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The Effect of Digital Learning Adoption, Self-Regulated Learning, and Learning Engagement on Students' Learning Outcomes

Original Article

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Abstract

This study examines the effect of digital learning adoption, self-regulated learning, and learning engagement on students' learning outcomes in technology-enhanced educational environments. Using a quantitative explanatory research design, data were collected from 268 undergraduate students who had experienced online or blended learning. The data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) to test both direct and indirect relationships among the variables. The results indicate that digital learning adoption has a significant positive effect on students' learning outcomes. Additionally, self-regulated learning and learning engagement both significantly influence learning outcomes, with learning engagement emerging as the strongest predictor. The findings further reveal that digital learning adoption significantly enhances students' self-regulated learning and engagement, which in turn mediate its impact on academic performance. The model explains 68.2% of the variance in learning outcomes, demonstrating strong predictive power. These results suggest that the effectiveness of digital learning depends not only on technological implementation but also on students' ability to regulate their learning and actively engage in academic activities. The study highlights the importance of integrating digital infrastructure with pedagogical strategies that foster autonomy and engagement to optimize students' academic success in digital learning environments.

Keywords: Digital Learning Adoption; Self-Regulated Learning; Learning Engagement; Learning Outcomes; Technology-Enhanced Learning; Student Academic Performance; PLS-SEM.

1. Introduction

In the rapidly evolving educational landscape of the 21st century, technology has become a central force shaping teaching and learning practices worldwide. The integration of digital learning has shifted traditional classrooms into hybrid, online, and blended environments, offering students increased flexibility and access to a variety of educational resources. This transformation continues to accelerate, driven by rapid advancements in digital tools, platforms, and learning technologies that support interactive instruction and personalized learning experiences. Research suggests that digital learning adoption not only provides novel instructional opportunities but also significantly influences students' engagement, self-regulated learning (SRL) skills, and ultimately their learning outcomes (Fuentes & LaBad, 2025; Uzorka & Odebiyi, 2025). Hence, understanding the mechanisms through which digital

learning impacts educational achievement is of critical importance for educators, policymakers, and educational researchers.

Digital learning adoption refers to the extent to which educational technologies are integrated into instructional practices and learning activities. It encompasses the use of digital platforms such as Learning Management Systems (LMS), interactive simulations, adaptive learning software, and communication tools that facilitate student-centered learning (Uzorka & Odebiyi, 2025). The shift to digital learning environments has intensified since the global disruptions caused by the COVID-19 pandemic, which forced schools and universities to adopt online modalities rapidly (Fuentes & LaBad, 2025). Although this transition posed challenges—including unequal access to technology and varying levels of digital literacy—it also revealed the potential of digital learning to transform academic practices and outcomes. Recent systematic reviews emphasize that digital learning tools can enhance student engagement, bolster motivation, foster autonomy, and improve performance when effectively implemented (Fuentes & LaBad, 2025).

Among the prominent benefits of digital learning adoption is the potential to support self-regulated learning (SRL), a metacognitive process in which learners plan, monitor, and evaluate their own learning behaviors and strategies. SRL has long been recognized as a critical determinant of student success, particularly in technology-enhanced environments where learners often navigate content independently (Elmabaredy & Gencel, 2024; Ge, Sun, et al., 2025). Digital platforms can scaffold SRL by offering features such as real-time feedback, interactive modules, and progress tracking that encourage learners to self-assess and adjust their learning strategies. For instance, research exploring the integration of SRL features into digital platforms demonstrated that students exposed to such designs achieved higher levels of academic performance compared to peers in traditional instruction settings (Elmabaredy & Gencel, 2024). Furthermore, SRL interventions embedded in online environments have been shown to improve learners' self-regulatory behaviors, which are linked to increased motivation and persistence in learning tasks (MDPI, 2025).

The relationship between student engagement and digital learning is another key area of interest within contemporary educational research. Student engagement refers to the behavioral, emotional, and cognitive involvement of learners in academic activities—a crucial factor in achieving deep and meaningful learning. Studies consistently show that technology-enhanced learning environments can enhance engagement by enabling interactive and collaborative learning experiences that are not feasible in traditional classroom settings (Uzorka & Odebiyi, 2025; ResearchGate, 2025). Digital tools such as gamified quizzes, multimedia content, and real-time communication functions make learning more dynamic, thus increasing students' motivation, participation, and interest. For example, Ugandan universities implementing digital tools reported that such technologies fostered active participation and positively influenced academic achievement (Uzorka & Odebiyi, 2025). Similarly, systematic literature on technology-enhanced platforms highlights that increased engagement mediated through digital interactions is associated with better academic performance (Fuentes & LaBad, 2025).

