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The Influence of Distance Education and Peer Self-Regulated Learning Mechanism on Learning Effectiveness, Motivation, Self-Efficacy, Reflective Ability, and Cognitive Load

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Abstract: COVID-19 has resulted in the increased use of distance learning around the world. With the advancement of information technology, traditional classroom teaching has gradually integrated the Internet and distance learning methods. Students need to be able to learn on their own in a distance learning environment, so their ability to self-regulate their learning in a distance learning environment cannot be ignored. However, in previous studies on self-regulated learning, most learners learn alone. When they have academic doubts, they cannot obtain help and support from their studies, resulting in reduced learning outcomes. This study uses the peer self-disciplined learning mechanism to establish a distance teaching system that assists students and to improve their own learning status by meeting with peers at a distance. It can also help learners orient themselves by observing their peers' learning status and goal considerations. The participants in this study were 112 college students in the department of information management. The control group used a general self-regulated teaching system for learning, and the experimental group used a distance learning system, incorporating peer self-regulated learning. The results of the study found that learners who used the distance peer learning mechanism were more effective than those who used the general distance self-regulated learning system; learners who used the distance peer-regulated learning mechanism had better motivation, self-efficacy, and reflection after the learning activity than those who used the general distance self-regulated learning system. In addition, with the aid of such mechanisms, learners' cognitive load can be reduced, and learning effectiveness can be improved.

Keywords: distance education; self-regulated learning; self-explanation

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1. Introduction

The outbreak of COVID-19 has caused significant disruptions to traditional classroom teaching around the world, leading to increased use of distance-learning methods [1–3]. This change has been made possible by the rapid development of information technology, which has made it possible for students to complete their education at a distance. Traditional classroom teaching has gradually integrated the Internet and distance learning methods [4]. While this transition has been challenging for some educators and students, it has also opened up new opportunities for flexible and accessible learning [5,6]. With the ongoing global pandemic, distance learning will likely continue to play an important role in the future of education. Due to the rapid development of technology, distance learning has become a new learning trend that allows learners to create a learning environment that is not limited by space and time. Learners have the flexibility to learn at anytime and anywhere, allowing them to customise their learning plans according to their progress and paces [7]. However, because learning can take place without the constraints of space and time, it is difficult for students to feel engaged in the actual classroom [8]. Teachers are also unable to provide more personalised instruction.

Cognitive load refers to the mental effort required to process information during learning. The complexity of the textbook content and the way the content is presented can impact cognitive load. When students experience a high cognitive load, it can impede their ability to process information and negatively impact their learning outcomes. Therefore, it is important to consider the impact of cognitive load on students in a distance learning environment and to develop effective learning strategies to minimise its effects. Research indicates that students who are low achievers are more passive in the learning process. They struggle with achieving a thorough understanding of the subject area, developing effective learning skills, and identifying opportunities for success in their studies. Thus, they gradually lose motivation for learning and achieving the necessary goals. It has also been shown that students who do not employ efficient learning strategies during the self-adjustment phase of learning in a distance environment cannot efficiently gain knowledge [9]. Therefore, in order to learn in a distance environment and achieve good learning outcomes, students' self-regulated learning skills must not be neglected.

The development of students' self-regulated learning is an important goal of education today. Prior studies on self-regulated learning have mostly focused on how learners monitor their own learning outcomes, self-adjustments, and improvements. Reflective ability plays a crucial role in this process, as learners who are able to reflect on their learning experiences can identify their strengths and weaknesses and make necessary adjustments to their learning strategies. Yet, in certain situations where learners experience psychological or theoretical doubts, they may not be able to receive emotional, academic, instrumental, and informational assistance from a self-regulated learning environment.

If students can receive feedback and interact with others, it might make them feel less isolated. Such interactions with others can also help the learners work through various psychological and emotional issues, thus ultimately increasing learning effectiveness [10]. Effective self-discipline practices are essential for enhancing students' learning outcomes since they have a positive influence on their self-motivation and self-efficacy [11]. While teaching students knowledge, it is crucial to cultivate good self-discipline habits and enhance peer support in the learning environment.

This can significantly enhance students' learning results while enhancing their motivation for studying, self-efficacy, sense of accomplishment, and ability to cope with stress [12–14]. Hence, this study will use the remote peer self-regulated learning mechanism to (1) construct a self-regulated learning system to aid learners in observing their peers' learning status and goals during the learning process, and (2) enable learners to set their own learning goals and provide mutual support through remote peer learning. It aims to investigate the impact of incorporating a distance peer learning mechanism on learners' motivation and learning effectiveness in the self-regulated learning process, and further analyze the effect of students' varying levels of learning achievements.

The research questions are as follows:

(1) Can learners improve learning outcomes when involved in distance peer self-regulated learning mechanisms?
(2) Do high achievers enhance learning outcomes when involved in a distance peer self-regulated learning mechanism?
(3) Do low achievers enhance learning outcomes when involved in a distance peer self-regulated learning mechanism?
(4) Do both homogeneous groups and heterogeneous groups improve their learning outcomes when involved in a distance peer self-regulated learning mechanism?
(5) What are the differences in learning motivation, reflective ability, self-efficacy, cognitive load, and technology acceptance between learners who are involved in a distance peer self-regulated learning and those who are involved in a general self-regulated learning?

2. Related Work

2.1. Distance Learning

With the progress of technology, people's use of the Internet has also changed with the development of the times. Thus, traditional face-to-face teaching methods are gradually being replaced by distance learning in teaching and learning. This allows learners to create a learning environment that is not limited by space and time. Learners can adjust their own learning plans to fit with their paces. As distance learning offers diverse resources for learning, it has become an increasingly popular mode of education [15].

When learning in a digital environment, learners gain greater control than in traditional learning. They have more flexibility in their management of time and space, and choose methods and tools that match their preferences, abilities, and learning pace. Therefore, in the digital learning environment, the ability of learners to control themselves and use learning strategies will have a profound impact on learning outcomes.

Among the types of distance learning, several types of teaching materials for students are listed. These include "lecture capture, talking-head lecture", which records students' reactions and the teachers teaching in the classroom. Another type is "voice-after entering the screen", which briefs the teacher's voice and picture-in-picture. A third type is "picture-in-picture", which includes images, sounds, and digital teaching materials in the teacher's classroom through post-production and their integration with digital teaching materials, etc. [16].

The effectiveness of instruction in distance education was assessed in light of students' self-learning abilities, teaching skills, teachers' instruction, and textbook content. The results revealed that most students have a positive view toward the implementation of distance education and appreciate its effectiveness. On the contrary, the are several disadvantages associated with distance education, including the following [17–20]:

1. One-way or asynchronous course model: little interaction between instructor and students. While students watch pre-recorded videos, they do not take part in real-time class discussions, which makes learning less motivating;
2. Lack of immersion in the course: in distance learning, students may have trouble concentrating on the course content due to distractions in their learning environment or personal events;
3. Uniformity of course materials: the uniformity of materials in distance learning can prevent instructors from giving personalised feedback and guidance to students. It may result in students with weaker self-regulated learning skills falling behind.

Therefore, this study developed a distance peer learning system for an algorithms course to explore how students can receive peer support and assistance in a self-regulated learning process, focussing on course materials to enhance learning effectiveness and motivation.

2.2. Self-Regulated Learning

Self-regulated learning is a set of behaviour adopted by individuals to achieve learning goals, including control of thoughts, emotions, and environmental behaviour. Learning can be adjusted through strategies such as goal setting, strategy selection, and monitoring [21]. Therefore, it has been crucial to build students' self-regulation skills during the learning process in aid of strengthening areas of deficiency based on their past learning experiences.

