Impacts of Concept Map-Based Collaborative Mobile Gaming on English Grammar Learning Performance and Behaviors

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ABSTRACT: EFL (English as a foreign language) students usually learn by rote when they study English grammar. They usually memorize all the grammar rules mechanically instead of learning grammar in a structured way. Researchers have suggested that students can internalize knowledge via using knowledge construction tools and collaborated learning activities. Therefore, in this study, a grammar concept mapping-based collaborative English mobile gaming approach has been developed. A quasi-experiment on an English course was carried out in an elementary school to evaluate the learning achievement of the low- and high-achieving students. Moreover, the students' learning behavioral patterns were explored by analyzing their interactive logs in the mobile discussion forum. The results showed that the students using the proposed approach revealed significantly higher English grammar achievements than those who learned with the collaborative English gaming approach; moreover, the grammar concept mapping strategy can help the low-achieving students to have better learning achievements, and to realize the concept structure of English grammar to internalize their knowledge. In addition, it was also found that the low-achieving students had significantly higher mental load than the high-achieving students, implying that the use of the grammar concept mapping approach provided a challenging but helpful task to help the low achievers focus on the gaming process and successfully organize the grammar structures they had learned.

Keywords: Grammar concept mapping, Game-based learning, English grammar, Behavioral analysis, High- and low-achieving

1. Introduction

In recent years, due to the huge global economic development, learning English, especially grammar which is the fundamental concept of language, is essential for students in many countries. English grammar includes structural rules and clear classification so the ability of organization is emphasized when learning. However, in the current Taiwan education model, students are usually asked to absorb large volumes of material in a very short time, so they tend to learn by rote rather than as a result of understanding. Students who learn English as a foreign language experience many kinds of learning difficulties, such as a lack of learning motivation, self-efficacy and high English anxiety (Cheng & Chen, 2019; Ping, Baranovich, Manueli, & Siraj, 2015). In previous studies, many researchers have investigated how to design effective learning strategies to help students with different learning abilities (Cheng & Chen; Hwang et al., 2017b; Fu, Lin, Hwang, & Zhang, 2019). Consequently, an increasing number of researchers have proposed various mobile learning strategies and models to give students personalized and situated learning support (Hung et al., 2018; Hwang, Chu, & Lai, 2017; Tu & Hwang, 2018). Among them, the game-based learning approach has attracted widespread attention (Chu, Yang, & Chen, 2015; Chang & Hwang, 2018; Reinders & Wattana, 2014).

In the past decade, game-based learning has been considered as an effective learning strategy that can help students reduce their English anxiety and improve their investment in learning (Hwang et al., 2017b; Hwang & Wang, 2016). Moreover, many studies have pointed out that game-based learning can enhance students' learning achievement (Chu, Yang, & Chen, 2015; Hwang et al., 2017a; Hwang & Wang, 2016; Chen, Liu, & Hwang, 2015). Hwang et al. (2017a) indicated that computer games can make complicated problems become lively contexts, and can help to build a virtual learning environment in which students can learn and solve problems. This model can effectively stimulate students' interest and motivation. Chen, Chen, and Dai (2018) pointed out that games can create situations with challenging goals in which users are willing to participate actively. However, previous studies have found that without proper learning strategies integrated into game-based learning, students' learning outcomes might be limited (Chu et al., 2015). Moreover, if students could construct their knowledge structure during the game-based learning process, they could deeper their schema of knowledge (Fu et al., 2019; Hwang, Hung, Chen, & Liu, 2014). Therefore, it is important to integrate effective knowledge construction tools or strategies into game-based learning (Chu et al., 2015; Chang, Wu, Weng, & Sung, 2012; Hwang, Yang, & Wang, 2013).

Collaborative learning is a potential learning strategy which has been widely used in various learning environments. Past studies have pointed out that students could establish self-confidence in learning by interacting with peers and solving problems together (Magen-Nagar & Shonfeld, 2018; Sung & Hwang, 2013). Online collaborative learning could help students maintain a positive attitude towards the development of cognitive structures and stronger motivation for completing learning tasks (Lowenthal & Dunlap, 2010; Wu, Hsieh, & Yang, 2017). Moreover, researchers have pointed out that guiding students to collaborate in games to discuss and complete tasks will result in more positive learning outcomes (Sung & Hwang, 2018; Shiue & Hsu, 2017).