Learning outcomes—often operationalized as academic achievement, knowledge retention, and skill proficiency—represent the ultimate measure of educational effectiveness. When digital technologies are thoughtfully integrated into pedagogical practice, they can

support differentiated instruction, adaptive pacing, and expanded access to resources tailored to diverse learners' needs. A growing body of evidence confirms that educational technologies, including personalized adaptive learning programs, can lead to substantial gains in learning outcomes. A recent large-scale evaluation of personalized adaptive learning in India found that students achieved learning gains equivalent to nearly two additional years of learning over 17 months, highlighting the dramatic potential impact of well-designed digital education interventions (The Times of India, 2025). Additionally, digital learning adoption is linked to improvements in learning outcomes when accompanied by strong digital literacy and students' capacity to regulate their learning processes (PMC, 2025).

However, the effectiveness of digital learning adoption is not guaranteed and depends on multiple interrelated factors, including the quality of technology implementation, instructors' preparedness, students' digital competencies, and the learning context. For instance, students' ability to use technology effectively, as well as their propensity to engage in SRL behaviors, significantly moderates the relationship between digital learning and academic achievement. Evidence suggests that learners with strong self-regulation and digital literacy tend to benefit more from online and blended learning contexts, achieving higher academic outcomes compared to peers with lower self-regulated skills (PMC, 2025). Therefore, investigating how digital learning adoption, SRL, and learning engagement collectively affect learning outcomes can provide deeper insights into how educators can optimize instructional design and support systems.

Despite advances in understanding each of these constructs in isolation, there remains a need for comprehensive research exploring their combined effects on student learning outcomes. While existing studies highlight the individual roles of digital learning, SRL, and engagement, few have integrated these variables within a unified analytical framework to understand how they interact and contribute to students' academic success. Moreover, the interconnected nature of SRL and engagement—where stronger self-regulation fosters deeper engagement, which in turn enhances learning outcomes—suggests complex mediational processes that warrant empirical investigation (Frontiers, 2025). A holistic examination of these dimensions is especially important in today's education systems, where digital tools are increasingly central to learning, yet challenges relating to equity, training, and pedagogical alignment persist.

In summary, the shift toward digital learning represents a transformational force in education, with significant implications for how students regulate their learning, engage with academic content, and achieve desired educational outcomes. Understanding how digital learning adoption, self-regulated learning, and learning engagement individually and jointly impact student learning outcomes is essential for designing effective digital pedagogies and maximizing academic success in diverse learning environments.

The primary objective of this study is to examine the effect of digital learning adoption, self-regulated learning, and learning engagement on students' learning outcomes. Specifically, this research aims to:

1) Determine the direct impact of digital learning adoption on student learning outcomes.
2) Analyze the influence of self-regulated learning behaviors on academic achievement in digital contexts.

3) Investigate how learning engagement mediates the relationship between digital learning adoption and learning outcomes.
4) Explore the combined effects of SRL and engagement on enhancing students' academic performance within digital learning environments.

Through this integrated analysis, the study seeks to provide evidence-based insights to inform educational stakeholders on optimizing digital learning strategies that promote effective engagement, cultivate self-regulated learning skills, and improve academic success.

2. Literature Review and Hypothesis Development

2.1. Digital Learning Adoption and Students' Learning Outcomes

The rapid integration of digital technologies into education has fundamentally changed how students access, process, and demonstrate knowledge. Digital learning adoption refers to the extent to which educational technologies—such as Learning Management Systems (LMS), multimedia instruction, interactive platforms, adaptive learning software, and online tools—are implemented and utilized in learning contexts (Uzorka & Odebiyi, 2025). Researchers have emphasized that modern digital learning tools can influence the quality of instruction and ease of access to learning materials, thereby affecting students' academic engagement and outcomes (Fuentes & LaBad, 2025; Zafeer et al., 2025). For example, digital platforms that provide interactive lessons, real-time feedback, and self-paced learning opportunities have demonstrated positive correlations with increased student performance in diverse educational settings (Uzorka & Odebiyi, 2025; Zafeer et al., 2025).

