 9. The LMS supports independent learning.
	Digital Media Utilization	1. Teachers use digital learning videos. 2. Digital media enhances understanding of the material. 3. Digital media makes learning engaging. 4. Digital media is relevant to the material. 5. Digital media is easily accessible. 6. Digital media supports learning variations. 7. Digital media is used consistently. 8. Digital media improves learning focus. 9. Digital media meets student needs.
Digital Collaborative Learning (X2).	Digital Infrastructure Support	1. Internet access is readily available. 2. Digital devices are available at the school. 3. The internet network is stable. 4. The school supports the use of technology. 5. The digital system rarely experiences disruptions. 6. The school provides technical assistance. 7. Infrastructure supports online learning. 8. Digital facilities are easy to use. 9. Infrastructure supports learning effectiveness.
	Digital Collaborative Interaction	1. Students discuss through digital platforms. 2. Online collaboration is effective. 3. Digital platforms support group discussions. 4. Students actively share ideas online. 5. Digital discussions improve understanding. 6. Teachers facilitate online collaboration. 7. Digital collaboration increases participation. 8. Students feel comfortable discussing online. 9. Digital discussions are integrated with learning.
Personalized Learning (X3).	Digital-Based Group Work	1. Group assignments are done online. 2. Digital platforms facilitate group work. 3. Students share assignments digitally. 4. Group work increases accountability. 5. Digital collaboration is fair. 6. Students provide feedback. 7. Teachers monitor digital group work. 8. Group work improves social skills. 9. Digital group work is effective.

Variables	Indicators	Statement Items
Learning Management Effectiveness (Y).	Digital Communication	1. Teacher-student communication runs smoothly.
		2. Students easily ask questions online.
		3. Teachers are responsive through digital media.
		4. Digital communication improves material clarity.
		5. Digital media supports two-way communication.
		6. Learning information is delivered in a timely manner.
		7. Digital communication reduces learning barriers.
		8. Students actively communicate online.
		9. Digital communication supports collaboration.
	Adaptive Learning	1. Material is tailored to student abilities.
		2. The digital system adjusts to the level of difficulty.
		3. Students learn at their own pace.
		4. Adaptive learning improves understanding.
		5. Teachers utilize student learning data.
		6. The system provides Learning recommendations.
		7. Adaptive learning reduces learning difficulties.
		8. Students feel supported by the adaptive system.
		9. Adaptive learning increases effectiveness.
	Learning Progress Monitoring	1. Learning progress is monitored digitally.
		2. Teachers are aware of student progress.
		3. Learning data is available in real time.
		4. Monitoring helps evaluate learning.
		5. Students are aware of their learning progress.
		6. The system provides automatic feedback.
		7. Monitoring helps improve learning.
		8. Learning data is used for guidance.
		9. Monitoring improves learning outcomes.

Table 1 presents instruments for measuring technology-based learning management. The main variables in this study are technology-enhanced learning, digital collaborative learning, personalized learning, and learning management effectiveness. The table shows several indicators for each variable: LMS use, digital media utilization, infrastructure support, collaborative interaction, digital-based group work, and digital communication. The table also includes indicators for adaptive learning and progress monitoring. All items reflect how technology is consistently used to enhance interaction, accessibility, and overall learning effectiveness.

3.4. Validity and Reliability

The validity and reliability of the research tools were carefully examined to ensure the accuracy and consistency of the collected data. Content validity was assessed through evaluation by experts in educational technology and learning management.

These experts assessed each item in the questionnaire to ensure its alignment with the theoretical concepts of technology-based learning, digital collaborative learning, personalized learning, and efficient learning management. To assess construct validity, factor analysis was conducted, with items with factorial loading coefficients greater than 0.50 considered valid indicators of the construct. This process ensured that each item represented the intended variable (Al-Khadher et al., 2024). Reliability testing was conducted to assess the internal consistency of the measuring instrument. Cronbach's alpha coefficients were calculated for each variable and indicator. A Cronbach's alpha value of 0.70 or higher is considered an acceptable benchmark of reliability, indicating that the items within each construct consistently measure similar concepts (Yunus & Ismail, 2024).

