Application and Effectiveness Analysis of Digital Learning Environments in Early Childhood Education and Care (ECEC) Professional Courses

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***Abstract*—This study investigates the impact of technology-assisted learning on Self-Regulated Learning (SRL) and academic performance in Early Childhood Education and Care (ECEC) courses. Given the increasing emphasis on digital learning and sustainable education aligned with the United Nations Sustainable Development Goals (SDGs), this study examines how digital learning platforms can enhance students' engagement, learning behaviors, and motivation. The research adopts an experimental design, involving 84 university students, and employs pre-tests and post-tests to assess their self-regulated learning competencies before and after the intervention. The study integrates various technology-assisted learning activities, including online instructional videos, course readings, digital discussions, and collaborative learning via Microsoft Teams. Students' learning progress was evaluated through a combination of quantitative and qualitative methods, such as usage frequency tracking, task completion rates, assessments, and reflective journals. The results reveal a statistically significant improvement in self-regulated learning behaviors, digital learning engagement, and learning motivation. Post-test findings indicate increased student participation in digital learning environments (Mean Difference = +0.33, $F = 15.67$, $p < 0.001$, $d = 0.40$) and self-regulated learning behaviors (Mean Difference = +0.33, $F = 14.23$, $p < 0.001$, $d = 0.36$). Furthermore, students perceived digital learning platforms as more beneficial ($F = 13.89$, $p < 0.001$, $d = 0.39$) and demonstrated greater self-regulated learning motivation ($F = 12.34$, $p = 0.002$, $d = 0.30$). A notable improvement was observed in self-regulated learning cognition ($F = 16.78$, $p < 0.001$, $d = 0.40$), highlighting the effectiveness of technology-assisted learning in developing critical thinking and metacognitive skills. The most significant impact was found in academic achievement test scores, which increased by +5.17 points with a large effect size ($F = 97.02$, $p < 0.001$, $d = 1.05$), confirming the effectiveness of digital learning strategies in improving overall academic performance. In conclusion, the study demonstrates that technology-assisted learning significantly enhances students' self-regulated learning abilities, engagement, and academic performance. While digital learning platforms provide effective scaffolding for self-regulated learning, further research is recommended to explore long-term retention, strategies for sustaining learning motivation, and optimization of digital learning tools to maximize educational outcomes.**

***Keywords*—technology-assisted learning, digital learning, self-regulated learning, learning motivation, academic performance, Sustainable Development Goals (SDGs), Early Childhood Education and Care (ECEC)**

I. Introduction

When planning early childhood learning environments, kindergarten teachers often face challenges such as limited classroom space, restrictions on the arrangement of storage cabinets and furniture, insufficient teaching materials, and budget constraints [1]. These limitations prevent them from providing a diverse range of play materials and learning experiences. However, a learning environment is more than just a physical space—it plays a crucial role in fostering children's self-directed learning and exploration abilities. The Reggio Emilia approach emphasizes that the environment serves as "the third teacher" [2], advocating for the incorporation of natural, stimulating elements in learning spaces while avoiding excessive reliance on commercial toys and synthetic materials [3]. This approach aims to enhance children's sensory development and autonomous learning. Consequently, leveraging technological resources to support the planning and design of early childhood learning environments has become a critical issue in modern early childhood education.

Since the United Nations introduced the Sustainable Development Goals (SDGs) in 2015, the education sector has increasingly focused on environmental sustainability and social responsibility [4]. For example, kindergarten curricula have started incorporating initiatives such as "reducing plastic products" and "emphasizing environmental education". However, sustainable development extends beyond environmental protection—it also addresses social equity, economic growth, and access to education. Thus, integrating SDG-related topics into early childhood education and enhancing students' awareness of environmental and social issues has become a key priority in early childhood professional education.

In the era of rapid technological advancement, traditional classroom teaching methods are no longer sufficient to meet the diverse learning needs of students.