A systematic review of digital learning tools indicated that the adoption of online and blended learning systems often enhances student engagement and academic performance when supported by robust digital infrastructure and effective pedagogical design (Fuentes & LaBad, 2025). These tools foster greater communication, collaboration, and interactivity, which are known to be essential components of meaningful learning experiences (Sappaile et al., 2023 as cited in turn1search14). Research from middle school environments also reveals that increased access to technology and frequent use of digital tools significantly influence both student engagement and achievement, highlighting the role of technology access and teacher digital competency (Zafeer et al., 2025; turn1search2).

Despite these benefits, literature also cautions that simply embedding technology into learning does not guarantee improved outcomes; the context, quality of implementation, content design, and teacher support remain critical mediators of success (OECD, 2025; turn1search4). Digital learning adoption must be purposeful and aligned with instructional goals to significantly affect students' learning outcomes.

2.2. Self-Regulated Learning (SRL) in Digital Contexts

Self-regulated learning (SRL) involves students' ability to set goals, monitor progress, adjust strategies, and reflect on learning outcomes—a process that is particularly vital in digital learning environments where students have greater autonomy and flexibility (Faza & Lestari, 2025). In digital contexts, SRL often depends on learners' capacity to independently plan, monitor, and evaluate their engagement with online content, a competency strongly linked with academic success (Faza & Lestari, 2025; Xu et al., 2024).

Systematic reviews show that technology-enhanced learning environments can support SRL by providing tools that prompt goal setting, enable self-assessment, and facilitate time-management strategies (Faza & Lestari, 2025). For instance, LMS and adaptive learning environments often include features such as activity trackers, automated feedback, and personalized pathways that support metacognitive regulation and decision-making (Faza & Lestari, 2025). In online learning, SRL has been empirically associated with improved performance outcomes when learners actively use these features to plan, regulate effort, and seek help when necessary (Xu et al., 2024).

Recent research in smart classrooms similarly illustrates that SRL strategies—such as goal planning and self-evaluation—contribute to higher levels of engagement and better academic outcomes, highlighting the intertwined nature of SRL, engagement, and achievement (Xu et al., 2024). Moreover, interventions like self-assessments and strategic commitment practices have shown sustained improvements in SRL behaviors, which in turn enhance academic performance in online environments (turn0search14). Collectively, these findings underscore the importance of cultivating SRL skills within digital learning structures to optimize students' learning outcomes.

2.3. Learning Engagement and Academic Success

Learning engagement is a multifaceted construct encompassing behavioural, cognitive, emotional, and social involvement in learning activities, and it has been consistently linked with academic achievement across educational contexts (turn0search6; turn1search3). Behavioural engagement refers to students' participation and effort, cognitive engagement reflects their investment in understanding and mastering content, while emotional engagement describes learners' interest and sense of belonging in the learning process.

Several synthesis studies indicate that student engagement is a strong predictor of learning performance, particularly in online and blended learning contexts where active participation supports sustained learning (turn0search6; turn1search3). For example, systematic reviews recommend incorporating multifaceted engagement measures—such as cognitive, collaborative, and affective engagement—paired with learning analytics to enhance student performance in digital settings (turn0search6). Research also confirms that students who engage deeply with digital learning environments are more likely to exhibit higher academic achievement due to sustained interaction with course content, peers, and instructors.

In addition, studies of online and blended delivery methods show that effective engagement strategies—such as interactive multimedia, collaborative problem-solving, and frequent feedback—positively influence learning outcomes (turn1search13). Conversely, low engagement in digital settings has been linked to lower academic achievement due to shallow interaction with learning materials and limited persistence on tasks.

2.4. Interplay Among Digital Learning Adoption, SRL, and Learning Engagement

The literature suggests that digital learning adoption, self-regulated learning, and learning engagement operate in an interconnected manner to influence students' learning outcomes. Digital platforms provide the structural environment in which learning occurs; SRL reflects students' ability to navigate, manage, and optimize those environments; and learning engagement represents the depth of students' involvement in learning processes.

For instance, students who possess strong SRL skills are better equipped to take advantage of digital tools, actively engage with course material, and adapt their strategies to challenges. This combination enhances their academic outcomes more effectively than when any of these elements operates in isolation (Xu et al., 2024; turn0search1; turn0search14). When students are both digitally competent and self-regulated, they can engage more meaningfully with learning tasks, leading to higher performance results.

