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PAPER

Influence of Learning Activities Based on the Constructionism Approach in Digital Learning Ecosystem on Self-directed Learning Skills

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ABSTRACT

Due to the advancement of digital technology in the 21st century, self-directed learning (SDL) skills have become crucial for learning in the digital era, which is characterized by rapid change. Most previous studies have focused on enhancing SDL skills through various instructional methods. Today, technology plays a crucial role in learning. In the current context, exploring the outcomes of incorporating digital technology in teaching methods to enhance SDL skills is an intriguing subject. This study investigated the impact of SDL skills and learning achievement promotion by employing learning activities based on the constructionism approach in a digital learning ecosystem (DLE). The study used a quasi-experimental research approach with a non-equivalent pre-test and post-test control group design. The participants were eleventh-grade students. The results showed that both the SDL skills and learning achievement of the experimental group increased more compared to those of the control group. Based on the findings of this study, it can be concluded that learning-by-marking within an environment where numerous digital technologies serve as learning tools has a positive impact on SDL skills and learning achievement.

KEYWORDS

self-directed learning (SDL), constructionism, and the digital learning ecosystem (DLE)

1 INTRODUCTION

The advancement of digital technology in the 21st century has ushered in an era characterized by unprecedented uncertainty and volatility. The evolving socio-economic landscape of this century necessitates that students acquire a new skill set to thrive and compete in a future marked by complexity and constant change. This skill set is referred to as "21st-century skills" [1] [2]. To nurture these vital competencies, teachers must shift their role from lecturers to learning facilitators in a student-centric online learning environment. They should effectively utilize digital

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tools to help students explore, construct, and communicate knowledge to solve complex real-life problems. Therefore, learning in the digital age should promote active student participation and empower students to take control of their learning processes to achieve their goals. These are known as self-directed learning (SDL) skills [3], [4], and [5]. SDL skills are among the most important competencies in the 21st century [6], [7], as they constitute the foundational abilities for learning within a rapidly changing digital landscape [8]. Moreover, skills in SDL serve as indicators of academic learning achievement [9] and are key characteristics of lifelong learners. These skills enable individuals to unlock their full learning potential, take responsibility for their learning and work [10] [11], and be prepared to tackle any challenges and solve problems that may arise in the future [12] [13].

Given the significance of SDL skills, there has been a surge in interest in their development, accompanied by a corresponding increase in research papers dedicated to this subject [14]. Most previous research on SDL skill development has typically focused on its enhancement through different learning approaches, such as problem-based learning [15], [16], [17], [18], and gamification strategies [19]. However, there may be a lack of emphasis on integrating the use of digital resources with instructional methods, which is a characteristic of the current learning environment where technology has become easily accessible to everyone. This accessibility enables personalized learning experiences that are supported by easy access to data and resources. This shift in the learning environment has made it interesting to investigate the impact of learning approaches on enhancing SDL skills when used in conjunction with 21st-century technology [20]. In order to build upon previous research, this study focuses on investigating the promotion of SDL skills resulting from the influence of an instructional approach integrated with digital technology. In this study, we have utilized the learning activities associated with the constructionism approach in a DLE, a model developed by Techakosit and Rukngam [21]. The objective of this study is to investigate the impact of the constructionism approach in a DLE on SDL skills and learning achievement. Therefore, the study questions are as follows:

Q1: How do learning activities based on the constructionism approach in DLE influence the acquisition of SDL skills compared to the instructional learning method?

Q2: How do learning activities based on the constructionism approach in DLE influence the acquisition of learning achievement compared to the instructional learning method?

2 LITERATURE REVIEW

2.1 Self-directed learning

Lifelong learning is of significant importance in the present era, marked by rapid change driven by the digital revolution. Within this context, SDL emerges as a crucial skill for promoting lifelong learning [22]. It encompasses the ability of the individual to independently search for sources of information out of curiosity, connect new ideas with existing knowledge, check understanding, inquire about things not understood, synthesize newfound knowledge, and apply it in real-world scenarios [23]. Techakosit and Rukngam [21] have proposed that SDL skills encompass three abilities: 1) the ability to autonomously motivate oneself to learn, create a personal awareness of meaningful learning, and take responsibility for setting one's learning plans and goals; 2) the ability to learn efficiently through the adoption of appropriate learning strategies, demonstrate autonomy, and persistently work towards predefined goals; and 3) the ability to monitor and assess one's own learning with confidence. In this study, these three abilities were used as a framework for developing the SDL skills questionnaire.