According to past research, high achievers are more likely to plan their learning according to their learning status, set clear goals, use more learning strategies in the learning process, and constantly review themselves and adjust their learning status. The four steps of the self-regulated learning cycle model proposed by Zimmerman [21] include self-assessment and monitoring, goal setting and planning of strategies, implementation and monitoring of strategies, and monitoring of strategy outcomes, as described below:

1. Self-Assessment and Self-Monitoring: first, students will assess their level of performance on a learning task and determine how effective their learning is based on their past performance and effectiveness;

2. Goal Setting and Strategy Planning: first, students will analyse the learning task then set a clear goal for learning and plan strategies to achieve the goal;
3. Strategy Implementation and Strategy Monitoring: in a structuration learning environment, students try to implement a learning strategy and monitor the impact of its implementation;
4. Strategy Outcome Monitoring: students focus their attention on the "process of the strategy" and "learning outcomes" to determine the effectiveness of the strategy.

Self-regulated learning systems allow distance learners to have plans and goals, and learners can adjust their learning status during the self-regulated learning based on past learning experiences to address deficiencies. Zimmerman illustrates that learners go through a three-stage cycle of self-regulated learning, consisting of forethought, performance or volitional control, and self-reflection [12]. Forethought is a process in which learners analyze a task, set goals, and plan how to achieve them before performing the task. Performance or Volitional Control is the process by which learners monitor their progress while performing tasks and using self-control strategies to maintain their motivation to participate. Self-Reflection is an assessment of how well a student completes tasks that are attributed to their success or failure. These attributions produce self-reactions that can have a negative or positive effect on students' performance in the later stages of learning.

According to previous research on self-regulated learning systems, most students can only see their own learning performance and cannot see the learning status and performance of other learners, nor can they interact with each other. When learners encounter difficulties or face setbacks in the learning process, peer support is a buffer that helps learners express their emotions and restore their learning goals. Therefore, this study developed a model based on the three-stage cycle of self-regulated learning described by Zimmerman above. In the forethought stage, past learning records and peer set goals are provided for learners, allowing them to evaluate and formulate learning strategies in a structured manner according to their own learning conditions, rather than setting them haphazardly, which may result in poor learning outcomes. Test questions are employed to monitor learners' learning to ensure that learners are focusing on the curriculum and to compare their learning with that of their peers, thereby identifying appropriate learning strategies.

With the prevalence of distance teaching, research on self-disciplined learning has received increasing attention in recent years. Joo et al. [22] used the MSLQ scale to explore the "self-efficacy of traditional teaching", "self-efficacy of self-disciplined learning", and "self-efficacy of online learning". The results of the study found that "self-efficacy of online learning" is better than "self-efficacy of traditional teaching". Kao [23] proposed scaffold-assisted research on self-disciplined learning in asynchronous network teaching. The experimental background is a general course of asynchronous network teaching at a university. The setting of learning goals is used to explore college students' self-disciplined learning abilities. The results showed that this teaching environment and the mechanism of self-disciplined learning can effectively improve the situation, quality, and regularity of learning.

Hwang et al. [24] proposed that using a computer-assisted self-disciplined learning system helps assist students in classroom learning. With the availability of current school equipment resources, teachers can have a considerable impact on students' self-disciplined learning by formulating learning strategies. Therefore, it is feasible and essential to develop a self-disciplined learning system. Chen [25] established a personalised learning systems, "PELS", assisted by a self-disciplined learning mechanism. This system can help students increase their learning performance in a self-disciplined learning setting. The empirical results have proved that the self-disciplined learning mechanism, built by scholars, can facilitate students' learning effectiveness and self-discipline abilities.

The above research on self-disciplined learning found that most learning systems are aimed only at individuals and offer limited chances for peer learning via distance learning systems. Real-time detection and monitoring of student performance in self-disciplined learning are also missing. Therefore, this study aims to (1) enhance students' learning status by monitoring and detecting their performance during self-disciplined learning and providing peer support, while (2) also promoting students' learning effectiveness and motivation.

2.3. Self-Explanation

Self-explanation is a related discourse on solving problems or things [26]. It is a learning activity that can enhance the depth of learning. Many studies have also demonstrated the effectiveness of self-explaining learning and teaching strategies, and they have been widely used in different learning areas [27], such as programming, math, refs. [28–32], science [33–36], and biology [37–39]. These studies have confirmed that self-explanation has a positive effect; it helps to improve students' learning achievement and problem-solving skills.

Chi [40] believes that self-explanation integrates prior knowledge and external knowledge via reflection, which allows students to identify gaps in their understanding and fill them in the learning process [41]. In order to produce better quality descriptive knowledge [42], many scholars also mentioned that reflection is crucial to the construction of knowledge and can significantly boost students' learning performance [24,43–45].

Therefore, when learning reaches a certain level, the system provides test questions. When accessing incorrect answers in the test, they are engaged in self-explanation to reflect on their problem or seek help from peers if they are unable to solve the problem. By reflecting first and then gaining feedback from peers, learners can enhance their understanding and solve problems more easily. In this study, a distance peer self-regulated learning system was developed to investigate the effect of the peer self-regulated learning mechanism on the learning outcomes. During the learning process, learners can see the progress of their peers to stimulate their motivation to learn. When a student encounters a problem, they can seek help from peers by reflecting on the options for the question they answered incorrectly. Peers will explain the options based on the reflection. After the study, students can review their learning results and reflect on and adjust their learning to the areas where they fall short of their peers. Therefore, this study explores the effect of a distance peer learning mechanism on students' learning effectiveness and motivation and analyses the effects of different learning achievements on students' learning effectiveness.

3. Research Method

3.1. Conceptual Framework

In this study, students enrolled in an algorithm course at the Department of Information Management of a university in Taipei were divided into the control group and the experimental group. The variables of self-efficacy, motivation, learning effectiveness, reflective ability, and cognitive load of learners with different learning outcomes are all explored separately in relation to the effects of self-regulated learning with and without distant peer learning mechanisms The independent variables include learning strategies and learning achievement. The section on learning strategies includes general self-regulated learning mechanisms and peer self-regulated learning mechanisms and discusses the impact of different teaching strategies on learners. Additionally, the section on earning achievement will discuss whether two different types of learning achievement learners have different effects on the effectiveness of distance peer self-regulated learning mechanisms. The dependent variables are the effects and differences in learning effectiveness, motivation, self-efficacy, reflective ability, and cognitive load after the learners have completed learning. The control variable was examined before learning to ensure that students in both groups had the same prior knowledge of the algorithm and that both the control and experimental groups used the same materials and learning system.

The research structure of this study is shown in Figure 1, which includes the following three research variables:

1. Arguments

It contains two independent variables: teaching strategy and learning achievement. The section on teaching strategies discusses two methods: the general self-regulated learning system and the self-regulated learning system using the distance peer learning mechanism. The results of different learning strategies and learning effectiveness on learners are also examined. In addition, the section on learning achievement explores whether successful learners demonstrate different effects and differences as a result of the distance peer self-disciplined learning mechanism.

2. Dependent variables

It comprises six dependent variables: learning effectiveness, learning motivation, self-efficacy, reflective ability, cognitive load, and technology acceptance. When the students have completed the learning, the system will display the learning results in the post-learning test. The study uses an independent sample *t*-test analysis to explore the differences between the control group and the experimental group before and after the test. Then, the covariate analysis was used to compare learning effectiveness, self-efficacy, and reflective ability before and after the changes from the questionnaire results. Finally, the study uses an independent sample *t*-test analysis to examine the results of learners' acceptance of technology and cognitive load after learning.

3. Control variables

The variables work to strengthen the study's internal validity of this study and prevent against unrelated variables. Thus, the teaching materials and learning systems used in the control group and the experimental group must be the same, and the "Divide-and-Conquer" in the algorithm, "Dynamic Programming", "The Greedy Approach", and "Backtracking" are the four units of this study. A pre-test was used to make sure that both sets of students had the same prior algorithmic knowledge before the learning activities began.