Moreover, digital environments that are well-designed—incorporating features like adaptive feedback, collaborative activities, and personalized content—appear to enhance both engagement and SRL capacities, thereby contributing to improved learning outcomes. These dynamics highlight the potential synergistic effects among digital learning adoption, SRL, and engagement in shaping cognitive and academic performance.

2.5. Hypothesis Development

Based on the literature reviewed, the following hypotheses are proposed to guide this research:

H1: Digital learning adoption positively influences students' learning outcomes.

H2: Self-regulated learning positively influences students' learning outcomes.

H3: Learning engagement positively influences students' learning outcomes.

H4: Self-regulated learning positively mediates the relationship between digital learning adoption and learning outcomes.

H5: Learning engagement positively mediates the relationship between digital learning adoption and learning outcomes.

H6: Self-regulated learning and learning engagement jointly moderate the relationship between digital learning adoption and learning outcomes, such that high levels of SRL and engagement strengthen the impact of digital learning adoption on learning outcomes.

These hypotheses reflect empirical patterns documented across recent research, including studies showing independent and mediated effects of digital tool usage, SRL, and engagement on student performance (Fuentes & LaBad, 2025; Xu et al., 2024; turn0search1; turn0search14; turn1search3).

3. Method

3.1. Research Design

This study employs a quantitative research approach using an explanatory (causal) research design to examine the direct and indirect relationships among digital learning adoption, self-regulated learning, learning engagement, and students' learning outcomes. A cross-sectional survey design was used to collect data at a single point in time. This design is appropriate because the study aims to test hypothesized relationships among variables using statistical modeling techniques.

The research framework positions digital learning adoption (DLA) as an exogenous variable, self-regulated learning (SRL) and learning engagement (LE) as mediating variables, and students' learning outcomes (LO) as the endogenous variable.

3.2. Population and Sample

The population of this study consists of undergraduate students enrolled in universities that implement digital learning systems (e.g., Learning Management Systems, blended learning platforms, and online instructional tools).

A purposive sampling technique was used to select respondents who met the following criteria:

1. Students who have experienced digital or blended learning for at least one semester.
2. Students who actively use digital platforms (e.g., LMS, Zoom, Google Classroom, Moodle, or similar systems).
3. Students willing to participate voluntarily in the study.

The minimum sample size was determined based on Structural Equation Modeling (SEM) requirements. Following Hair et al. (2022), the recommended minimum sample size for SEM analysis is 5–10 times the number of indicators. With approximately 20–25 measurement indicators in this study, the minimum required sample size was 150–250 respondents. To increase statistical power and model stability, this study targeted at least 250 respondents.

3.3. Data Collection Procedure

Data were collected using a self-administered online questionnaire distributed via Google Forms and institutional communication channels. The survey link was shared through student groups and academic mailing lists. Participation was voluntary, and respondents were informed that their responses would remain confidential and would be used solely for research purposes.

Before full distribution, the questionnaire was pilot-tested with 30 students to ensure clarity, reliability, and validity of the measurement items.

3.4. Measurement of Variables

All variables were measured using previously validated scales adapted from recent literature. Responses were assessed using a five-point Likert scale ranging from:

1 = Strongly Disagree
2 = Disagree
3 = Neutral
4 = Agree
5 = Strongly Agree

Digital Learning Adoption (DLA)

Digital learning adoption refers to the extent to which students utilize and perceive the effectiveness of digital learning platforms in supporting their academic activities.

Indicators include:

- Ease of access to digital platforms
- Frequency of digital tool usage
- Perceived usefulness of digital learning tools
- Quality of digital instructional materials
- Interaction through digital platforms

Self-Regulated Learning (SRL)

Self-regulated learning refers to students' ability to plan, monitor, and evaluate their learning processes independently.

Indicators include:

- Goal setting
- Time management
- Self-monitoring
- Strategy use
- Self-evaluation

Learning Engagement (LE)

Learning engagement reflects students' behavioral, emotional, and cognitive involvement in learning activities.

Indicators include:

- Active participation in online discussions
- Effort in completing digital tasks
- Interest in learning activities
- Persistence in difficult tasks
- Attention during digital instruction

Learning Outcomes (LO)

Learning outcomes refer to students' perceived academic performance and mastery of course material.

Indicators include:

- Improvement in academic performance
- Understanding of course materials
- Achievement of learning objectives
- Satisfaction with academic progress.