The abilities of organization and classification can help students learn English grammar, as it includes many concepts and rules. Concept mapping is known to be an effective Mindtool that helps learners memorize and organize past concepts and new knowledge (Hwang, Wu, & Ke, 2011; Novak & Gowin, 1984; Pankratius, 1990). In addition, concept mapping can promote learners' higher level thinking and help them clarify the incorrect concepts (Hwang, Hung, Chen, & Liu, 2014; Hwang, Kuo, Chen, & Ho, 2014; Novak, Gowin, & Johansen, 1983). Grammar concept mapping extends the advantage of concept mapping and emphasizes its application in language learning. Therefore, this study proposes a grammar concept mapping-based collaborative English game in an elementary school English course. The game includes many grammar concept mapping materials to assist learners in building a strong English grammar foundation.

Accordingly, the following research questions are examined:

- Does the grammar concept mapping-based collaborative English gaming approach benefit the students' learning achievement more than the collaborative English gaming approach?
- Can the grammar concept mapping-based collaborative English gaming approach reduce the students' cognitive load in comparison with the collaborative English gaming approach?
- Are there differences between the learning behaviors of the students in gaming phase 1 (personalized learning) and phase 2 (collaborative discussion) when playing the different English gaming approaches?

2. Literature review

2.1. English game-based learning

Game-based learning enables students to learn in interactive and enjoyable learning environments which combine the important elements of education smoothly and fluently into games (Prensky, 2001). Many researchers have reported their research of using game-based learning in helping students improve their learning performance (Chen, Liu, & Hwang, 2015; Hwang et al., 2017a; Hwang & Wang, 2016; Sandberg, Maris, & Hoogendoorn, 2014).

Hung, Young, and Lin (2015) developed a collaborative game-based learning system to help students learn English. According to the qualitative and quantitative results, the learning context created by their system increased students' interaction with their peers and closed the achievement gap. Hwang, Hsu, Lai, and Hsueh (2017) developed a problem-based English listening game which consists of three stages from simple to difficult. In order to pass the learning tasks, students needed to answer questions by listening to the pronunciation of word cards or interacting with the NPC. The results showed that the game-based learning strategy positively affected the students' learning achievements and learning motivation.

Although many studies have pointed out the advantages of game-based learning, it is not only presenting teaching content in games that is important (Chu, Yang, & Chen, 2015; Hwang et al., 2017b; van Eck, 2006); designing the games according to the teaching objectives is also critical (Johnson, Vilhjálmsson, & Marsella, 2005). In addition, it can lead to better learning outcomes if appropriate teaching strategies are integrated into games (All, Castellar, & van Looy, 2015; Hwang et al., 2017b; Hwang & Wang, 2016).

2.2. Collaborative and group discussion improved game-based learning

Collaborative learning is defined as an instructional approach that engages students in learning tasks aimed to achieve a common goal, generally in small teams (Donato, 1994). Sung and Hwang (2013) compared collaborative and individual games applied using the game-based learning approach, and found that students who learned with the collaborative game showed better learning achievements than those who learned with the individual game. Chang and Hwang (2018) developed a collaborative educational game in a science course and

found that it not only benefited the students' learning achievements and attitudes, but also improved their collaboration skills. Sung and Hwang (2018) integrated the collaborative knowledge construction mechanism into the gaming process to guide students to discuss with peers to complete the task. The result showed that students could learn effectively, organize their knowledge and deal with problems using the knowledge they learned in the game.

However, researchers also indicated that in order to improve the effects of collaborative game-based learning, appropriate scaffolds should be well-designed and provided during the students' learning process (Chen & Law, 2016).

2.3. Grammar concept mapping

Concept mapping is an effective visual learning tool that helps learners memorize and organize their knowledge (Chu, Yang, & Chen, 2015; Hwang & Chen, 2019; Hwang, Shi, & Chu, 2011, Novak & Gowin, 1984; Pankratius, 1990). It can also promote learners' high-level thinking and help them present knowledge and clarify the incorrect concepts (Hwang, Lee, & Chen, 2019; Novak, Gowin, & Johansen, 1983; Rosciano, 2015; Wang, Chu, & Wang, 2018).