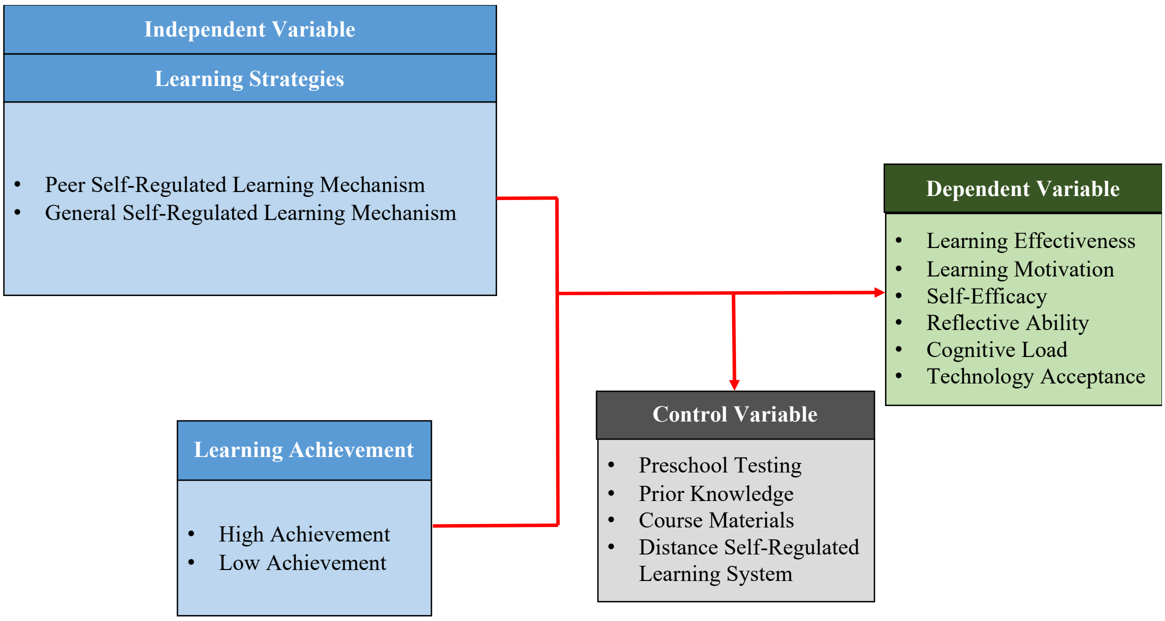

Figure 1. Conceptual Framework.

3.2. System Interface

This study uses distance education and the peer self-regulated system, and the following is a description of the system function and system screen.

The system's peer grouping rooms: in each study session, the system will set seven periods for peers to choose freely. The system will limit the number of students in each session to four, with two of them being high achievers and the other two being low achievers. If the number of high achievers or low achievers reaches two, they will no longer be able to join the session, and the system will hide the session option (Figure 2).

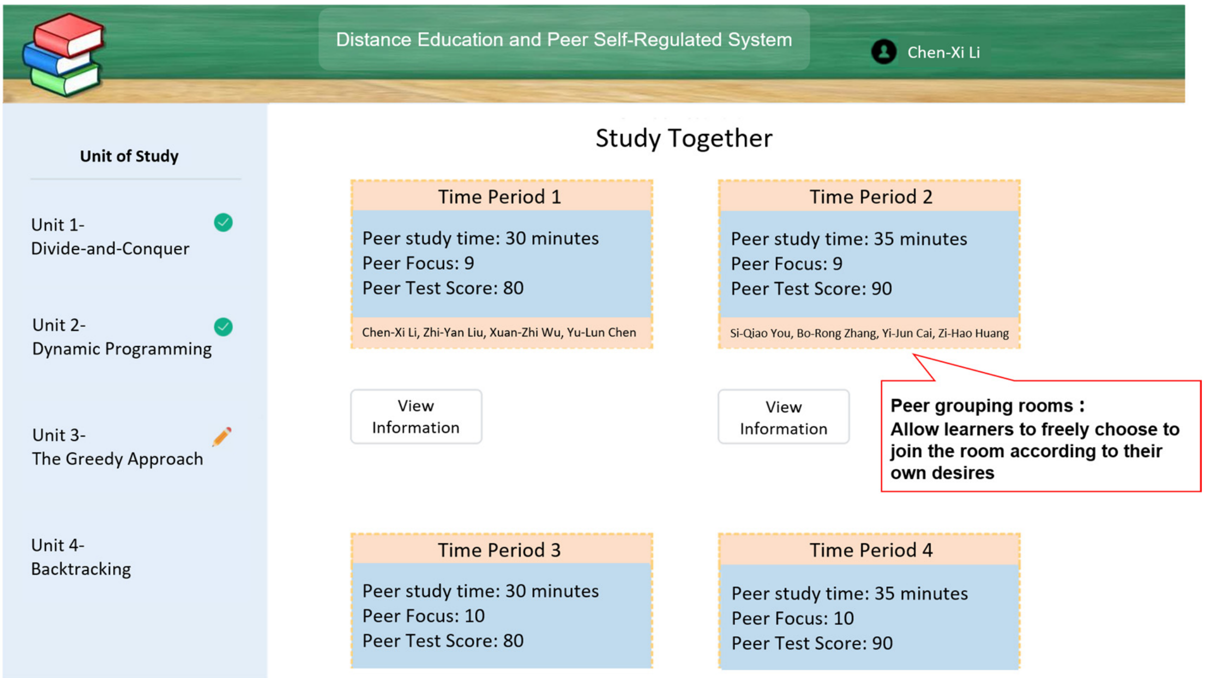

Figure 2. Self-regulated learning goal setting form.

Self-regulated learning goal setting: learners can set individual goals for this learning unit based on their past learning experiences and the goals of the team learning in this group room (Figure 3). The system will measure the learning effectiveness based on the learning goals set by the students themselves, as the study [12] suggests, when students can achieve their self-set goals, they can increase their motivation to learn.

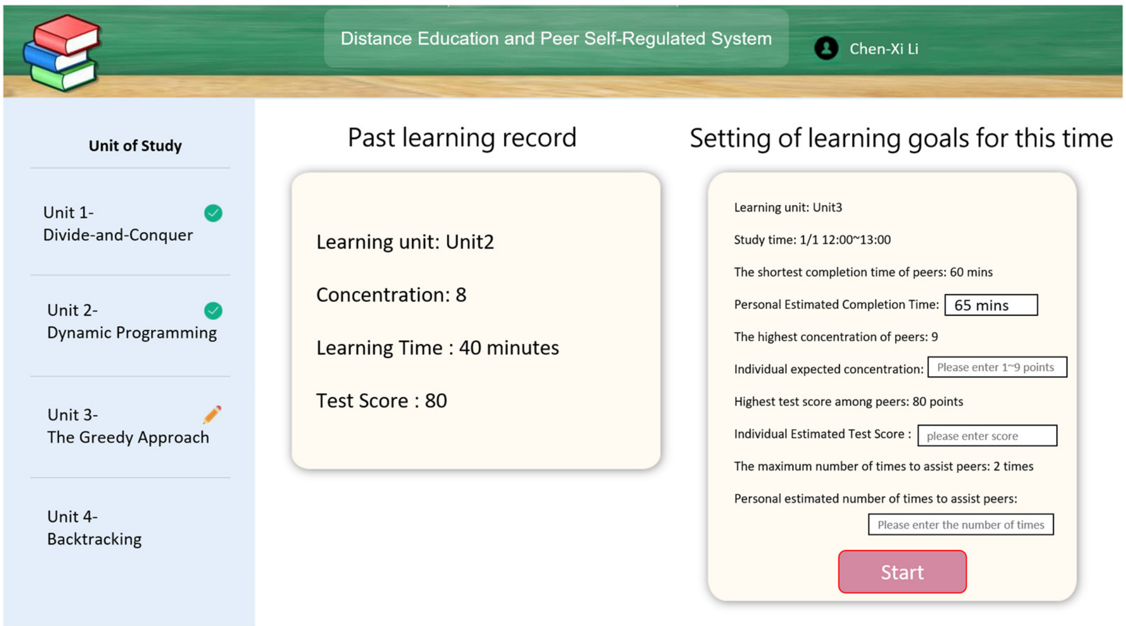

Figure 3. Self-regulated learning goal setting.