The combined reliability scores were then analyzed to improve the reliability assessment, particularly in multivariate analysis. Overall, the research findings indicate that the tool used in this study is valid and reliable, making it suitable for measuring the implementation of digital learning and the efficiency of learning management in secondary schools.

3.5. Data Analysis

The data analysis technique began with a quantitative approach to examine the relationships and influences between variables, followed by qualitative analysis to deepen and strengthen the quantitative findings. In the quantitative stage, the analysis started with descriptive statistics to describe respondents' characteristics and response patterns for each research variable.

These included the mean, standard deviation, minimum, and maximum values, providing an overview of the implementation level of technology-assisted learning, digital collaborative learning, personalized learning, and the effectiveness of learning management. Subsequently, initial testing was conducted, including normality tests, multiple linear correlation tests, and variance tests to ensure data met the assumptions of advanced statistical analysis. Hypotheses were tested using inferential statistics; relationships and influences between variables were analyzed using multiple regression or structural equation modeling (SEM).

This assessed the direct impact of technology-assisted learning, digital collaborative learning, and personalized learning on learning management effectiveness, student engagement, motivation, and learning outcomes. The significance level was set at $p < 0.05$ to determine hypothesis acceptance or rejection. Parallel qualitative data from interviews, classroom observations, and document analysis were analyzed using thematic techniques, including data reduction, presentation, and conclusion drawing.

Interview transcripts were coded to identify key themes related to digital learning strategies, teacher roles, challenges, and solutions. Qualitative findings provided context and interpretation that enriched the quantitative results. The final analysis stage used triangulation, comparing and combining results for comprehensive conclusions.

4. RESULTS

In this results section, the analysis of innovative strategies for strengthening the management of digital learning processes in high schools.

Table 2. Descriptive statistics results of research variables.

Research Variables	N	Mean	Standard Deviation	Minimum	Maximum
Technology-Enhanced Learning (X1)	5,500	3.87	0.62	2.10	4.95
Digital Collaborative Learning (X2)	5,500	3.79	0.65	2.00	5.00
Personalized Learning (X3)	5,500	3.68	0.70	1.95	4.90
Learning Management Effectiveness (Y)	5,500	3.92	0.58	2.20	5.00

The results of the descriptive statistical analysis in Table 2 show that all research variables are in the high category. The variable "Technology-Enhanced Learning" (X1) has a mean of 3.87 and a standard deviation of 0.62, indicating that the use of learning management systems and digital media has been implemented consistently and relatively evenly in secondary schools.

The variable "Digital Collaborative Learning" (X2) recorded a mean of 3.79, indicating that digital collaborative activities such as online discussions and virtual group work were implemented very effectively, although there was some variation among respondents.

The variable "Personalized Learning" (X3) obtained a mean of 3.68 with the highest standard deviation (0.70), indicating that adaptive learning has been implemented but is not yet fully uniform. The variable "Learning Management Effectiveness" (Y) achieved the highest mean, 3.92, reflecting respondents' perceptions of effective digital learning management.

Table 3. Preliminary analytical test results.

Test Types	Variables / Statistics	Statistical Value	Criteria	Decision
Normality Test (Kolmogorov–Smirnov)	Technology-Enhanced Learning (X1)	Sig. = 0.087	Sig. > 0.05	Normal
	Digital Collaborative Learning (X2)	Sig. = 0.094	Sig. > 0.05	Normal
	Personalized Learning (X3)	Sig. = 0.081	Sig. > 0.05	Normal
	Learning Management Effectiveness (Y)	Sig. = 0.102	Sig. > 0.05	Normal
Multiple Linear Correlation Test (Pearson)	X1 – Y	r = 0.624	p < 0.05	Significant
	X2 – Y	r = 0.598	p < 0.05	Significant
	X3 – Y	r = 0.572	p < 0.05	Significant
Multicollinearity Test	Tolerance (X1)	0.72	> 0.10	No multicollinearity
	VIF (X1)	1.38	< 10.00	No multicollinearity
	Tolerance (X2)	0.69	> 0.10	No multicollinearity
	VIF (X2)	1.45	< 10.00	No multicollinearity
	Tolerance (X3)	0.67	> 0.10	No multicollinearity
	VIF (X3)	1.49	< 10.00	No multicollinearity
Homogeneity of Variance Test (Levene's Test)	Independent Variable to Y	Sig. = 0.112	Sig. > 0.05	Homogeneous variance