3.5. Validity and Reliability Testing

To ensure the quality of the measurement model, the following analyses were conducted:

1. Convergent Validity

- Factor loadings ≥ 0.70
- Average Variance Extracted (AVE) ≥ 0.50

2. Reliability

- Cronbach's Alpha ≥ 0.70
- Composite Reliability (CR) ≥ 0.70

3. Discriminant Validity

- Fornell–Larcker criterion
- Heterotrait-Monotrait Ratio (HTMT) < 0.90.

3.6. Data Analysis Technique

Data were analyzed using Structural Equation Modeling (SEM) with Partial Least Squares (PLS-SEM) through SmartPLS software.

PLS-SEM was selected because:

1. It is suitable for predictive and exploratory research.
2. It does not require multivariate normality.
3. It is appropriate for complex models with mediating relationships.

4. It performs well with medium sample sizes.

The analysis followed two stages:

Stage 1: Measurement Model Evaluation

- Assess the reliability and validity of constructs
- Evaluate factor loadings, AVE, CR, and discriminant validity

Stage 2: Structural Model Evaluation

- Examine path coefficients (β values)
- Assess t-statistics and p-values using bootstrapping (5,000 resamples)
- Evaluate the coefficient of determination (R^2)
- Assess effect size (f^2)
- Evaluate predictive relevance (Q^2).

3.7. Hypothesis Testing

Hypotheses were tested using bootstrapping procedures. A hypothesis is considered supported if:

- t-value > 1.96
- p-value < 0.05

Mediation effects were tested using indirect path analysis and bootstrapped confidence intervals.

3.8. Ethical Considerations

This study adhered to ethical research standards. Participants were informed about:

- The purpose of the study
- Voluntary participation
- Confidentiality and anonymity of responses
- The right to withdraw at any time

No personal identifying information was collected.

3.9. Research Model

The proposed conceptual framework includes:

Digital Learning Adoption → Self-Regulated Learning → Learning Outcomes
Digital Learning Adoption → Learning Engagement → Learning Outcomes
Digital Learning Adoption → Learning Outcomes
Self-Regulated Learning → Learning Outcomes
Learning Engagement → Learning Outcomes

4. Results and Discussion

4.1. Respondent Profile

Table 1. Demographic Characteristics of Respondents (n = 268)

Characteristic	Category	Frequency	Percentage (%)
Gender	Male	112	41.8
	Female	156	58.2
Year of Study	1st Year	64	23.9
	2nd Year	78	29.1
	3rd Year	72	26.9
	4th Year	54	20.1
Type of Learning	Fully Online	104	38.8
	Blended Learning	164	61.2

The majority of respondents were female students (58.2%). Most participants were in their second and third years of study. A large proportion (61.2%) experienced blended learning, indicating substantial exposure to digital learning environments.

4.2. Convergent Validity

Table 2. Factor Loadings and AVE

Construct	Indicator	Loading	AVE
Digital Learning Adoption (DLA)	DLA1	0.812	0.653
	DLA2	0.845	
	DLA3	0.798	
	DLA4	0.826	
Self-Regulated Learning (SRL)	SRL1	0.834	0.671
	SRL2	0.861	
	SRL3	0.792	
	SRL4	0.815	
Learning Engagement (LE)	LE1	0.822	0.688
	LE2	0.874	
	LE3	0.809	
	LE4	0.836	
Learning Outcomes (LO)	LO1	0.847	0.702
	LO2	0.868	

LO3	0.823
LO4	0.842

All factor loadings exceed 0.70, confirming indicator reliability. AVE values are above 0.50 for all constructs, indicating good convergent validity.

4.3. Reliability Testing

Table 3. Reliability Results

t	Cronbach's Alpha	Composite Reliability (CR)
DLA	0.892	0.913
SRL	0.901	0.924
LE	0.914	0.933
LO	0.907	0.927

All Cronbach's Alpha and Composite Reliability values exceed 0.70, confirming strong internal consistency and reliability of the constructs.

4.4. Discriminant Validity (Fornell-Larcker Criterion)

Table 4. Discriminant Validity

Construct	DLA	SRL	LE	LO
DLA	**0.808**			
SRL	0.612	**0.819**		
LE	0.645	0.701	**0.830**	
LO	0.598	0.676	0.742	**0.838**

(Note: Diagonal values represent √AVE)

The square root of AVE for each construct is higher than its correlations with other constructs, confirming discriminant validity.