Peer progress: during the learning process, the progress bar at the bottom allows you to see the progress of the peers, and you can use it to help you improve your own learning status (Figure 4).

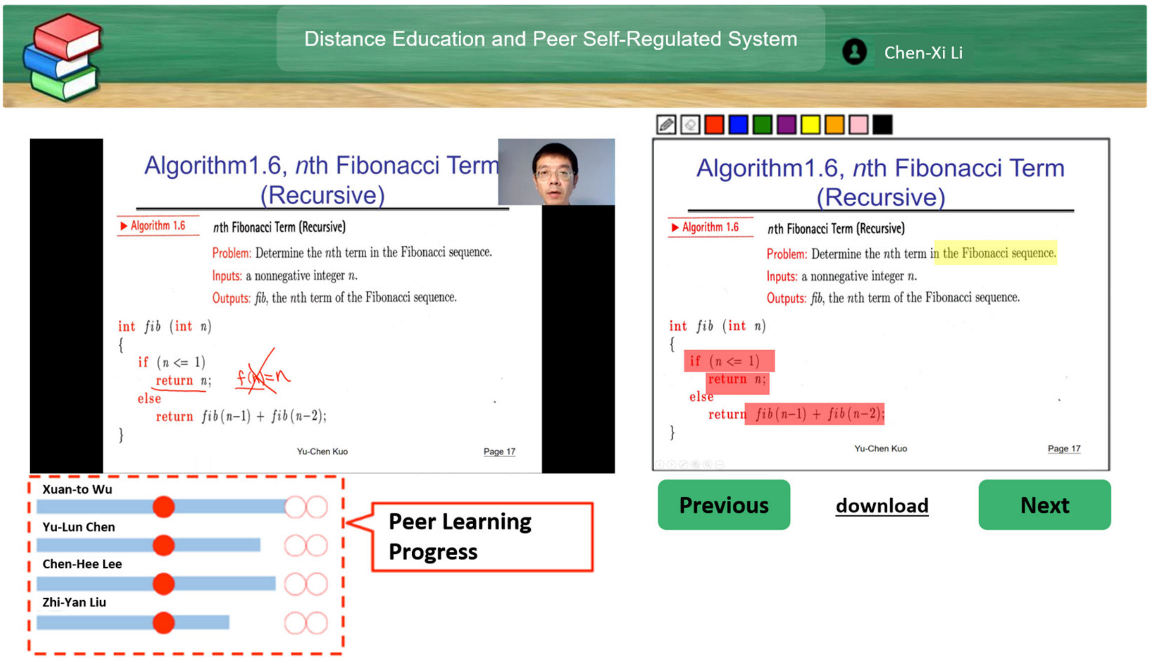

Figure 4. Peer progress.

Peer assistance: if a student responds to a question incorrectly, she or he may seek peer assistance. However, they must first reflect on the question and identify the specific part of it that they do not understand (Figure 5).

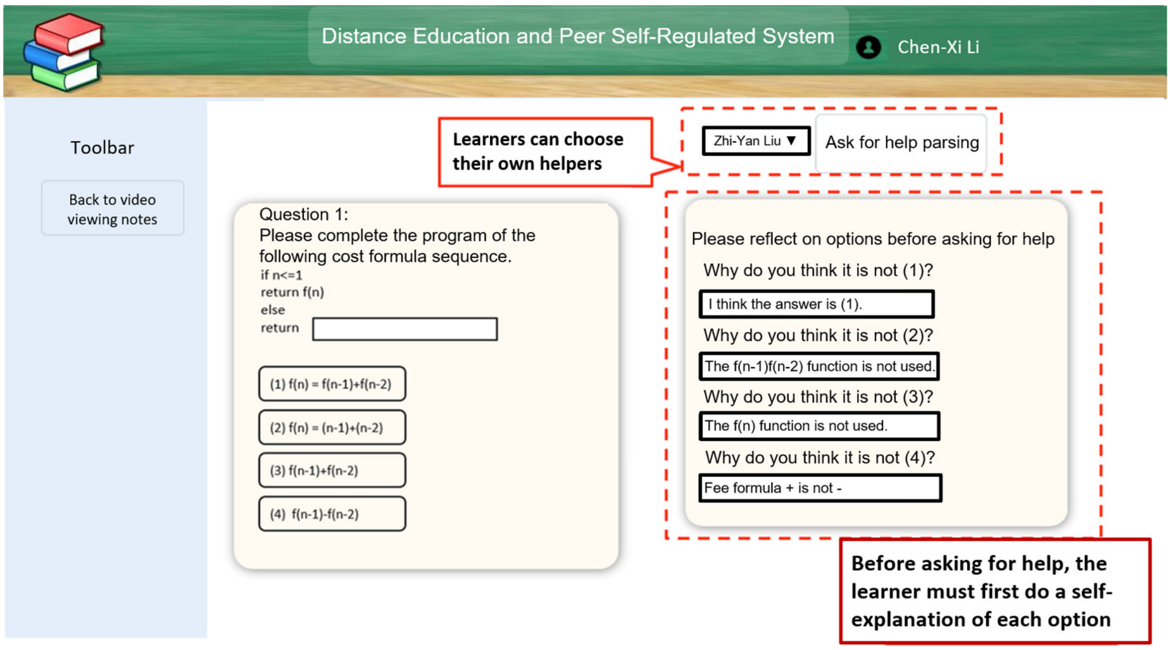

Figure 5. Seeking peer assistance.

When a learner is chosen to be a helper, the current video will be paused and the question from the requester will pop up. The helper will reply to the learner after giving the explanation (Figure 6).

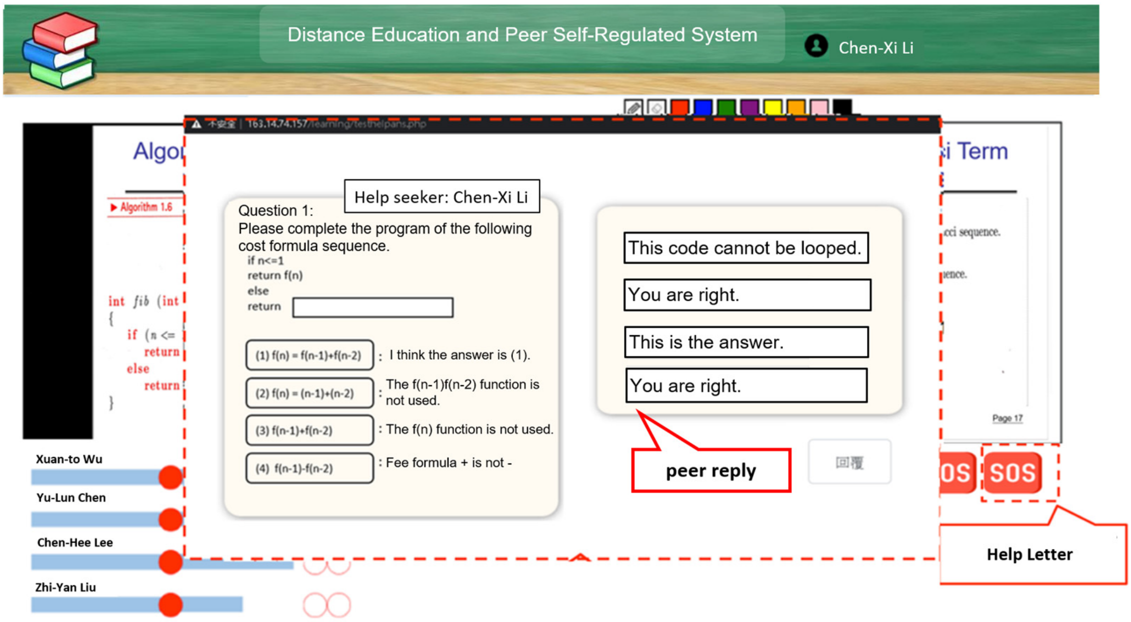

Figure 6. Peer assistance.