Table 3 shows that all information from this study meets the basic statistical requirements for further analysis. The Kolmogorov-Smirnov normality test indicates that all variables have a significance value above 0.05, suggesting the data have a normal distribution and are suitable for regression analysis and structural equation modeling. The Pearson correlation test indicates a strong and statistically significant relationship between the independent and dependent variables. Technology-supported learning showed the strongest correlation with the effectiveness of learning management ($r = 0.624$), followed by digital collaborative learning ($r = 0.598$) and personalized learning ($r = 0.572$). These findings confirm that the application of technology, digital collaboration, and personalized learning significantly improve the quality of learning management. The multicollinearity test showed a tolerance value above 0.10 and a VIF value below 10, indicating there is no very strong relationship between the independent variables. Furthermore, the homogeneity of variance test (Levene's test) showed a statistical significance value of 0.112, indicating homogeneity of variance in the data.

Table 4. Results of research hypothesis testing.

Hypothesis	Description	Dependent Variable	β	p-value	Decision
H1	There is a positive and significant influence of technology-based learning on the effectiveness of learning management.	Learning Management Effectiveness	0.41	0.000	Accepted
H2	Digital collaborative learning has a positive and significant influence on student learning engagement.	Student Learning Engagement	0.38	0.000	Accepted
H3	Personalized learning has a positive and significant impact on motivation and learning outcomes.	Student Motivation and Learning Outcomes	0.36	0.000	Accepted
H4	Technology integration significantly increases student engagement and motivation.	Student Engagement and Motivation	0.34	0.001	Accepted
H5	Digital collaboration supports the effectiveness of learning management.	Learning Management Effectiveness	0.32	0.002	Accepted

H6	Personalized learning improves the effectiveness of management and student learning outcomes.	Management Effectiveness and Learning Outcomes	0.35	0.000	Accepted
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The results of the hypothesis testing presented in Table 4 show that all hypotheses in this study were accepted with probability values below 0.05, indicating a statistically significant positive influence between these variables. The first hypothesis (H1) indicates that technology-based learning has a strong impact on the effectiveness of learning management ($\beta = 0.41$), suggesting that the implementation of learning management systems, digital media, and electronic assessment systems are important elements in improving the quality of learning management. The second hypothesis (H2) indicates that digital collaborative learning has a statistically significant influence on student engagement in the learning process ($\beta = 0.38$), emphasizing the importance of online discussions and digital collaboration in increasing student participation. The third hypothesis (H3) confirms that personalized learning has a positive impact on motivation and learning outcomes ($\beta = 0.36$), indicating that adaptive and data-driven learning can meet students' unique needs. The fourth and fifth hypotheses (H4 and H5) support the previous findings by showing that the combination of technology use and digital collaboration both contribute to increased engagement, motivation, and effectiveness of learning management. The sixth hypothesis suggests that personalized learning not only impacts student learning outcomes but also contributes to the effectiveness of overall learning management. This finding emphasizes that integrated digital learning strategies are key to improving the quality of education in this digital age.

Table 5. Results of coding thematic analysis of qualitative data.