4.5. Coefficient of Determination (R^2)

Table 5. R-Square Values

Endogenous Variable	R^2	Interpretation
SRL	0.374	Moderate
LE	0.416	Moderate
LO	0.682	Substantial

Digital Learning Adoption explains 37.4% of the variance in SRL and 41.6% in Learning Engagement. Together, DLA, SRL, and LE explain 68.2% of the variance in Learning Outcomes, indicating strong predictive power.

4.6. Hypothesis Testing (Direct Effects)

Table 6. Path Coefficients

Hypothesis	Path	β	t-value	p-value	Result
H1	DLA → LO	0.214	3.102	0.002	Supported
H2	SRL → LO	0.298	4.876	0.000	Supported
H3	LE → LO	0.401	6.542	0.000	Supported
H4	DLA → SRL	0.612	10.334	0.000	Supported
H5	DLA → LE	0.645	11.207	0.000	Supported

Digital Learning Adoption has a significant positive effect on Learning Outcomes (β = 0.214). Self-Regulated Learning and Learning Engagement both significantly improve Learning Outcomes, with Learning Engagement showing the strongest effect (β = 0.401). Additionally, Digital Learning Adoption strongly influences SRL and LE.

4.7. Mediation Analysis (Indirect Effects)

Table 7. Indirect Effects

Hypothesis	Indirect Path	β	t-value	p-value	Result
H6	DLA → SRL → LO	0.182	4.221	0.000	Supported
H7	DLA → LE → LO	0.259	5.784	0.000	Supported

Self-Regulated Learning significantly mediates the relationship between Digital Learning Adoption and Learning Outcomes. Learning Engagement also significantly mediates this relationship and demonstrates a stronger indirect effect. This suggests that digital learning improves academic outcomes largely by increasing students' engagement and self-regulation.

4.8. Effect Size (f^2)

Table 8. Effect Size

Path	f^2	Effect Size
DLA → LO	0.072	Small
SRL → LO	0.118	Small-Medium
LE → LO	0.214	Medium
DLA → SRL	0.598	Large
DLA → LE	0.642	Large

Digital Learning Adoption has a large effect on SRL and LE. Learning Engagement has a moderate impact on Learning Outcomes, making it the most influential predictor of academic performance in this model.

4.9. Discussion

This study aimed to examine the effect of digital learning adoption, self-regulated learning (SRL), and learning engagement on students' learning outcomes. The findings provide strong empirical support for the proposed model and demonstrate that digital learning adoption significantly enhances learning outcomes both directly and indirectly through SRL and learning engagement. Overall, the model explains 68.2% of the variance in students' learning outcomes, indicating substantial predictive power and confirming the importance of these variables in contemporary digital education environments.

First, the results confirm that digital learning adoption has a significant positive effect on students' learning outcomes. This finding suggests that when digital platforms are effectively integrated into learning processes—through accessible systems, interactive materials, and supportive technological infrastructure—students are more likely to achieve better academic performance. This supports prior research indicating that digital tools enhance flexibility, access to learning resources, and opportunities for personalized learning. However, the effect size of the direct relationship between digital learning adoption and learning outcomes was relatively small compared to indirect effects. This suggests that technology alone does not automatically improve academic performance; rather, its impact depends on how students interact with and utilize digital environments.

Second, self-regulated learning was found to significantly influence learning outcomes. Students who actively set goals, manage their time effectively, monitor their understanding, and evaluate their performance tend to achieve higher academic success. This finding reinforces the theoretical foundation of self-regulation theory, which posits that learners who take active control of their cognitive and motivational processes perform better academically. In digital learning contexts, SRL becomes even more critical because students often have greater autonomy and fewer direct monitoring mechanisms from instructors. Therefore, learners must independently manage distractions, maintain motivation, and persist in completing tasks.

The significant relationship between SRL and learning outcomes indicates that digital learning environments should not only provide content but also integrate features that scaffold self-regulation. For example, progress tracking dashboards, automated reminders, goal-setting tools, and formative feedback systems can help students regulate their learning more effectively. These tools enhance metacognitive awareness, allowing students to adjust strategies when encountering difficulties. The findings suggest that educational institutions should incorporate SRL development programs alongside digital transformation initiatives to maximize academic performance.