Peer feedback function: after the peers finished the learning activity, the tutor and tutee can enter the peer feedback room to complete a feedback form and evaluate the performance of both parties during the real-time instruction (Figure 6).

Self-regulated learning effectiveness view: once a student completes a learning task, the system will display his or her learning effectiveness on the page. The report includes learning units, learning time, test scores, peer averages, grade curves, and the number of times the students assisted their peers and received help. This is intended to help promote self-regulated skills (Figure 7).

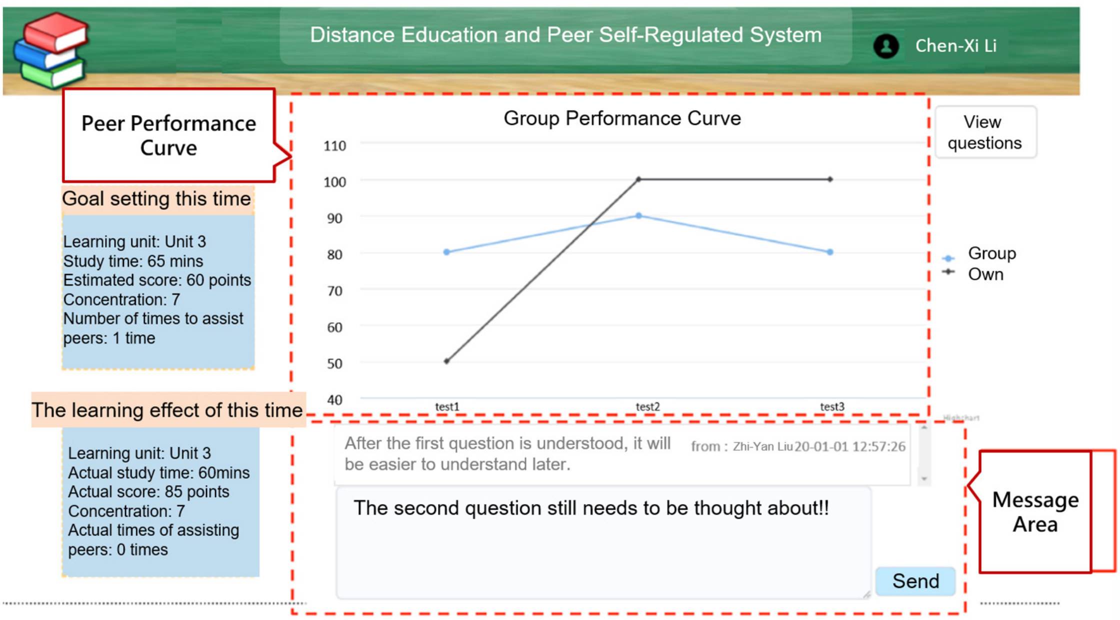

Figure 7. Self-regulated learning effectiveness view.

3.3. Experimental Design

3.3.1. Participants

The participants in this experiment were 112 college students in the department of information management. They were divided into the experimental and control groups, with 56 in the experimental group and 56 in the control group.

3.3.2. Grouping Method

The experimental group used the best grouping method proposed by Chen [46] to conduct paired groupings of students. After sorting the students' pre-test scores from large to small, the median was used as the standard value. The number of people closest to the standard value was taken as a homogeneous group, and the rest of the students were grouped into a heterogeneous group. In order to divide both groups evenly, 28 people are divided into the homogeneous group (a group of 4 people), with 7 groups, and 28 people are divided into the heterogeneous group (a group of 4 people), with 7 groups.

3.3.3. Learning Process

This study discusses the effect of using a distance peer learning mechanism on students' learning effectiveness and analyses the effect of students' learning outcomes with different learning achievements during the self-regulated learning process (Figure 8).

Students in the control group used a general, distance learning self-regulated system in which learners set their learning goals before learning. During the learning process, there are unit tests. If the learner answers the questions incorrectly, the system will give an analysis directly. At the end of the learning process, students can examine their learning results. They are expected to enhance their learning by adjusting their learning strategies. The system also collected learners' scores to compare with those of the experimental group. On the other hand, students in the experimental group were taught using a distance learning system with a peer self-regulated learning mechanism. Students in the experimental group will be classified into three categories of academic achievement based on their pre-test scores: high achievement, moderate achievement, and low achievement. Meanwhile, the high-achievement and low-achievement groups will be combined into a heterogeneous group, while the moderate-achievement group will be combined into a homogeneous group.

Before learning, the experimental group can set their team's learning goals with their peers and forecast their scores, learning time, and the number of times they offered help and received help from their peers. During the learning process, they can study together with their peers and watch their learning progress to improve their own learning status. There will be unit tests during the study. When learners answer a question incorrectly, they can ask for help from their peers. At the end of the study, they can watch the average score of their peers and the set and adjust their learning goals themselves.

The experiment was conducted for 4 weeks, with each week lasting 50 min. At the end of the experiment, tests and questionnaires will be administered to analyse the effects of a peer self-regulated learning mechanism on students' learning effectiveness, self-efficacy, reflective ability, motivation, cognitive load, and technology acceptance. The procedure is as follows:

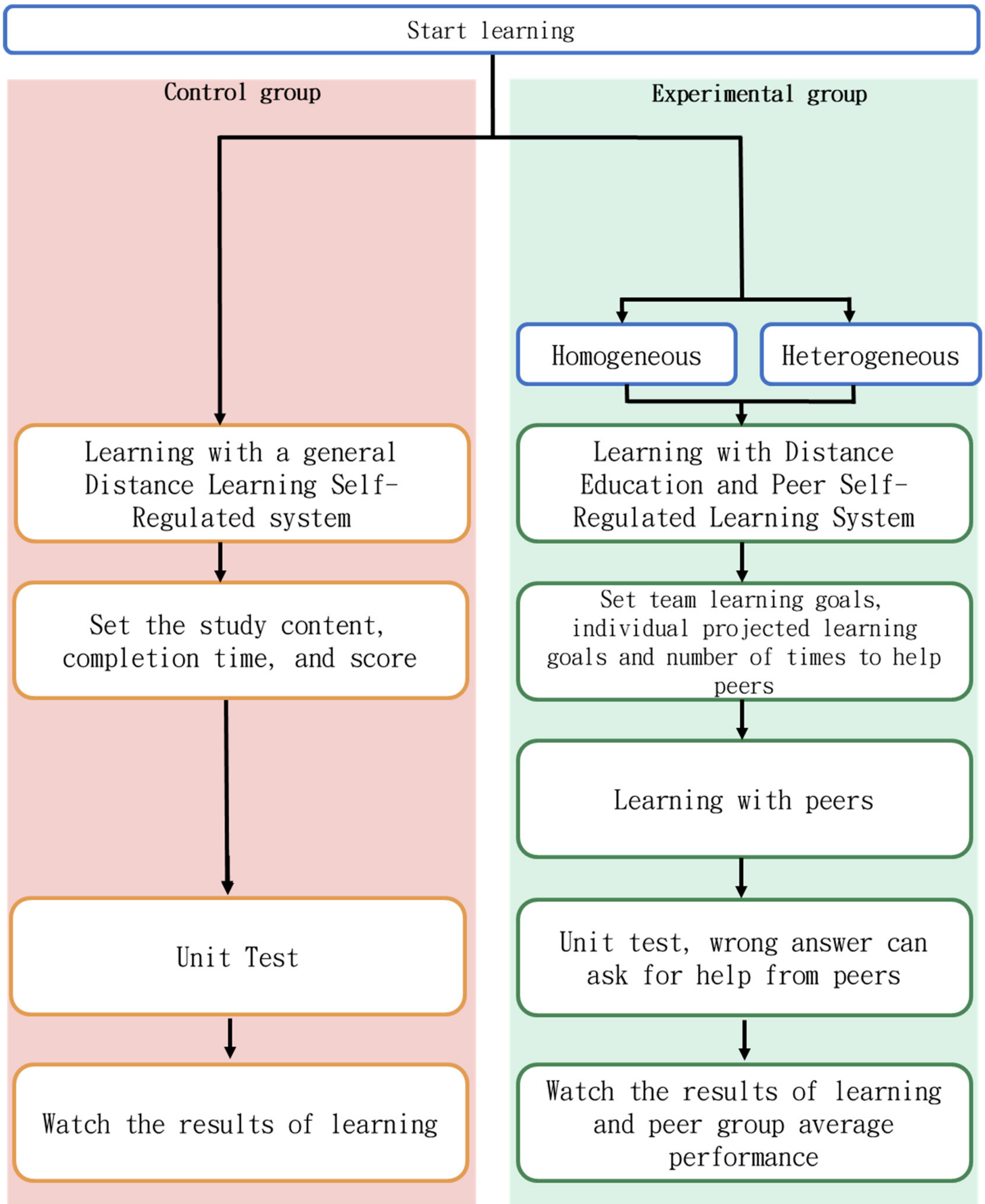

Figure 8. Experimental flowchart.