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Digital learning tools offer greater flexibility by breaking through time and space constraints, allowing students to engage in online learning, discussions, and interactions. However, research suggests that digital learning is not necessarily more effective than traditional teaching [5]. The key determining factors lie in whether students possess strong self-regulated learning strategies and digital literacy [6]. Richardson *et al*. [7] analyzed the relationship between self-regulated learning strategies and academic performance in higher education and found that self-discipline (self-regulation), time management, and critical thinking were the most significant factors influencing academic achievement. Therefore, to effectively integrate digital learning tools into early childhood education courses, it is essential not only to provide appropriate learning resources but also to cultivate students' self-regulated learning abilities to enhance their overall learning performance.

As the demand for digital learning in Early Childhood Education and Care (ECEC) courses continues to grow, both teachers and students must develop the necessary digital literacy to effectively integrate physical and digital tools into the design of learning environments. Digital learning resources (such as virtual classrooms and digital teaching materials) can enhance interactivity and practical application in courses. However, current teaching models still have limitations. Traditional classrooms rely heavily on lectures, providing limited hands-on opportunities for students to engage in learning environment design. Additionally, unequal distribution of teaching resources and insufficient educational tools in some schools or programs restrict students' ability to learn the latest trends in early childhood learning environment design, ultimately affecting learning outcomes.

Nevertheless, technology-assisted learning offers significant advantages. Digital learning platforms can provide real-time feedback and interactive features, helping students grasp learning content more efficiently [8]. Self-regulated learning tools (such as online simulations and digital materials) enable students to overcome time and space limitations, allowing them to manage their own learning schedules. However, technology-assisted teaching still faces multiple challenges, including variations in students' digital learning literacy. Some students are unfamiliar with digital learning platforms, which can negatively impact learning efficiency and motivation. To address this, additional guidance and support are needed to ensure that all students can effectively utilize these platforms. Furthermore, cultivating self-regulated learning abilities is crucial for the success of digital learning, yet not all students possess effective learning strategies. Therefore, it is essential to design structured guidance mechanisms, such as learning plans and reflection journals, to help students develop self-regulated learning habits.

Adapting assessment methods remains a significant challenge. Traditional evaluation approaches may not accurately measure students' learning outcomes in a digital learning environment. As a result, new assessment models tailored for digital learning should be developed, such as learning progress tracking and self-regulated learning performance analysis, to ensure the effectiveness and successful implementation of digital learning.

This study aims to address the following questions:

(1) Can technology-assisted teaching enhance students' understanding of the Sustainable Development Goals (SDGs)?
(2) How do students' self-regulated learning motivation and learning strategies change in a technology -assisted learning environment?
(3) How do digital learning tools impact students' learning performance in early childhood learning environment design courses?

II. Literature Review

Self-Regulated Learning (SRL), also known as autonomous learning, mainly refers to learners' learning strategies, which involve monitoring, directing, and regulating behaviors to obtain information, expand knowledge, and self-correct for improvement [9]. It is also the process by which learners initiate and maintain their behaviors, as well as their cognitive and emotional functions [3, 10–12]. Robson *et al*. [13] highlighted the impact of self-regulated learning in predicting children's future performance. Self-regulation in children before the age of 4 is positively correlated with social competence, school engagement, and academic achievement. In children before the age of 8, self-regulation is positively correlated with academic achievement (mathematics and literacy), while children's self-regulation is negatively correlated with unemployment, aggression and criminal behavior, depression and anxiety, obesity, smoking, alcohol and drug abuse, and symptoms of physical illness in adulthood. This suggests that early self-regulated learning is important. The model of self-regulated learning strategies is briefly described as follows:

Panadero [14] explored six models of SRL from an educational psychology perspective, focusing on four aspects: 1. history and development; 2. description of the models (including the number of models); 3. data support; 4. measurement tools constructed based on the models.

The models were then compared across multiple dimensions: a. citation contexts; b. phases and sub-processes; c. conceptualization of metacognition, motivation, and emotion within the models; d. top-down/bottom-up approaches; e. automaticity, and f. context. The research findings indicated that SRL interventions have different effects on students at different educational levels, relatively improving learners' approaches and attitudes towards successful learning [15, 16].