Researchers have applied concept mapping in education and have found it to have good teaching effectiveness. Hwang, Shi, and Chu (2011) applied concept mapping to develop collaborative mental tools in a ubiquitous learning environment to help students observe butterflies in a science course, and discovered that using collaborative mental tools can enhance learners' self-efficacy and learning outcomes. Hwang, Yang, and Wang (2013) combined concept mapping with game-based learning strategies in the science course to help students organize the concepts they learned in the game. The results showed that through the proposed method, students' learning achievement is significantly improved and their cognitive load is significantly reduced.

As concept mapping assists abstract knowledge learning, researchers have begun to use it for language education. Yang (2015) used the concept mapping strategy for non-native English students to teach English writing, and found that it improved the students' reading comprehension and their paragraph writing ability. Liu (2016) integrated concept mapping into the teaching of English words and found that learning material designed by concept mapping can improve students' learning outcomes more than that only shown by text. Wang and Chen (2018) developed a multimodal framework of learning analytics with the concept mapping (Cmap) approach to improve students' vocabulary and reading abilities and found positive effects of Cmap. Therefore, this study applied the concept mapping strategy for English grammar teaching to develop grammar concept mapping learning materials to assist students in building a strong English grammar foundation.

2.4. The grammar concept mapping-based collaborative English gaming approach

In this study, we developed the grammar concept mapping-based collaborative English gaming system and collaborative English gaming system using Unity (also see Wang, Chu, & Wang, 2018). It was hoped that this game would enhance students' learning motivation and assist them in understanding the relationship of English grammar concepts. The structure of the game, including a learning materials module, a gaming rules module, and a learning portfolio module, is shown in Figure 1. The learning material module consists of grammar concept mapping, vocabulary and sentence examples, and English grammar tasks. The gaming rules module is responsible for executing the game and showing the gaming interface through combining the gaming rule scripts. The learning portfolio module is used to record the students' learning behaviors and their discussion in the game.

The game system includes two phases, the "Personal Learning phase" and the "Collaborative Learning phase" (as shown in Figure 2). The Personal Learning phase has four units, namely "Countable and uncountable nouns," "Singular nouns," "Plural nouns," and "Proper, material and abstract nouns." The system guides students to read the grammar learning material, and then provides some tasks to test them. The learning material was designed using a grammar concept map for the learning objective of each unit. In the Collaborative Learning phase, the learning material combines all of the grammar concept maps from the Personal Learning phase to help the students organize their English grammar knowledge and understand the relationships between concepts.