3.3.4. Research Tool

- Learning Materials and Learning Effectiveness Quiz:

The content of the textbook used in this study is an algorithm course, and 4 units are selected as the learning topics, namely “Divide-and-Conquer”, “Dynamic Programming”, “The Greedy Approach”, and “Backtracking”.

The learning achievement test is divided into “effectiveness of the pre-test” and “effectiveness of the post-learning test”. Before the experimental activity, a pre-learning test will be carried out on the learner. The test content is algorithm-related questions, with a total of 5 questions and a total score of 100 points. The pre-test is to determine whether learners have the same prior knowledge before participating in the activity, and to use this as a standard to classify learners’ learning achievements into three categories, namely, high, medium, and low achievement. High- and low-achievement students are classified as a heterogeneous group, while middle-achievement students are classified as a homogeneous group. Further, using S-shaped grouping in the homogeneous group, middle-achieving learners will also be divided into the two groups of high and low achievement based on their level of achievement.

After the experimental activity, a post-learning test is conducted for the learners. The post-learning test is based on the teaching material in the learning activity. The teacher will select the test questions related to the content of the teaching material. The test content is the unit content of the learning video. There are 5 questions in total. The score is 100 points. It mainly analyses the impact of using a distance peer learning mechanism on learners' learning effectiveness, and deeply analyses the impact of students' effectiveness with different learning achievements.

- Learning Motivation Questionnaire: The study's questionnaire is based on Pintrich's [47] learning motivation, which primarily investigates changes in students' learning motivation for algorithms before and after learning. Using a 5-point Likert scale, the Cronbach's alpha of the pre- and post-questionnaires was 0.85 and 0.87, respectively;
- Self-Efficacy Questionnaire: The questionnaire for this study is quoted from the self-efficacy questionnaire proposed by Pintrich [47], which mainly explores the changes in students' self-efficacy of algorithms before and after learning. Using a 5-point Likert scale, the Cronbach's alphas of the before and after questionnaires was 0.83 and 0.83, respectively;
- Reflective Ability Questionnaire: The questionnaire employed in this study is based on the reflective ability questionnaire proposed by Kember et al. [48], which mainly examines how students' reflective abilities to algorithms alter both before and after learning. Using a 5-point Likert scale, the Cronbach's alphas of the before and after questionnaires was 0.77 and 0.78, respectively;
- Technology Acceptance Questionnaire: The questionnaire of this study was quoted from the questionnaire proposed by Wang, Yang, and Hwang [49], which mainly examines whether students' use of the functions of the system is helpful for learning and whether the operation is simple and easy to use. Using a 5-point Likert scale, the Cronbach's alpha is 0.83;
- Cognitive Load Questionnaire: The questionnaire for this study was adapted from the cognitive load questionnaire proposed by Paas [50] and Hwang et al. [49]. The content of the questionnaire is divided into two categories: mental load and mental effort. Both aspects use a 7-point Likert scale, and the respective Cronbach's alphas are 0.92 and 0.89;
- Interview Questions: The interview questionnaire for this study was adapted from Kuo et al. [51] and Hwang, Yang, Tsai, and Yang [52], with a total of 7 questions. The experimental group's students were asked to participate in one-on-one interviews after the experiment to acquire a better understanding of their opinions and suggestions for improving the learning activities.

3.3.5. Analytical Method

The analysis of the experimental results of this study is carried out using two analysis methods, "independent sample *t*-test" and "covariate analysis". Firstly, a pre-class test was implemented in both groups using the independent sample *t*-test to determine whether they all had the same prior knowledge before participating in the activity. After the experimental activities, a post-learning test will be given to the learners. The post-learning test will be based on the teaching materials in the learning activities. The teacher will select the test questions related to the content covered in the teaching materials.

The test contains the entirety of the instructional video material and consists of 100 points. Its main focus is on analyzing the effect of the distance peer learning mechanism on the learning effectiveness of both groups during the self-regulated learning process.

Meanwhile, the study further analyses the homogeneous and heterogeneous groups of the experimental group, which aims to explore whether there is a significant difference in the learning outcomes of high-achieving students. In addition, a post-learning questionnaire is implemented to examine how learners' learning motivation, self-efficacy, cognitive load, and technology acceptance changed during the entire learning activity.

The survey results are utilised to help explain the findings of the statistical test.

4. Results

4.1. Learning Performance

In order to find out whether the students in the experimental and control groups had the same basic algorithmic skills, a pre-test was conducted before the experimental activity and the differences in the prior knowledge of the students in the experimental and control groups in terms of algorithms were analysed using an independent samples t-test. The results of the analysis are shown in Table 1. It was found that there was no significant difference between the pre-test scores of the experimental and control groups (t = 0.25, p = 0.803 > 0.05); therefore, it can be considered that the experimental and control groups have the comparable basic algorithmic ability.

Table 1. Pre-test of learners between the experimental group and the control group.

Group	N	Mean	SD	t
Experimental	56	75.53	11.09	0.25
Control	56	76.07	11.60	
Experimental High Achievement	28	82.52	8.96	0.98
Control High Achievement	28	82.92	9.82	
Experimental Low Achievement	28	68.54	10.23	0.84
Control Low Achievement	28	69.22	9.18	
Homogeneous	28	72.82	10.28	0.15
Heterogeneous	28	78.24	8.46	

The experimental group and the control group were further divided into high and low achievement samples for the independent sample t-test. The analysis revealed that there was no significant difference between the pre-test scores of high and low achievement learners in the experimental and control groups (t = 0.98, p = 0.749 > 0.05) and (t = 0.84, p = 0.403 > 0.05).

The experimental group was further divided into homogeneous and heterogeneous groups to conduct an independent sample t-test. It was found that there was no significant difference between the homogeneous group and the heterogeneous group (t = 0.15, p = 0.748 > 0.05).

After the learning activities, to analyse whether there were significant differences in the student's learning outcomes in the experimental and control groups, a post-learning test will be implemented at the end of the learning activity. An independent sample t-test will be administered with the post-learning test results to discuss the difference in algorithmic ability between the experimental and control groups. The results of the analysis are shown in Table 2. The post-learning test scores of the experimental group were significantly higher than those of the control group (t = −2.05, p = 0.008 < 0.01, d = −0.501). Therefore, the experimental group using the distance peer self-regulated learning mechanism helped to improve the students' learning effectiveness.

Further, post-learning tests were administered to high achievement and low achievement learners, and independent sample t-tests were administered using the results of the post-learning tests. The results of the analysis are shown in Table 3. The post-learning test scores of experimental high achievements were significantly higher than those of control high achievement (t = −2.18, p = 0.000 < 0.001, d = −1.043). The post-learning test scores of experimental low achievements were also significantly higher than those of control low achievement ($t = -1.29$, $p = 0.025 < 0.05$, $d = -0.603$). Thus, both experimental high achievement and experimental low achievement using distance peer self-regulated learning mechanisms help to improve learners' learning effectiveness.

Table 2. Post-learning test of learners between the experimental group and the control group.