Social cognitive theory [9] posits that individuals acquire knowledge through observing others and social interactions [17]. Zimmerman proposed a Triadic Analysis model (as shown in Fig. 1) based on the interaction of three forms of SRL: environment, behavior, and personal (self). He also developed the cyclical phases model of SRL and the multilevel model [15, 18]. In the SRL model, the use of strategies based on personal emotions, physiology, and cognition is self-regulated in the internal process.

Feedback from learning behavior and the learning environment, along with strategy use, prompts educators to consider the creation of a supportive learning environment and classroom management.

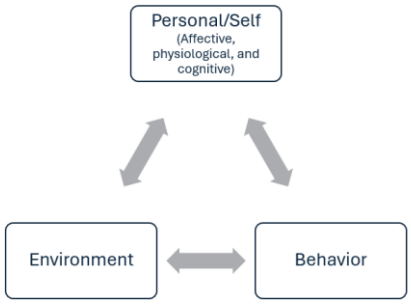

Fig. 1. SRL Triadic Analysis Model [14].

Feedback is a crucial component of Self-Regulated Learning (SRL) [18, 19]. In the application of the SRL model, technology-assisted learning has become one of the most effective teaching tools. The use of digital learning platforms to provide both synchronous and asynchronous feedback serves as an essential scaffolding support for self-regulation. According to Zimmerman [18, 20], the self-regulated learning cycle model consists of three continuous stages: forethought, performance evaluation, and self-reflection. The provision of feedback helps learners compare their prior expectations with their current performance, enabling them to gain more successful learning experiences.

An empirical study by Ting and Kuo [21] found that compared to self-study or traditional remedial instruction, adaptive dynamic assessment provides the most effective guidance. Furthermore, in terms of learning effectiveness in self-regulated learning, it is evident that in a personalized digital learning environment, self-regulated learning abilities have a significant positive impact on learning outcomes [19]. Additionally, good self-regulated learning habits can enhance learning performance [15, 20].

In alignment with recent studies emphasizing that the most common practice in sustainability-related education is the integration of the Sustainable Development Goals (SDGs) into curricular schedules, this study deliberately embedded SDG-focused themes into its instructional design. Specifically, from Weeks 7 to 13, students engaged with sustainability issues—such as eco-friendly classroom design, responsible material selection, and ethical decision through a digital learning platform. These activities included asynchronous modules, collaborative group tasks, and digital reflective journals, all designed to foster Self-Regulated Learning (SRL). The integration of SDGs not only enriched the course content but also supported the cultivation of 21st-century competencies, including learner autonomy, critical thinking, and global citizenship [22].

III. Materials and Methods

A. Instructional Design and Planning Explanation

The instructional design of this study (as shown in Table I) begins by introducing and guiding SRL planning methods (Fig. 2). Each week, course materials and weekly progress analyses are provided. Based on the goal setting and strategic planning (discussing how to do it?) of the task analysis in the planning phase, and self-motivation (connecting with previous learning, desired outcomes), the implementation phase includes self-control (What strategies are used? What difficulties are encountered? Who can help?) and self-observation (Try this method?). The self-reflection phase includes self-judgment (Am I doing well enough?) and self-reaction (What else can I do?). Each Monday, the weekly course theme is introduced and explained, followed by small group (4 people) discussions and concept clarification. Following the cyclical phase model, the goal is to achieve learning outcomes where students are self-aware, self-managing, self-evaluating, and thus self-improving.