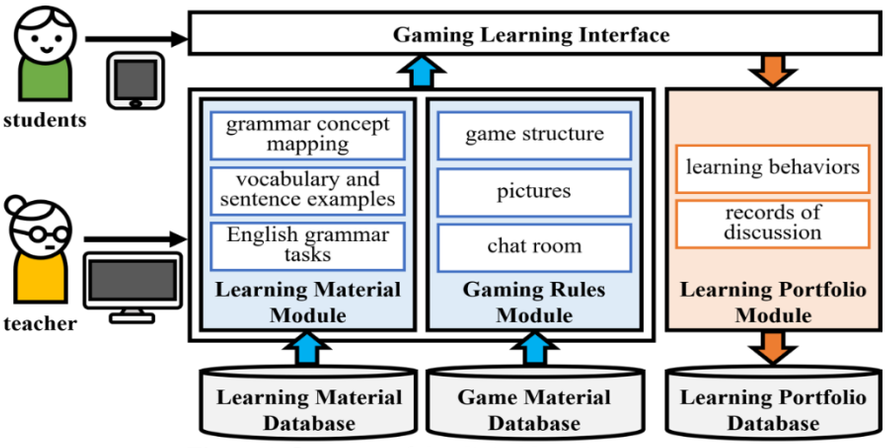


Figure 1. Structure of the digital learning game

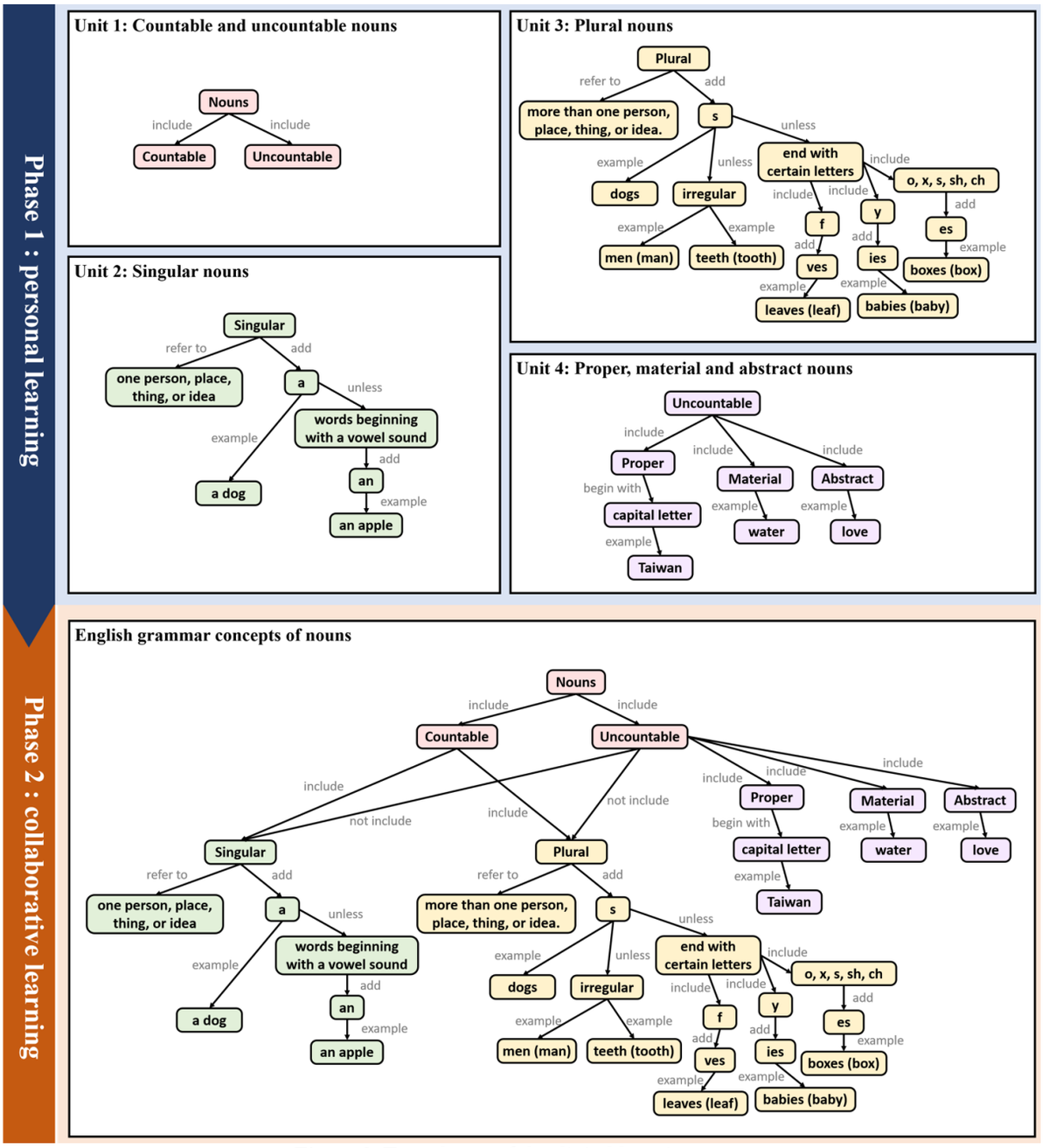


Figure 2. Two phases of the digital learning game

The players were firstly given the background story of the game to lead them into the gaming context. The learning objective is learning English grammar and vocabulary. The name of the game is “Save the Princess with Teddy.” The storyline begins with a brave bear learning English grammar in order to fight the monsters and save the princess who is trapped in the forest. In the Personal Learning phase, the game shows the grammar concept mapping materials to help students understand the grammar concepts (as shown in Figure 3). Then, the system displays some questions about the concepts (as shown in Figure 4). The design of the task is the drag and drop question type to avoid the students guessing answers. While answering questions, students are allowed to review the grammar materials and vocabulary throughout the whole learning process. If they fail to answer correctly, the system guides them to read the grammar materials again. Each level must be answered correctly before entering the next unit to ensure that they fully understand the content. After the students complete all levels of the Personal Learning phase, the system will guide them into the Collaborative Learning phase.