2.2 Constructionism

In constructionism, a pedagogical theory derived from constructivism and developed by Seymour Papert, the acquisition of knowledge is described as learning-by-making [24]. In this approach, providing students with opportunities to create meaningful artifacts has a greater impact on their learning than learning through listening to a teacher lecture. Teachers assume the role of learning facilitators and advisors, guiding students towards achieving learning objectives by engaging in the creation of artifacts, fostering creativity, and tackling problem-solving while working on their assignments [25]. Techakosit and Rukngam [21] have proposed an instructional model that embodies the principles of the constructionism approach, consisting of six steps (see Figure 1). The first step, labeled "challenge," aims to inspire learning by posing questions about current issues or challenges, motivating the students to become active contributors to society. The second step, "search," involves an effort to identify the causes of the chosen problem and explore potential solutions by collaboratively searching, gathering, verifying, and summarizing information. The third step, "design," involves having students create a draft of the prototype for solving the problem, considering any existing restrictions and conditions. The fourth step, "create," involves developing a tangible artifact based on the draft with guidance from both teachers and subject matter experts. The fifth step, "evaluate," involves students presenting their artifact and reflecting on what they have learned so that they can apply it to further their learning.

Fig. 1. Constructionism approach in DEL to promote SDL skills [21]

2.3 Digital learning ecosystem

In science, an ecosystem is defined as a network structure comprising both biotic and abiotic components within a particular environment that rely on one another and engage in interactions. This concept has been applied to the interplay among components within IT systems, leading to the emergence of the concept of a digital ecosystem [26], which is now used to explain the diversity of information and communication technologies (ICT) [27]. Consequently, when ICT acts as the connecting network for the components involved in learning, it becomes a DLE. Techakosit and Rukngam [21] categorized the components and features of a DLE into two groups: 1) the biotic components that assume roles related to teaching and learning with regard to students, teachers, and external experts, and 2) the abiotic components comprising digital tools that facilitate both formal and informal learning, including computers, the Internet, and software applications. The key characteristic of a DLE is that it focuses on creating a learning environment where learning outcomes result from interactions among its components and where digital tools are employed to help students achieve their learning objectives.

3 METHODOLOGY

3.1 Research design

This study was designed as quasi-experimental study with a non-equivalent pre-test and post-test control group design, a commonly used model in social science research [28], because participants were not randomly assigned to groups. This study design is suitable for investigating the responses to the research questions in this study. The aim is to explore the impact of an intervention using a matching technique to compare the pre-test and post-test results of an experimental group with those of a control group.

3.2 Participants

The participants in this study were 38 eleventh-grade students enrolled in a non-science-focused program at a laboratory school affiliated with the Faculty of Education at a university in Bangkok, Thailand. Among these, 22 students comprised the experimental group, where the learning activities associated with the constructionism approach were applied. The remaining 16 students were designated as the control group and received instruction based on the instructional teaching method.

Table 1. Number of participants in each group

Group	Male	Female	Total
Experimental group	10	12	22
Control group	7	9	16

3.3 Instruments

The instruments used in this study included: 1) learning activities based on the constructionism approach in a DLE; 2) a SDL skills questionnaire; and 3) a learning achievement test. The details are as follows:

Learning activities based on the constructionism approach in a DLE: The lesson plans for this study were tailored to the subject of electromagnetic waves and were intended for use in science classes within a program that is not science-focused. These lesson plans consisted of three sub-topics: 1) components of electromagnetic waves; 2) the functioning of electromagnetic equipment; and 3) the applications of electromagnetic waves in communication. The lesson plans for the experimental group were designed based on the constructionism instructional model in a DLE and consisted of five steps.

Step	Learning Activities Based on the Constructionism Approach in DLE
Challenge	The students learned about electromagnetic wave components via in-class and out-of-class activities. Outside the class, they learned from video resources in Metaverse using the Spatial program.
Search	The students learned the other two sub-topics independently. They were divided into seven groups; each group selected a sub-topic aligned with their interests, and sought knowledge from various sources, including external experts.
Design	The students created storyboards for video presentations covering their respective sub-topics.
Create	The students produced videos explaining the concepts related to electromagnetic equipment and communication.
Evaluate	The students presented their self-produced videos and learned from the video presentations of other groups through Metaverse, using the Spatial program.