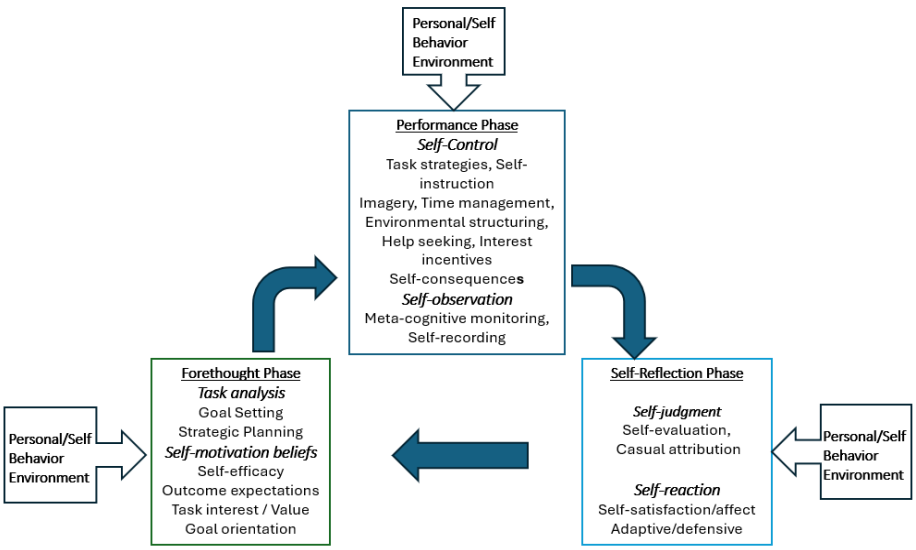

Fig. 2. Application of triadic analysis and cyclical phase model [14].

TABLE I. COURSE CONTENT

Week (Session)	Course Theme	Content & Activities [Description]	Notes
1	The Meaning of Self-regulation	The nature of early childhood learning and discussion: Self-regulated learning and play-based autonomy.	*Pre-test/ Questionnaire*
2–4	Exploring Early Childhood Learning & Environment	Principles and concepts of designing learning environments for young children. Digital teaching materials, task assignments. Introduction to early childhood education curriculum models and sustainable environments. Discussion of the functionality of indoor and outdoor learning environments.	Design Preparation
7–8	Sustainable Development of Learning Centers	Definition and practice of organic classrooms—Steps and blueprints for planning learning centers, problems, and discussion.	Design Preparation
9	Design Implementation	Elements of learning environment design—Presentation sharing and presentation.	Inter-group peer evaluation
11–13	Exploring Sustainability Issues	1. Discussion of sustainability issues. 2. "Toy? Material? Teaching Aid? Which one do you want?	Self-observation, Self-judgment, Self-reaction
14–16	Self-Regulated Learning Task Implementation	Each group completes the design of indoor and outdoor learning environments (age group, indoor and outdoor learning environments).	Peer evaluation and response
17–18	Presentation of Results	Each group shares their indoor and outdoor learning environment designs.	*Post-test/ Questionnaire*

B. Research Methods

The main purpose of this study is to examine students' learning performance when engaging with technology -assisted instruction. Participation is measured through usage metrics such as time spent on the platform, task completion rates, and engagement frequency. Students' learning autonomy literacy—including self-regulation, learning motivation, and cognitive performance—serves as a moderating variable.

Technology-assisted learning activities were implemented via a digital learning platform, where students completed multiple tasks: watching instructional videos on computers, tablets, or smartphones (with tracked time and frequency); engaging with course readings and submitting assignments (measured by completion percentage); and participating in digital discussions and feedback sessions centered around materials related to the Sustainable Development Goals (SDGs).

From Weeks 7 to 13, SDG-related themes—such as sustainable classroom design, eco-friendly materials, and ethical decision-making—were integrated into the course content. Students worked in groups using Microsoft Teams to collaborate on design projects, document their reflections, and assess the impact of digital teamwork. Through these structured digital activities, the course aimed to enhance students' self-regulated learning abilities while simultaneously fostering sustainability awareness and collaborative learning skills.

For student learning assessment, a multi-dimensional evaluation approach is employed. In addition to tracking learning activity engagement (time and frequency), the study also incorporates mid-term tests, final practical assessments, and reflective journals. By collecting both quantitative and qualitative data, the research aims to cross-validate and analyze students' learning performance comprehensively, providing deeper insights into their learning effectiveness within the course's applied research framework.

C. Participants

The participants of this study consist of 84 university students, engaging in various learning activities that include individual tasks, group discussions, hands-on practice, and problem-solving discussions. These diverse learning modes aim to foster active engagement, collaboration, and practical application of knowledge within the course.