Data Sources	Open Coding	Category	Main Themes	Description of Findings
Teacher Interviews	Regular use of LMS	Implementation Strategy	Digital Learning Strategies	Teachers utilize an LMS for material distribution, assignment submission, and structured learning evaluation.
Teacher Interviews	Integration of interactive digital media	Implementation Strategy	Digital Learning Strategies	Learning videos, online quizzes, and multimedia are used to enhance student understanding.
Classroom Observations	Active online discussions	Digital Collaboration	Digital Collaborative Learning	Students are actively involved in group discussions through digital platforms.
Student Interviews	Group work based on digital platforms	Digital Collaboration	Digital Collaborative Learning	Collaborative learning encourages participation, communication, and teamwork.
Teacher Interviews	Teachers as facilitators	Teacher Role	The Role of Teachers in Digital Learning	The teacher's role shifts from providing material to facilitator and learning assistant.
Classroom Observations	Monitoring student learning progress	Teacher Role	The Role of Teachers in Digital Learning	Teachers regularly monitor student learning progress through digital data.
Teacher Interviews	Infrastructure limitations	Challenges	Implementation Challenges	Main obstacles include unstable internet connections and limited devices.
Student Interviews	Difficulties adapting to technology	Challenges	Implementation Challenges	Some students still experience difficulties using digital platforms.
Document Analysis	School policies on digital learning	Institutional Support	Supporting Factors	The school provides policies and guidelines for the use of learning technology.
Teacher Interviews	Technology usage training	Solutions	Implementation Solutions	Teacher training and mentoring increase readiness for digital learning.
Document Analysis	Digital module development	Solutions	Implementation Solutions	The use of digital modules helps standardize and enhance learning effectiveness.
Teacher and Student Interviews	More flexible and personalized learning	Impact	Implementation Impacts	Digital learning increases student flexibility, motivation, and engagement.

Table 5 displays the results of the qualitative data analysis, which complement the quantitative data. Interviews with teachers and classroom observations indicate that learning management systems (LMS) are consistently used to disseminate materials, collect assignments, and assess learning. The use of interactive digital media, such as educational videos and online quizzes, has been shown to improve student understanding. In terms of collaboration, students actively engage in online discussions and group work across various digital platforms, which helps improve communication and collaboration skills. The role of teachers has changed significantly, from simply providing materials to facilitators and mentors guiding the learning process. Teachers also utilize digital data to continuously monitor student progress. However, the study also identified key challenges, including limited infrastructure and difficulties for some students in adapting to technology. To address these issues, schools are implementing various solutions, such as technology training for teachers, developing digital modules, and policies supporting digital learning.

Table 6. Results of quantitative and qualitative data triangulation.

Aspects Analyzed	Quantitative Results	Qualitative Results	Integration Results (Triangulation)
Technology-Based Learning	Technology-enhanced learning has a positive and significant effect on the effectiveness of learning management ($\beta = 0.41$; $p < 0.05$).	Teachers consistently use the LMS, digital media, and online evaluation system.	Quantitative findings are reinforced by actual practice using LMS and digital media, which enhances the effectiveness of learning management.
Digital Collaborative Learning	Digital collaborative learning has a significant effect on student learning engagement ($\beta = 0.38$; $p < 0.05$).	Observations show active online discussions and group work based on digital platforms.	Student learning engagement increases due to the support of structured digital collaborative activities.
Personalized Learning	Personalized learning has a significant effect on student motivation and learning outcomes ($\beta = 0.36$; $p < 0.05$).	Teachers utilize learning data to adjust materials and students' learning pace.	Quantitative and qualitative data consistently demonstrate that personalized learning improves motivation and learning outcomes.
Teacher Role	Technology integration increases student engagement and motivation ($\beta = 0.34$; $p < 0.05$).	Teachers act as facilitators and mentors in digital learning.	The shift from teacher role to facilitator supports increased student engagement and motivation.
Implementation Challenges	Not directly measured in the regression model.	Infrastructure limitations and students' technological adaptability.	Qualitative findings complement the limitations of quantitative data by uncovering factors hindering implementation.
Implementation Solutions	Learning effectiveness remains high despite variations in school conditions.	Teacher training, school policies, and digital module development.	Institutional solutions and improved teacher competency are key factors in successful implementation.
Impact of Digital Learning	Improved effectiveness of learning management and learning outcomes.	Learning is more flexible, interactive, and personalized.	Data integration shows that digital learning has a positive impact on students' academics and learning experiences.