This learning process involved ten classroom sessions, each lasting 50 minutes, over a span of four weeks. Additionally, a learning management system (LMS) was employed to facilitate activities outside the classroom. The suitability of these lesson plans was evaluated by a panel of five experts, all of whom hold PhDs in science education and have significant teaching and research experience in the field of science education. The overall evaluation score was $\bar{x}$ = 4.56 and the S.D. was 0.64, indicating the highest level of suitability [28]. Furthermore, Cronbach's alpha coefficient analysis returned a value of.94, where a value exceeding 0.70 indicates a high level of reliability [29].

SDL skills questionnaire: In the context of this study, an SDL skill questionnaire was developed. It contains 50 questions using a five-level rating scale and items aligned with the concept of the SDL skill framework proposed by Techakosit and Rukngam [21]. The content validity of this assessment procedure was examined using the index of item-objective congruence (IOC) with the assistance of five experts, all of whom hold PhDs in instructional design and have significant experience in teaching and research in instructional design. After the examination, 35 items passed the content validity test. Subsequently, this assessment was administered to 17 eleventh-grade students studying in a non-science-focused program who were not part of the groups participating in the experiment. Cronbach's alpha coefficient analysis yielded a result of 0.84, indicating a high level of reliability.

Learning achievement test: Additionally, a learning achievement assessment was designed. It consisted of 15 multiple-choice questions with four answer choices. The content validity of this assessment was evaluated by five experts, each holding a PhD in science education and possessing substantial experience in teaching and research in the field of science education. The results of the content validity test demonstrated that the assessment was valid. W hen this assessment was administered to 25 twelfth-grade students in a non-science-focused program, it was found that all questions met the criteria for difficulty and discrimination power. Subsequently, a Kuder-Richardson analysis was conducted, revealing a reliability coefficient of 0.56, indicating moderate reliability.

3.4 Data collection

The data collection process in this study consisted of three sessions: pre-test, treatment, and post-test, as shown in Figure 2.

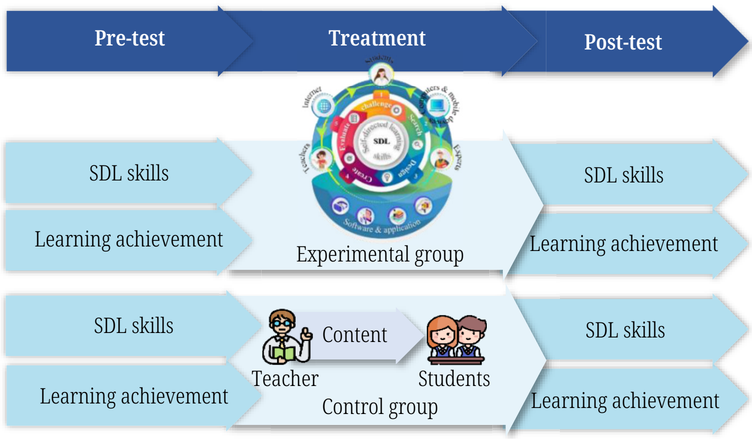

Fig. 2. Data collection process

The pre-test consisted of the data obtained to assess the SDL skills and learning achievements of the participants in both the experimental and control groups before the treatment. The treatment in this study was a type of instructional activity. The two groups were given different treatments. The learning activities based on the constructionism approach were employed in the DLE for the experimental group, while the traditional learning method was used for the control group. Participants in both groups spent a total of 4 weeks on the designated instructional activities. The post-test for both groups of participants consisted of the results of SDL skills and learning achievement scores after the treatment.

3.5 Data analysis

In this study, descriptive statistics were used to analyze the data in the form of pre- and post-test scores concerning the SDL skills and learning achievements of the participants. However, there were fewer than 50 participants. Therefore, before statistical processing, the data had to be checked for normality. The Shapiro-Wilk test was used to investigate the normality of data distribution because it is suitable for small sample sizes (<50) [30]. The dependent t-test method was used to compare the SDL skills and learning achievement scores of the participants in each group before and after the learning intervention. Additionally, a one-way analysis of covariance (ANCOVA) was used to compare the experimental group's results in terms of SDL skills and learning achievement evaluation post-test with those of the control group, using the pre-test scores as covariates.

3.6 Compliance

This study received approval from the Research Ethics Committee in Thailand to use data collection instruments on participants. To assure participants in this study that their data would remain anonymous and not be used for any other purpose, a statement was provided. All participating students under the age of 18 and their parents signed the consent form for child volunteers.

4 RESULTS

The results of the data analysis are used to address the two research questions.

4.1 The influence of the learning activities based on constructionism in a DLE on SDL skills compared to the traditional learning method

As one of the prerequisites for statistical data analysis, all data must be examined for normality. In this section, the normality of the data distribution of the pre-test and post-test results related to SDL skills was assessed using the Shapiro-Wilk test. These are as shown in Table 2.