This applied research adopts an experimental design to examine students' self-regulated learning competencies. To assess changes in students' self-regulated learning, pre-tests and post-tests were conducted at the beginning and end of the course. These tests aimed to evaluate students' performance in different phases of self-regulated learning: Planning Phase (Task analysis and self-motivation), Execution Phase (Self-control and self-observation), Self-Reflection Phase (Self-judgment and self-reaction) (Fig. 2). To assess students' self-regulated learning abilities, the study utilized a modified version of the Comprehensive Self-Regulated Learning Scale as the primary research instrument. The scale's framework is based on the Adaptive Learning Network and has been validated with high reliability and validity [7]. The content validity of the scale was established through expert evaluation, statistical testing, and experimental validation, ensuring construct validity and criterion-related validity.

D. Reliability and Validity Analysis

The reliability of both the pre-test and post-test questionnaires was found to be high (> 0.8), indicating a strong internal consistency in measuring digital learning usage and behavior. The post-test reliability was slightly higher than the pre-test, which may suggest that students had a more consistent understanding of the questionnaire during the post-test phase. For self-regulated learning behavior, the pre-test reliability was high (0.89), and the post-test reliability was excellent (> 0.9), indicating very strong internal consistency in measuring self-regulated learning behavior. The increase in post-test reliability may

reflect that students had a more uniform understanding of self-regulated learning behavior by the time they took the post-test.

Regarding the perceived assistance from digital learning platforms, the pre-test reliability was good (0.87), and the post-test reliability was excellent (> 0.9), suggesting that the questionnaire was highly consistent in measuring students' perceptions of digital learning platform support. The increase in post-test reliability may indicate that students developed a more consistent perception of the assistance provided by digital learning platforms.

For self-regulated learning motivation, the reliability of both the pre-test and post-test was excellent (> 0.9), demonstrating extremely high internal consistency in measuring self-regulated learning motivation. The slightly higher post-test reliability suggests that students' understanding of self-regulated learning motivation became more consistent over time.

In terms of self-regulated learning cognition, the pre-test reliability was high (0.88), while the post-test reliability was excellent (> 0.9), indicating a strong internal consistency in measuring self-regulated learning cognition. The increase in post-test reliability may reflect a more consistent understanding of self-regulated learning cognition among students during the post-test.

The statistical analysis of this study showed that reliability improved across all dimensions in the post-test, which may be attributed to the following factors:

(1) Students became more familiar with the questionnaire content by the time of the post-test.
(2) The instructional or experimental process helped students develop a more consistent understanding of the different dimensions measured.
(3) The questionnaire design was further refined for the post-test, leading to improved reliability.

As shown in Table II, all Cronbach's α coefficients exceeded 0.8, confirming that the scale demonstrated high reliability. Additionally, factor analysis was conducted to examine the construct validity of the questionnaire. The results showed that the factor loadings of all items on their respective dimensions were above 0.5, indicating that the questionnaire had strong construct validity.

TABLE II. CRONBACH'S A COEFFICIENT TO ASSESS THE INTERNAL CONSISTENCY OF A SCALE

Dimensions of Self-Regulated Learning	Cronbach's α	
	Pro-	Post
Self-Regulated Learning Behavior	0.86	0.88
Assistance from Digital Learning Platforms	0.89	0.91
Self-Regulated Learning Motivation	0.87	0.90
Self-Regulated Learning Cognition	0.90	0.92
Self-Regulated Learning Behavior	0.88	0.91

IV. RESULT AND DISCUSSION

The Table III. presents the pre-test and post-test results for 84 participants, evaluating five aspects related to digital learning and self-regulated learning behaviors. The values are reported as Mean (SD), showing the average scores and standard deviations before and after the intervention, along with the percentage of students who reported engaging in these behaviors "Always" or "Often". The findings indicate a positive impact of digital learning on student engagement, self-regulation, and motivation.