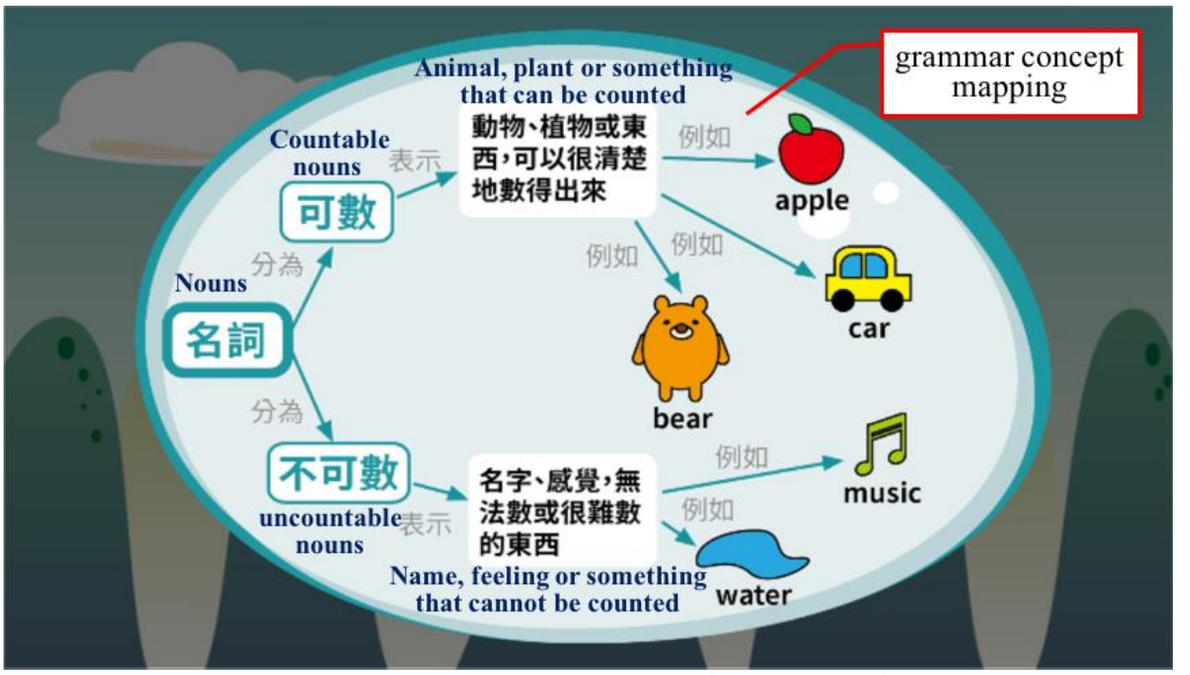


Figure 3. Grammar concept mapping learning material

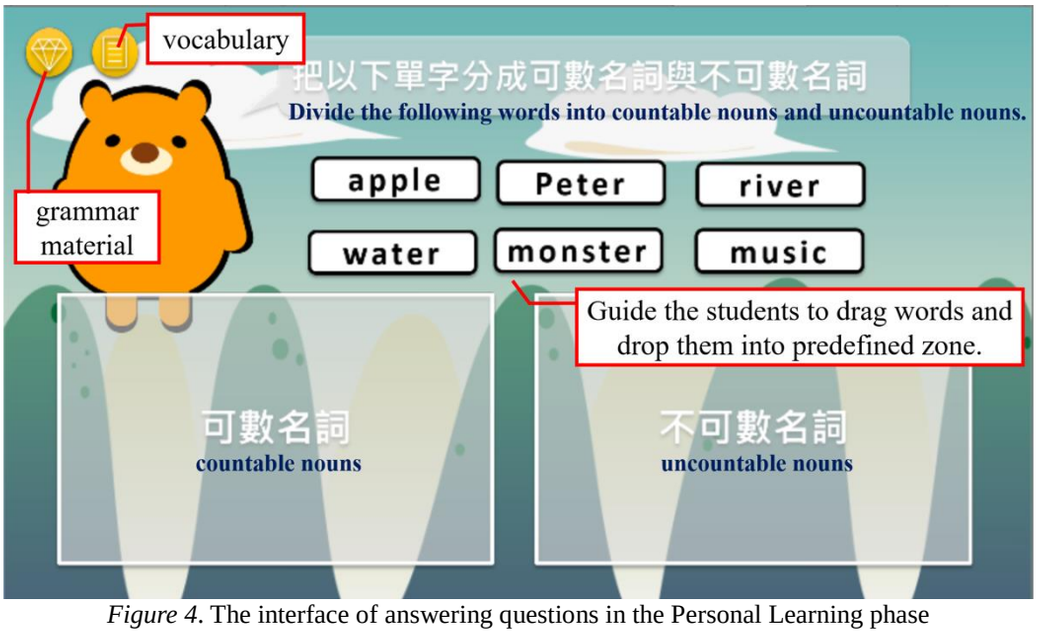


Figure 4. The interface of answering questions in the Personal Learning phase

In the Collaborative Learning phase, the interface is divided into two parts, the “fill-in-the-blank questions of the grammar concept map” on the left-hand side and the “chat room” on the right-hand side. In this phase, students are asked to fill in correct concepts in the blanks to complete their own grammar concept mapping. At the same

time, they can discuss with their team members to share their knowledge and correct their ideas (as shown in Figure 5).

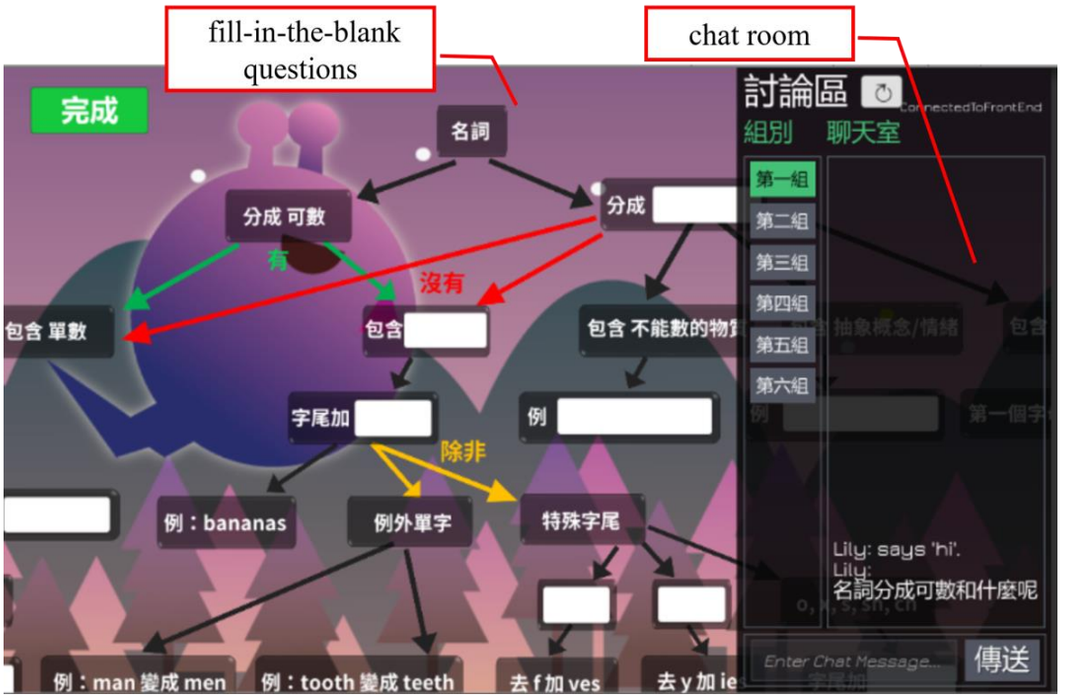


Figure 5. The interface of the Collaborative Learning phase

3. Research design

3.1. Participants

The participants of this experiment included six classes of fifth graders in an elementary school (11.5 years old on average) in northern Taiwan. A total of 130 students participated in this study. Three classes were assigned to be the experimental group (n = 68) who learned with the grammar concept mapping-based collaborative English gaming approach, while the other three classes were assigned to be the control group (n = 62) who learned with the collaborative English gaming approach. Both groups were taught by the same teacher in their regular English course. This teacher has over 10 years of experience teaching the English course. During the second phase, the students in both groups were assigned to small learning groups. Each group had three to four randomly chosen members.