Group	N	Mean	SD	*t*	*d*
Experimental	56	80.78	19.68	−2.05 **	−0.501
Control	56	70.96	19.55		

** $p < 0.01$.

Table 3. Post-learning test of learners with different learning achievements in the experimental and control groups.

Group	N	Mean	SD	*t*	*d*
Experimental High Achievement	28	96.90	8.96	−2.18 ***	−1.043
Control High Achievement	28	85.96	11.82		
Experimental Low Achievement	28	64.44	13.23	−1.29 *	−0.603
Control Low Achievement	28	56.48	13.18		

*** $p < 0.001$; * $p < 0.05$.

Pre-tests were administered to both homogeneous and heterogeneous groups of learners, and independent sample *t*-tests were conducted with the pre-test scores to investigate the differences in the algorithmic abilities of different groups of learners. The results of the analysis are shown in Table 4, where the learning effectiveness of the heterogeneous group was significantly higher than that of the homogeneous group ($t = 2.05$, $p = 0.04 < 0.05$, $d = 0.531$). The results showed that the heterogeneous group of learners who adopted the distance peer self-regulated learning mechanism demonstrated enhanced learning effectiveness.

Table 4. Post-learning test of learners in homogeneous and heterogeneous groups.

Group	N	Mean	SD	*t*	*d*
Homogeneous	28	75.03	18.63	2.05 *	0.531
Heterogeneous	28	84.96	18.74		

* $p < 0.05$.

4.2. Learning Motivation of Learners between the Two Group

The analysis of the pre-questionnaire on learning motivation was conducted using an independent sample *t*-test. As shown in Table 5, there was no significant difference in the learning motivation between the experimental and control groups ($t = 0.84$, $p = 0.40 > 0.05$).

Table 5. Pre-questionnaire of motivation of learners between the experimental group and the control group.

Group	N	Mean	SD	*t*
Experimental	56	3.90	0.51	0.84
Control	56	4.03	0.47	

After the learning activities, the two groups were given a post-questionnaire of learning motivation and the results were analysed by ANCOVA with the pre-questionnaire of learning motivation as a covariate. The results of the analysis are shown in Table 6, the learning motivation of the experimental group was significantly higher than that of the control group ($F = 5.49$, $p = 0.023 < 0.05$). Therefore, the experimental group that adopted the distance peer self-regulated learning mechanism demonstrated enhanced learning motivation.

Table 6. Post-questionnaire of motivation of learners between the experimental group and the control group.

Group	N	Mean	SD	Adjusted Mean	*F*	η^2
Experimental	56	4.18	0.42	4.20	5.49 *	0.08
Control	56	3.94	0.49	3.95		

* $p < 0.05$.

4.3. Self-Efficacy of Learners between the Two Group

The pre-questionnaire of self-efficacy was analysed using independent samples *t*-test. As shown in Table 7, there was no significant difference in motivation between the experimental and control groups ($t = -0.97$, $p = 0.336 > 0.05$).

Table 7. Pre-questionnaire of self-efficacy of learners between the experimental group and the control group.

Group	N	Mean	SD	*t*
Experimental	56	3.48	0.65	−0.97
Control	56	3.31	0.64	

After the learning activities, the two groups were given a post-questionnaire of self-efficacy and the results were analysed by ANCOVA with the pre-questionnaire of self-efficacy as a covariate. The results of the analysis are shown in Table 8, the self-efficacy of the experimental group was significantly higher than that of the control group ($F = 4.03$, $p = 0.043 < 0.05$). Therefore, the experimental group that adopted the distance peer self-regulated learning mechanism demonstrated enhanced self-efficacy.

Table 8. Post-questionnaire of self-efficacy of learners between the experimental group and the control group.

Group	N	Mean	SD	Adjusted Mean	*F*	η^2
Experimental	56	3.78	0.57	3.78	4.03 *	0.06
Control	56	3.49	0.41	3.49		

* $p < 0.05$.

4.4. Reflective Ability of Learners between the Two Group

The pre-questionnaire of reflective ability was analysed using independent samples *t*-test. As shown in Table 9, there was no significant difference in reflective ability between the experimental and control groups ($t = -0.41$, $p = 0.87 > 0.05$).

Table 9. Pre-questionnaire of reflective ability of learners between the experimental group and the control group.

Group	N	Mean	SD	*t*
Experimental	56	3.19	0.83	−0.41
Control	56	3.12	0.81	

After the learning activities, the two groups were given a post-questionnaire of reflective ability and the results were analysed by ANCOVA with the pre-questionnaire of reflective ability as a covariate. The results of the analysis are shown in Table 10, the reflective ability of the experimental group was significantly higher than that of the control group ($F = 0.786$, $p = 0.03 < 0.05$). Therefore, the experimental group that adopted the distance peer self-regulated learning mechanism demonstrated enhanced reflective ability.

Table 10. Post-questionnaire of reflective ability of learners between the experimental group and the control group.

Group	N	Mean	SD	Adjusted Mean	*F*	η^2
Experimental	56	4.18	0.72	4.15	0.786 *	0.33
Control	56	3.76	0.49	3.46		

* $p < 0.05$.

4.5. Cognitive Load of Learners between the Two Group

After the learning activities, the cognitive load questionnaire was administered to the experimental and control group students, and the questionnaire was divided into two aspects: mental workload and mental effort. The results of the analysis are shown in Table 11. The students in the experimental group achieved significant results in both mental workload ($t = 3.12$, $p = 0.04 < 0.05$, $d = 0.710$) and mental effort ($t = 2.63$, $p = 0.03 < 0.05$, $d = 1.034$). Therefore, although the content of the materials in the experimental and control groups were the same, the peer self-regulated learning mechanism helped the learners not only to improve their own learning status, but also to seek peer assistance for problems that could not be solved so that the learners could solve subsequent problems, thus reducing mental workload and mental effort.

Table 11. Questionnaire of cognitive load of learners between the experimental group and the control group.

	Group	N	Mean	SD	*t*	*d*
Mental Workload	Experimental	56	3.13	0.95	3.12 *	0.710
	Control	56	3.83	1.02		
Mental Effort	Experimental	56	2.19	1.27	2.63 *	1.034
	Control	56	3.54	1.34		

* $p < 0.05$.

4.6. Technology Acceptance of Learners between the Two Group

A technology acceptance questionnaire was administered to students in the experimental and control groups after the learning activities, and an independent sample *t*-test was used. As shown in Table 12, the acceptance of distance peer self-regulated learning system by the experimental group was significantly better than that of the control group ($t = -3.33$, $p = 0.009 < 0.01$, $d = -0.784$). The students who adopted the distance peer self-regulated learning system found the interface of the system clear and easy to understand and operate.

Table 12. Questionnaire of technology acceptance of learners between the experimental group and the control group.

Group	N	Mean	SD	*t*	*d*
Experimental	56	4.11	0.49	−3.33 **	−0.784
Control	56	3.80	0.27		

** $p < 0.01$.

4.7. Interview Method

To understand more about the experimental group learners' ideas of adopting the distance peer self-regulated learning system, four experimental group learners were invited to conduct individual interviews after the experimental activity: Homogeneous group A, Homogeneous group B, Heterogeneous group C, and Heterogeneous group D. The interviews focused on the interviewees' thoughts on the learning system, the areas for improvement and the learning mechanism.

Based on the results of the interviews, the core categories of the interviews were divided into two main categories: "Peer intervention" and "Reflecting on the theme and the function of helping peers". "Peer intervention" is intended to analyse the impact of peer intervention on students. "Peer intervention" makes students more engaged, and watching peers' learning progress during the learning process can make students more motivated to continue learning and can increase students' effectiveness and motivation.

"Reflecting on the theme and the function of helping peers" is intended to analyse the impact of reflecting on the theme and helping peers' learning. Reflecting on the theme and the function of helping peers can effectively help students develop a deeper understanding in their learning. The study further found that the homogeneous group was less active in helping their peers and did not receive immediate feedback when they were asked. In contrast, the heterogeneous group was more active in helping their peers, and the low achievers in the heterogeneous group asked their peers more often than the high achievers. Therefore, from the interview analysis, it can roughly be inferred that the heterogeneous group of learners is more suitable to use this mechanism for learning.