Table 2. The results of the Shapiro-Wilk test to determine the normal distribution of the pre-test and post-test SDL skills assessment results

Test	Variables	Group	Shapiro-Wilk Test		
			Statistic	df	Sig
Pre-test	SDL skills	Experimental	0.9660	22	0.6184
		Control	0.9490	16	0.4738
Post-test	SDL skills	Experimental	0.9499	22	0.3147
		Control	0.9237	16	0.1933

Table 2 shows that the pre-test and post-test SDL skills assessment results were normally distributed in both the experimental and control groups ($p > .05$).

The pre- and post-test SDL skills assessment results of each group were compared using the dependent t-test to examine the progress of participants in SDL skills within each group. The results of this analysis are shown in Table 3.

Table 3. The comparison of the results of SDL skill assessment before and after learning intervention

Group	n	Pre-Test		Post-Test		t-Test	p
		$\bar{x}$	S.D.	$\bar{x}$	S.D.		
Experiment	22	3.42	0.38	3.91	0.36	8.934	.000**
Control	16	3.46	0.56	3.54	0.54	3.753	.001**

Note: **$p < .05$.

Table 3 shows a statistically significant difference in SDL skill assessment results before and after the learning process for both the experimental and control groups, with a significance level of 0.05. On average, both groups showed higher levels of SDL skills after the learning intervention.

A one-way ANCOVA test was performed to compare the SDL skills of the participants in different learning activities, using the pre-test SDL skills assessment results as a covariate, as shown in Table 4.

Table 4. The comparison of SDL skills acquired through different instructional models

Source	Type III Sum of Squares	df	Mean Square	F	Sig
Corrected Model	6.999	2	3.500	93.021	< .001**
Intercept	.344	1	.344	9.149	.005**
Pre-test SDLskills	5.770	1	5.770	153.353	< .001**
Method	1.436	1	1.436	38.178	< .001**
Error	1.317	35	.038		
Total	543.141	38			
Corrected Total	8.316	37			

Note: **p < .01 (R Squared = .842, Adjusted R Squared = .833).

Table 4 shows that the various instructional models students experienced during the learning process had a statistically significant impact on the results of the SDL skill assessment, with a significance level of .01. The difference in SDL skills between the experimental group and the control group is shown in Table 5.

Table 5. The comparison of SDL skills after the experiment

(I) Method	(J) Method	Mean Difference (I–J)	Std. Error	Sig
Experiment	Control	.394*	.064	< .001
Control	Experiment	–.394*	.064	< .001

Note: *p < .05.

As shown in Table 5, the SDL skills of the experimental group and the control group differed significantly at the 0.05 significance level, with the experimental group demonstrating higher SDL skills than the control group.

4.2 The influence of the learning activities based on constructionism in a DLE on learning achievement compared to the traditional learning method

In this section, the normality of the pre-test and post-test learning achievement scores was assessed using the Shapiro-Wilk test, as shown in Table 6.

Table 6. The results of the Shapiro-Wilk test to determine the normal distribution of the pre-test and post-test of learning achievement scores

Test	Variables	Group	Shapiro-Wilk Test		
			Statistic	df	Sig
Pre-test	Learning achievement	Experimental	0.9415	22	0.2122
		Control	0.9441	16	0.4027
Post-test	Learning achievement	Experimental	0.9494	22	0.3073
		Control	0.9600	16	0.6612

Table 6 shows that the pre- and post-test learning achievement scores were normally distributed in both the experimental and control groups (p > .05).

The comparison of learning achievements before and after the instructional activities in both the experimental group and the control group was conducted using the mean, S.D., and dependent t-test, as presented in Table 7.

Table 7. The comparison of the results of learning achievement scores before and after learning intervention

Group	n	Pre-Test		Post-Test		t-Test	p
		$\bar{x}$	S.D.	$\bar{x}$	S.D.		
Experiment	22	4.95	2.03	11.18	2.44	14.794	.000**
Control	16	3.81	1.79	8.06	2.79	8.878	.00**

Note: **p < .05.

As shown in Table 7, there is a statistically significant difference, with a significance level of 0.05, in the average learning achievements of students before and after the learning process for both the experimental group and the control group. The average learning achievements following the learning process were higher for both the experimental and control groups compared to their respective outcomes in pre-tests.