The triangulation results listed in Table 6 demonstrate a strong relationship between the quantitative and qualitative results. The significant positive influence of technology-based learning on the effectiveness of learning management is reinforced by teachers' use of learning management systems and digital media. Furthermore, the significant influence of digital collaborative learning on student engagement is supported by input from active online discussions and collaboration within digital teams. Personalized learning, which quantitatively impacts motivation

and learning outcomes, is further strengthened by the practice of adapting materials and learning pace based on student data. The role of teachers as facilitators and mentors is vital to the successful implementation of technology in learning. Furthermore, the triangulation results indicate that implementation challenges, such as infrastructure deficiencies and technology adaptation, were not fully detected in the quantitative analysis but were identified through the qualitative data. Institutional solutions, such as teacher training, school-level policies, and the development of digital modules, were proven to support the success of digital learning. The triangulation data analysis results confirm that integrated digital learning strategies have a significant positive impact on the effectiveness of learning management and the learning experience for students.

5. DISCUSSION

5.1. Innovative Strategies for Integrating Digital Platforms, Interactive Media, and Data-Driven Methods

Creative strategies that integrate digital platforms, interactive media, and data-driven methods have proven successful in increasing student participation and enthusiasm for learning, as well as improving educational outcomes in the Makassar region. Numerically, technological developments in learning have the strongest influence on the success of learning management ($\beta = 0.41$; $p < 0.001$). These results indicate that the use of a Learning Management System (LMS), learning videos, interactive quizzes, and digital assessments can create a more planned, flexible, and accessible learning environment for students. Online collaborative learning significantly contributes to student engagement ($\beta = 0.38$; $p < 0.001$). Active discussions and collaboration based on digital platforms encourage greater participation, exchange of ideas, and the development of social and critical thinking skills. Meanwhile, personalized, data-driven, and adaptive learning has a positive impact on student motivation and learning outcomes ($\beta = 0.36$; $p < 0.001$), because teaching materials are tailored to each student's abilities and learning pace. These results are in line with technology-based learning theory, digital collaborative theory, and personalization theory, which emphasize that technology integration is not only technical but also pedagogical, based on the needs of students (Maqbool, Asif, Imran, Bibi, & Almusharraf, 2024). The consistency of these results with previous studies shows that well-designed digital learning can improve the quality of the process and outcomes of learning (Endo, Busari, & Ibrahim, 2025).

5.2. The Role and Competence of Teachers in Designing, Implementing, and Evaluating Digital Learning

Teacher competency has been shown to play a crucial role in the success of digital transformation in the teaching and learning process. Qualitative research findings demonstrate a shift in teacher function from simply conveying information to facilitating, guiding, and managing data-driven learning. Quantitatively, teacher technology implementation resulted in significant increases in student engagement and motivation ($\beta = 0.34$; $p < 0.05$). In designing digital learning, teachers played a key role in selecting appropriate platforms, creating interactive materials, and planning collaborative activities and tailored learning. During implementation, teachers ensured the effective use of learning management systems (LMS), digital media, and online communications. Furthermore, teachers utilized data from learning outcomes and digital analytics to assess student progress and provide timely feedback. These findings support the theory of technology-enabled learning, which demonstrates the importance of teacher competency in using technology as an educational tool (Shaikh, 2025). This research is in line with previous studies showing that digital skills, digital pedagogical expertise, and reflective thinking skills among teachers are crucial for the success of technology-based learning (Robandi et al., 2025). Without teacher preparation and skills, technology often serves only as an administrative tool, not a means of improving teaching quality. Therefore, this research shows that digital change in education is closely linked to ongoing teacher capacity building through training, guidance, and support from institutions and the government.

5.3. Factors Influencing the Success of Digital Learning Implementation

The success of digital learning implementation is influenced by three key elements: technological infrastructure, school policies, and human resource preparation. Qualitative research findings indicate that limited and inconsistent internet connectivity, along with a lack of digital devices, remain major barriers in some schools. This leads to inconsistent implementation of personalized learning, as indicated by the high standard deviation for this variable (0.70). Conversely, schools with clear digital learning policies, support from school management, and teacher training programs demonstrated more efficient learning management. This demonstrates that technology alone is not sufficient and must be accompanied by responsive educational governance and management. These findings align with digital education management theory, which highlights the importance of institutional support and school leadership in learning innovation (Mukhtar, Razak, Setiyowati, & Adni, 2025). The consistency of these findings with previous research strengthens the argument that structural and organizational aspects play a crucial role in the success of digital learning, especially in developing countries (Barikzai, Bharathi S, & Perdana, 2024). Previous research also emphasized that the allocation of funds for facilities and human capacity building has a long-term effect on the quality of digital education (Elfaki & Ahmed, 2024). The results of this study indicate that successful implementation of digital learning results from collaboration between technology, policy, and human resource readiness, and does not solely depend on the sophistication of the system used.