TABLE III. SUMMARY FOR ALL DIMENSIONS FOR ALL DIMENSIONS OF SELF-REGULATED LEARNING (SRL)

Dimensions of Self-Regulated Learning	Pre Mean (SD)	Post Mean (SD)	Pre (Always & Often)	Post (Always & Often)
Digital Learning Usage and Behavior	3.12 (.85)	3.45 (.78)	45%	58%
Self-Regulated Learning Behavior	3.45 (.92)	3.78 (.88)	52%	65%
Assistance from Digital Learning Platforms	3.23 (.89)	3.56 (.82)	48%	62%
Self-Regulated Learning Motivation	3.67 (.94)	3.95 (.91)	55%	68%
Self-Regulated Learning Cognition	3.34 (.87)	3.68 (.84)	50%	63%

Digital Learning Usage and Behavior improved from 3.12 (SD = 0.85) in the pre-test to 3.45 (SD = 0.78) in the post-test, with an increase in students frequently engaging in digital learning from 45% to 58%, suggesting greater engagement with digital learning tools. Similarly, Self-Regulated Learning Behavior increased from 3.45 (SD = 0.92) to 3.78 (SD = 0.88), with a rise in active participation from 52% to 65%, indicating that students developed better self-regulation strategies.

Perceptions of Assistance from Digital Learning Platforms also improved, with scores rising from 3.23 (SD = 0.89) to 3.56 (SD = 0.82) and frequent usage increasing from 48% to 62%, demonstrating that students found digital learning platforms more beneficial over time. Self-regulated learning motivation saw a notable increase from 3.67 (SD = 0.94) to 3.95 (SD = 0.91), with frequent engagement growing from 55% to 68%, reflecting enhanced student motivation for self-regulated learning. Lastly, self-regulated learning cognition improved from 3.34 (SD = 0.87) to 3.68 (SD = 0.84), with students reporting a rise in cognitive engagement from 50% to 63%.

These results suggest that technology-assisted learning effectively enhances students' engagement, self-regulation, and learning motivation, reinforcing the importance of integrating digital tools into educational settings to support independent learning behaviors.

Table IV provides a comprehensive statistical analysis of various aspects of digital learning and self- regulated learning behaviors, along with academic achievement test scores. The results include mean differences, F-values, p-values, and Cohen's d effect sizes, offering valuable insights into the impact of digital learning interventions on students' learning experiences and performance.

One of the key findings is the increase in digital learning usage and behavior, with a mean difference of +0.33 and a moderate effect size ($d = 0.40$). The F-value of 15.67 ($p < 0.001$) indicates that the change is statistically significant, suggesting that students engaged more frequently with digital learning tools after the intervention. Similarly, self-regulated learning behavior also showed a significant improvement ($F = 14.23$, $p < 0.001$, $d = 0.36$), reflecting that students became more independent and strategic in their learning processes.

The role of digital learning platforms was further reinforced, with students perceiving them as more beneficial after the intervention ($F = 13.89$, $p < 0.001$, $d = 0.39$). This finding aligns with previous research indicating that well-designed digital learning environments enhance student engagement and participation. However, while self-regulated learning motivation improved ($F = 12.34$, $p = 0.002$, $d = 0.30$), the effect size was smaller compared to other factors, suggesting that additional instructional strategies may be required to sustain and further enhance learning motivation in digital settings. A notable improvement was observed in self-regulated learning cognition, with a mean difference of +0.34 and a moderate effect size ($d = 0.40$, $F = 16.78$, $p < 0.001$). This suggests that digital learning interventions were particularly effective in developing students' critical thinking and metacognitive skills, reinforcing the idea that technology-assisted learning supports deeper cognitive engagement. Among all aspects, the most significant impact was observed in achievement test scores, which increased by +5.17 points with a large effect size ($d = 1.05$, $F = 97.02$, $p < 0.001$). This indicates that digital learning strategies were highly effective in enhancing students' overall academic performance, confirming the importance of integrating technology-driven learning interventions into educational settings.

TABLE IV. STATISTICAL ANALYSIS RESULTS FOR VARIOUS ASPECTS OF DIGITAL LEARNING FOR VARAVOUS

Dimensions of Self-Regulated Learning	Mean Difference	*F*-value	*P*-value	Cohen's d
Digital Learning Usage and Behavior	.33	15.67	<.001	.40
Self-Regulated Learning Behavior	.33	14.23	<.001	.36
Assistance from Digital Learning Platforms	.33	13.89	<.001	.39
Self-Regulated Learning Motivation	.28	12.34	.002	.30
Self-Regulated Learning Cognition	.34	16.78	<.001	.40
Achievement Test Scores	5.17	97.02	.000	1.05

In summary, the findings demonstrate that digital learning interventions significantly improved self-regulated learning behaviors, digital engagement, and academic achievement. While moderate improvements were observed in digital learning usage, cognitive engagement, and platform assistance, further strategies may be needed to enhance learning motivation and optimize long-term digital learning outcomes.