A one-way ANCOVA was conducted to compare the learning achievements of participants engaged in various learning activities, with the pre-test learning achievement assessment scores used as a covariate, as presented in Table 8.

Table 8. The comparison of learning achievements resulting from learning through different instructional models

Source	Type III Sum of Squares	df	Mean Square	F	Sig
Corrected Model	197.145	2	98.573	25.519	< .001**
Intercept	194.041	1	194.041	50.234	< .001**
Pre-test SDLskills	107.013	1	107.013	27.704	< .001**
Method	37.647	1	37.647	9.746	.004**
Error	135.197	35	3.863		
Total	4033.000	38			
Corrected Total	332.342	37			

Note: **p < .01 (R Squared = .593, Adjusted R Squared = .570).

As shown in Table 8, there is a significant difference in students' learning achievements when they are instructed using various instructional models at the 0.01 significance level. The outcomes of the comparison between the level of improvement in learning achievement of the experimental group and that of the control group can be found in Table 9.

Table 9. The comparison of learning achievement after the experiment

(I) Method	(J) Method	Mean Difference (I–J)	Std. Error	Sig
Experiment	Control	2.104*	.674	.004
Control	Experiment	–2.104*	.674	.004

Note: *p < .05.

Table 9 shows a statistically significant difference in learning achievement improvement between the experimental group and the control group after their learning experiences. The control group exhibited a greater improvement in learning achievement at the 0.05 significance level.

5 DISCUSSION

The findings of this study demonstrate that learning activities that follow the constructionism approach within a DLE have a greater impact on SDL skills and learning achievement compared to the traditional instructional model. This improved outcome can be attributed to the structured learning process of the constructionism approach, which students find challenging, thus motivating them to search for information in a way that is personally meaningful. Additionally, students learn through the process of designing, creating, and evaluating their own artifacts, as well as assessing their peers' progress. These findings are consistent with the research of Downey et al. [31], who also concluded that learning through the constructionism approach fosters lifelong learning skills. Hamlin [32] affirmed that active learning, which provides opportunities for students to apply their knowledge and participate in the learning process, is a strategy that promotes SDL skills. These findings are also supported by Tan and Ling [33], who found that SDL skills are developed when students have the freedom to design artifacts, participate in planning their learning journey, and verify and assess their learning. This is also consistent with the findings of Techakosit and Srisakuna [34].

In addition to teaching strategies, this study revealed that the abiotic components of the DLE, such as digital tools, play a crucial role in enhancing both student learning and teacher instruction within and beyond the classroom. This aligns with Reyna's research [35], which found that a DLE facilitates easier access to content for both teachers and students, promoting interaction and increasing student engagement. Furthermore, Sornok et al. [36] affirmed that in a DLE, students can leverage various digital tools, such as video simulators. These tools can assist in the development of a range of skills, including lifelong learning abilities. The findings of this study also align with those of Sastre-Merino et al. [37], which highlight the positive value of DLE in facilitating knowledge sharing among students. They also resonate with Wali's findings [38], which identified the positive impact of digital technology in the classroom on students' attitudes towards expanding their learning horizons. This will definitely promote their SDL skill development.

In our study, we found that students in the experimental group, who were taught using the constructionism instructional model in a DLE, showed higher average levels of SDL skills compared to those in the control group. Additionally, the average learning achievement of the experimental group exceeded that of the control group. These findings align with Yoesya et al.'s [39] discovery that students with SDL skills can take control of their own learning, indirectly impacting their academic performance. Therefore, SDL skills serve as important and reliable indicators of successful learning [40].

6 CONCLUSION

The uncertainty and volatility resulting from the advancement of digital technology in the 21st century have made SDL skills critical for learning in an era marked by rapid change. The primary aim of this study is to examine the effects of enhancing SDL skills through learning activities based on the constructionism approach in a DLE, utilizing a quasi-experimental, non-equivalent pre- and post-test control group design. The subjects of this study were eleventh-grade students enrolled in a non-science-focused program. SDL skills and learning achievement related to lessons about electromagnetic waves were assessed both before and after the learning process. This analysis revealed statistically significant differences in SDL skills and learning achievement between students taught with the different instructional models. Specifically, the experimental group exhibited significantly higher averages in terms of SDL skill levels and learning achievement after the learning process. Based on the findings of this study, it can be concluded that instructional activities emphasizing providing students with the opportunity to learn by creating meaningful artifacts within the context of using suitable digital tools and platforms have a positive impact on SDL skills. However, there may be other factors that affect the promotion of SDL skills. Future studies may need to comprehensively examine other related factors.

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