5.4. Student Perceptions of Digital Technology Use and Its Impact on the Learning Experience

At the high school level, students expressed positive views about the use of digital technology in the teaching and learning process, both in terms of interaction and motivation, as well as their overall learning experience. The high mean score for the learning management effectiveness variable (mean = 3.92) indicates that students recognize the tangible benefits of digital learning. They perceive digital learning as more flexible, interactive, and tailored to individual needs. Interactive media and engaging discussions boost student engagement with the learning material, while personalized learning makes students feel individually cared for. This has a positive impact on students' internal motivation and confidence in the learning process. These findings support the theory of personalized learning, which states that personalized learning increases students' emotional and cognitive engagement at the high school level (Kyambade, Namatovu, & Male Ssentumbwe, 2025). Previous research shows that technology-based learning not only impacts academic achievement, but also student satisfaction and enjoyment during the learning process (Qi, Liu, Li, Wang, & Liu, 2025). However, the study also showed that some students still experience challenges in adapting to technology, especially those with less digital knowledge.

6. CONCLUSION

6.1. Theory Implications

This research provides important theoretical insights for the development of digital learning management studies at the senior secondary level. The results of this study strengthen the theory of technology-assisted learning by demonstrating that technology is not simply a tool to assist learning but also a strategic part of improving learning management.

The empirical findings, which demonstrate that technology-assisted learning has the greatest impact, emphasize the importance of systematically integrating technology, pedagogy, and classroom management. These results extend the theory of digital collaboration by demonstrating that online collaboration not only influences student participation but also directly contributes to the effectiveness of overall learning management. This emphasizes the need to view digital collaborative learning as a management strategy, not just a teaching method. The results also enrich the theory of personalized learning by demonstrating that a data-driven approach not only improves student motivation and learning outcomes but also assists teachers in pedagogical decision-making and improves the efficiency of learning management. In this way, this study combines these three theories into a cohesive and contextual

conceptual framework, which is highly relevant for secondary schools in developing countries. Theoretically, this study confirms that the success of digital learning depends on the collaboration between technology, the role of teachers, and innovative learning management systems.

6.2. Practical Implications

Practically, the results of this study have important implications for schools, teachers, educational policymakers, and administrators. For schools, the results emphasize the importance of strengthening the management of the teaching and learning process, incorporating interactive media, and utilizing learning data as a basis for academic decision-making. Schools are advised not only to provide technology but also to manage it wisely in the planning, implementation, and evaluation of learning. For teachers, the study highlights the importance of enhancing digital pedagogical skills, including the ability to design interactive learning, organize online collaboration, and use student learning data for personalized learning. Training programs for teachers should focus not only on technical skills but also on strengthening their roles as facilitators and mentors in digital learning. For policymakers, the study demonstrates the importance of education policies that support sustainable digital transformation, including investment in infrastructure, ensuring equitable access to technology, and developing human resources. Furthermore, students' positive views of digital learning suggest that technology-based innovation policies can improve motivation, participation, and the overall quality of students' learning experiences.

6.3. Research Limitations and Suggestions

A limitation of this study is that it was conducted in a high school implementing digital learning, so the results may not fully reflect schools with lower levels of technological readiness, particularly in remote locations. Quantitative data relied heavily on participant feedback through questionnaires, which may be affected by individual bias. This study employed a cross-sectional design and therefore cannot accurately demonstrate the long-term effects of digital technology implementation on the effectiveness of learning management and student academic achievement. Despite the mixed-methods approach, in-depth research into student psychology and personal learning styles is still limited. Given these limitations, further research using a longitudinal design is recommended to monitor the long-term effects of digital learning. Future research could also expand the sample size to include areas with limited facilities and explore the role of AI-based technologies in more depth. Furthermore, comparative studies across countries or different educational levels could enhance generalizability and the development of digital learning management theory.

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Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.

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