In conclusion, the post-test mean scores for all aspects were higher than the pre-test scores, indicating improvements in students' digital learning usage behavior, self-regulated learning behavior, perceived benefits of digital learning platforms, self-regulated learning motivation, and cognition.

V. CONCLUSION

This study examined the impact of technology-assisted learning on Self-Regulated Learning (SRL) behaviors, motivation, and academic performance in Early Childhood Education and Care (ECEC) courses. The results demonstrate that the integration of digital learning platforms significantly enhanced students' engagement, learning strategies, and academic achievements.

The findings of this study align closely with prior literature emphasizing the importance of Self-Regulated Learning (SRL) in digital environments. For example, Richardson *et al*. [7] demonstrated that self-regulation, time management, and critical thinking are among the most influential factors affecting academic performance in higher education. The significant improvements observed in students' SRL behavior ($F = 14.23$, $p < 0.001$, $d = 0.36$) and SRL cognition ($F = 16.78$, $p < 0.001$, $d = 0.40$) confirm the effectiveness of technology-assisted learning in enhancing metacognitive skills and strategic learning habits.

Furthermore, consistent with Broadbent and Poon [6], who argue that SRL strategies are essential to academic success in online learning, this study found that students' digital learning behaviors and academic achievement improved substantially—especially in the final performance measure (+5.17 points, $F = 97.02$, $p < 0.001$, $d = 1.05$).

However, while SRL motivation showed gains ($F = 12.34$, $p = 0.002$, $d = 0.30$), the effect size was comparatively smaller, indicating the need for more targeted motivational scaffolds, as also discussed by Zimmerman (2000) and Winne (2018) [12, 23].

Implications for future research and practice:

(1). Enhancing digital learning strategies

Future research should further explore the development of interactive digital learning tools, personalized feedback systems, and real-time assessment mechanisms. These tools can optimize SRL processes by promoting goal setting, strategy use, self-monitoring, and reflective thinking. Prior findings support that well-designed digital scaffolding enhances metacognitive awareness and strategic learning habits, especially in learner-centered environments.

(2). Addressing motivation challenges in SRL

While this study identified moderate improvements in students' SRL motivation, the effect size ($d = 0.30$) was smaller than for cognitive and behavioral dimensions. This

suggests that motivational support remains a critical area for future pedagogical innovation. Research may investigate gamification, adaptive learning pathways, and peer interaction tools to sustain engagement over time. Motivational interventions must be contextualized and continuously reinforced to yield meaningful impact in digital learning environments.

(3). Personalized and adaptive learning

Given the observed variation in students' digital literacy and SRL competencies, personalized support mechanisms should be emphasized. Future work should focus on adaptive learning systems that dynamically respond to learner needs, offer differentiated content, and adjust challenge levels to maintain optimal engagement. Such systems can bridge individual differences and promote equitable learning outcomes.

(4). Alternative assessments for SRL

Traditional evaluation methods often fail to capture the nuances of SRL in technology-enhanced learning. Future research should develop alternative assessment models, such as learning analytics dashboards, digital trace data visualizations, and reflection-based formative assessments, to better track students' SRL progress and cognitive engagement in real-time.

(5). Longitudinal studies on learning retention

Most existing research, including this study, captures short-term outcomes. To understand the sustainability of SRL development and digital learning's impact on lifelong learning skills, longitudinal designs are needed. These should monitor retention of metacognitive strategies, motivation persistence, and academic achievement across semesters or program stages.

(6). Advancing SDG 4: Quality and inclusive education

Aligning with Sustainable Development Goal 4, this study highlights how digital learning platforms can promote inclusive, equitable, and quality education. The integration of SRL frameworks into digital environments supports 21st-century competencies such as autonomy, critical thinking, and global citizenship. Future work may examine how such platforms can scale to underserved populations and culturally diverse contexts.

Conflict of Interest

The author declares no conflict of interest.

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