Third, learning engagement emerged as the strongest predictor of learning outcomes among all variables in this study. This highlights the central role of engagement—behavioral, cognitive, and emotional—in determining academic success. Students who actively participate in discussions, invest effort in completing digital assignments, demonstrate interest in course materials, and persist in challenging tasks are more likely to achieve better results. This aligns with engagement theory, which emphasizes that meaningful involvement in learning activities is a prerequisite for deep learning and knowledge retention.

The strong influence of engagement also suggests that digital learning platforms must go beyond content delivery and focus on interactive and collaborative features. Multimedia

resources, gamified elements, peer discussion forums, and synchronous interactions with instructors may foster higher engagement levels. If digital systems are poorly designed or overly passive, student engagement may decline, thereby weakening learning outcomes. Therefore, the quality of instructional design plays a crucial role in translating digital adoption into academic success.

Another key finding of this study is the significant effect of digital learning adoption on both self-regulated learning and learning engagement. The results show that students who frequently use and perceive digital platforms as useful tend to demonstrate higher levels of self-regulation and engagement. This suggests that digital environments can serve as enablers of autonomous and engaged learning when structured appropriately. Technology provides immediate feedback, flexible pacing, and access to diverse learning materials, all of which encourage students to take greater responsibility for their learning.

Importantly, mediation analysis revealed that both SRL and engagement significantly mediate the relationship between digital learning adoption and learning outcomes. In fact, the indirect effects through SRL and engagement were stronger than the direct effect of digital learning adoption on learning outcomes. This finding provides critical insight into how digital learning influences academic achievement. It is not merely the presence of technology that improves outcomes, but rather the behavioral and cognitive processes it stimulates in students.

Specifically, digital learning adoption enhances SRL by giving students more control over learning pace and access to learning analytics. This increased autonomy encourages goal setting, monitoring, and strategy adjustment. Simultaneously, digital tools enhance engagement by offering interactive content and collaborative opportunities. As students become more engaged and self-regulated, their academic performance improves. This sequential process confirms the integrated nature of digital learning, SRL, and engagement.

The results also have theoretical implications. This study supports the integration of self-regulation theory and student engagement theory within the framework of technology-enhanced learning. It demonstrates that digital learning environments function as contextual drivers that shape students' psychological and behavioral responses. These responses, in turn, determine academic performance. Therefore, digital transformation in education should be understood as a multidimensional process involving technological, cognitive, and affective components.

From a practical perspective, the findings suggest that universities and educators should focus on three strategic areas. First, they should invest in user-friendly, interactive, and reliable digital learning systems. Second, they should design instructional strategies that explicitly foster self-regulated learning skills, such as structured reflection activities, progress monitoring tasks, and time-management guidance. Third, they should prioritize engagement-enhancing strategies, including collaborative learning, problem-based tasks, and dynamic multimedia resources.

Although this study provides strong evidence of the interconnected relationships among digital learning adoption, SRL, engagement, and learning outcomes, some considerations should be acknowledged. The cross-sectional design limits causal interpretation, and future longitudinal research could examine how these relationships evolve. Additionally, differences in digital literacy levels or disciplinary contexts may influence the strength of these relationships and warrant further investigation.

In conclusion, this study confirms that digital learning adoption significantly improves students' learning outcomes, particularly when mediated by self-regulated learning and learning engagement. Learning engagement plays the most influential role in predicting academic success, followed by self-regulated learning. The findings emphasize that technology alone is insufficient; its effectiveness depends on how it fosters autonomous, engaged, and motivated learners. As digital transformation continues to shape education, institutions must adopt holistic strategies that integrate technological infrastructure with cognitive and motivational support systems to maximize student achievement.

5. Conclusion

This study concludes that digital learning adoption significantly enhances students' learning outcomes, particularly when supported by strong self-regulated learning (SRL) skills and high levels of learning engagement. While digital learning adoption has a direct positive impact on academic performance, its influence is substantially strengthened through students' ability to regulate their own learning processes and actively engage in academic activities. Learning engagement emerged as the most powerful predictor of learning outcomes, followed by self-regulated learning, highlighting the critical role of behavioral, cognitive, and emotional involvement in digital environments. Furthermore, the findings demonstrate that digital platforms are most effective not merely as technological tools, but as facilitators of autonomous and engaged learning. Therefore, educational institutions should integrate well-designed digital systems with strategies that foster self-regulation and active engagement to maximize academic success in technology-enhanced learning environments.

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