5. Conclusions and Discussion

(1) Learners who used a distance peer self-regulated learning mechanism can help improve their learning effectiveness compared with those who used a general distance self-disciplined learning system.

Under the condition that both groups of students have the equivalent basic ability of calculation, the analysis of this experiment shows that the students in the experimental group have significantly better scores on the learning effectiveness scale than the control group after the learning activities. During the interview, it can be found that although it is stressful to see the learning progress of peers while studying, it can also improve one's own learning status and make one more focused on the teaching materials. This echoes Zimmerman's [53] self-regulated learning concept, which suggests that the peers with whom you are learning can significantly affect your learning outcomes.

Apart from learning together and choosing learning objects, learners can also gain support and assistance from their peers, thereby improving learning motivation and learning effectiveness. This also echoes the earlier discussion about how peer intervention can effectively improve students' learning performance. It follows that using the distance peer self-regulated learning system developed by this study in the algorithm learning course has the benefit of enhancing the learning effect.

(2) High-achievers using the distance peer self-regulated learning mechanism can help improve learners' learning effectiveness compared with those high-achievers in the general distance self-regulated learning system.

As the students in both groups had similar prior knowledge of the subject of the algorithms, the analysis results further revealed that the learners in the experimental group with high achievement had significantly better scores on the learning effectiveness test than those in the control group. In light of findings from the interview, students with high academic achievement in the experimental group will improve their sense of accomplishment by helping their peers. Apart from more goals setting in the learning process, students with high academic achievement demonstrate their behaviours during examination and evaluation of their learning progress [47]. While offering responses to peers, they also review the learning content, which helps them focus more on the learning activities. Based on the above findings, the results are consistent with the concept of self-explanation associated with the development of students' reflection. While offering the response to peers, students would think of how to give explanations (self-explanations) and then integrate prior knowledge and external knowledge through reflection. While conducting self-explanation and reflection, they are able to identify possible gaps in knowledge and find out the solutions in order to produce better quality descriptive knowledge, which aligns with VanLehn, Johns, and Chi's [42] statement on the development of descriptive knowledge. The findings are also echoed in the interview that reflected on the topic; along with assisting peers, the process can effectively help students in their learning. Since a deeper understanding can be gained, it thus enhances learning effectiveness. Students with high academic achievement in the experimental group are more aware of arranging learning plans according to their own learning conditions. Therefore, in the algorithm learning course, it can be concluded that the distance peer self-regulated learning system developed by this research will have the advantage of enhancing the learning effect for the experimental group's high achievers.

(3) Low-achievers using the distance peer self-regulated learning mechanism can improve their learning effectiveness compared with low-achievers in the general distance self-regulated learning system.

As the students in both groups had similar prior knowledge of the subject of the algorithms, the analysis results further found that the learners in the experimental group with low achievement had significantly better scores on the learning effectiveness test than those in the control group. During the interview, it can be found that when learners in the control group with low achievement answer questions incorrectly, they can seek help from their peers. However, they must first respond to the questions and explain the parts that they do not understand. This method not only reduces learners' feelings of loss and frustration during their learning, but it also helps them internalise the knowledge given to them by their peers, thereby achieving the goal of teaching and learning. This echoes the extremely important role of reflection in the construction of knowledge, which can effectively improve the learning performance of the learner [54].

Reflection is a crucial learning activity that can increase the depth of learning and enhance learning [40]. Reflection is an important learning activity that can increase the depth of learning and improve learning, which echoes the previous analysis results. Students reflect on achieving the goal of teaching and learning. This echoes the extremely important role of reflection in the construction of knowledge, which can effectively improve the learning performance of the learner [54], which, in turn, echoes the previous analysis results. Reflecting on topics and assisting peers can effectively help students gain a deeper understanding of learning, thereby enhancing learning effectiveness. Therefore, in the process of learning algorithms, it can be inferred that the use of the distance peer self-regulated learning system developed by this research has the benefit of improving the learning effect for the low achievers in the experimental group.

(4) In comparison to homogeneous group learners, the heterogeneous group learners who used the distance peer self-regulated learning mechanism can improve learners' learning effect.

In this study, the experimental group is divided into two groups: the homogeneous group and the heterogeneous group. The results of the analysis further found that after the activities, the heterogeneous group had significantly better scores on the learning effectiveness test than the homogeneous group. Therefore, it can roughly be concluded that the learners in the heterogeneous group would benefit more from using the distance peer self-disciplined learning mechanism. Based on the interview, it was found that the students in the heterogeneous group were more active than those in the homogeneous group in terms of the number of times they assisted their peers. Immediate feedback can be provided to low achievers in heterogeneous groups. Students can increase their sense of accomplishment and reduce their frustration by helping their peers and being assisted, which helps them learn again. Students become more focused and motivated to work harder on the teaching materials, aligning with the learning content of the self-regulated learning concept proposed by Zimmerman [53]. The learning system will provide students with their learning history so that they can assess their progress and the effectiveness and status of their peers' learning. The learning situation aligns with the analysis results from the previous discussion. The learners in the heterogeneous group of the experimental group are more suitable to use this mechanism for learning. Therefore, in the algorithm learning course, it can be concluded that the use of the distance peer self-regulated learning system developed by this research has the benefit of improving the learning effect of the experimental group's heterogeneous group learners.

(5) Learners who used the distance peer self-regulated learning mechanism have a significant impact on their learning motivation, self-efficacy, reflective ability, and cognitive load after learning.

The results of the questionnaire analysis found that the learning motivation, self-efficacy, and reflection abilities of the students in the experimental group after learning were significantly better than those before the experiment in the distance peer self-disciplined learning system. The learning motivation, self-efficacy, performance, and reflective ability in the experimental group were also better than those of the control group. With the assistance of the peer self-regulated learning mechanism, the cognitive load of the learners can be reduced at the same time. This leads back to the previous discussion about how peer intervention can motivate students to work harder, continue learning, and improve their learning motivation. As a result, it can be concluded in the algorithm learning course that the distance peer self-regulated learning system developed in this study can effectively improve learners' learning motivation, self-efficacy, and reflection ability. Although the learners in the experimental group put more pressure on their peers to intervene at the beginning, they became more motivated to continue learning after receiving assistance from their peers and feedback from the learners. Therefore, the assistance of the peer self-regulated learning mechanism can not only sharpen the learners' own learning status, but also seek peer assistance for unsolvable problems. Learners can solve subsequent problems, thereby reducing mental load and mental effort. This study's distance peer-self-regulated learning system demonstrated that peer assistance can effectively improve learners' learning effects in a distance learning setting.

However, some limitations must be taken into account, which are described in detail as follows:

(1) Sample limit

The samples for this study are from 112 students who are studying algorithmic courses in the Department of Information Management of a university in Taipei City, including 56 students in the experimental group and 56 in the control group. The sample size for this study is too small since it only includes university department students. Thus, the inference cannot be generalised to learners in other levels and grades; it can only be applied to learners who share the same characteristics as those in this study.

(2) Study subjects

The chosen learning activities of this study are associated with an algorithm with four thematic units: "Divide-and-Conquer", "Dynamic Programming", "The Greedy Approach", and "Backtracking". The material is restricted to the article in this study. Thus, it remains to be determined if the findings of this study may be applied to other subjects or groups. The distance peer self-regulated learning system developed by this research shows that the experimental group students' outcomes in the algorithm course are significantly superior to those of the control group students. Still, due to the intervention and support of peers, learners can compare their learning status with that of their peers, and then find the learning strategies that suit them. According to the interview, the learning mode of four-person groups can be altered to two-person groups, which can better cater to low-achieving learners. In the future, the system will be able to support "Sharing Note". When studying, students are able to highlight key ideas and make notes in their textbooks. Shared notes can organise peers' notes, making it simple for learners to learn from others, observe how their peers make notes, and understand what the other party learns.

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