3.2. Learning procedure

Figure 6 shows the procedure of the experiment. In the first week, students were asked to finish the pre-test and the pre-questionnaires. In the second week, the teacher explained the learning mode of the grammar concept mapping-based or collaborative English gaming learning system and introduced the operation of the tablet. Then, the students in the experimental group were asked to use the grammar concept mapping-based collaborative English gaming to learn. On the other hand, those in the control group learned with a collaborative English gaming approach. All of the learning content was designed to consist of the two-phase learning stages. The storyline and learning process in the game, the gaming interface and the time of the learning activity were the same for the control group and the experimental group.

After completing the game-based learning, the students were asked to complete the post-test and post-questionnaires. According to the post-test, we could analyze their learning performances.

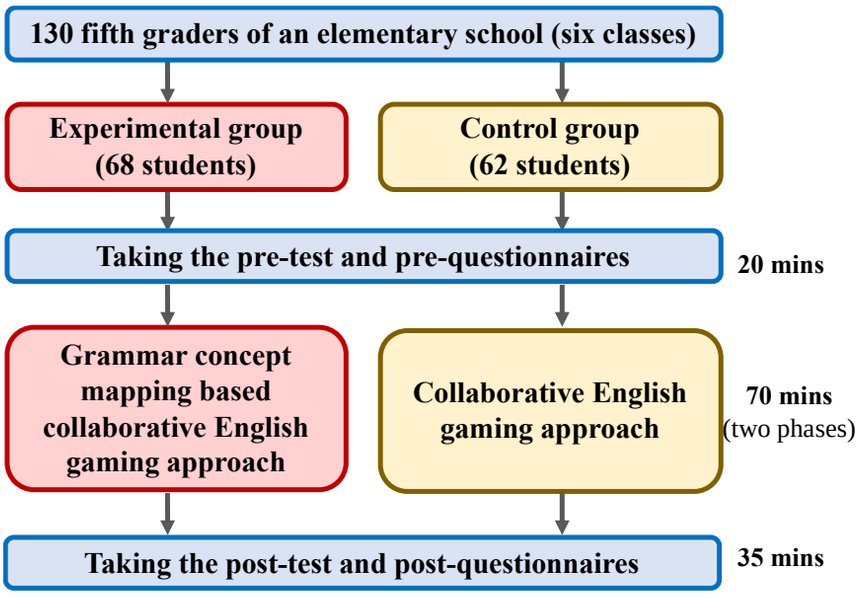


Figure 6. Experiment procedure

3.3. Instruments

The research tools in this study included a pre-test, a post-test, and the questionnaire for measuring the students' cognitive load and self-efficacy.

The pre-test and post-test were developed by two experienced teachers. The aim of the pre-test was to evaluate the students' prior knowledge in the English course before the class. It consisted of 25 multiple-choice items with a perfect score of 100. The post-test aimed to know the effect of the learning activity. It consisted of three multiple-choice items, 13 fill-in-the-blank items, and four correction items which asked students to circle the wrong words and write the correct answer. The perfect score of the post-test was 100.

The questionnaire of cognitive load was modified from the measures developed by Paas, van Merriënboer, and Adam (1994) and Hwang, Yang, and Wang (2013). It consists of five items with a 7-point Likert rating scheme, including three items for "mental load" and two for "mental effort." Mental load is related to the intrinsic nature of learning materials and students' expertise (knowledge level) for comprehending all of the learning elements or information, which is equal to the first category of cognitive load named "intrinsic load" (Paas, Renkl, & Sweller, 2004). Mental effort refers to the teaching methods and how they are organized and presented to the students. The degree of mental effort is related to how much effort students need to exert in order to comprehend the whole learning content. Higher ratings of cognitive load suggest that students experience higher cognitive loads during the learning process. The Cronbach's alpha values of the two dimensions are .86 and .83 respectively.

Regarding the analysis of students' collaborative content, we modified the Interaction Analysis Model (IAM) coding scheme, developed by Gunawardena, Lowe, and Anderson (1997). This scheme, which has already been adopted in previous research (Chen & Hwang, 2017; Chiang, Yang, & Hwang, 2014; Lucas, Gunawardena, & Moreira, 2014) has been used to examine students' behavior of knowledge construction in collaborative learning environments.

Table 1. Coding scheme for personal learning behaviors

Code	Definition	Description
RK	Review Key learning material	Students click the key learning material button to read English grammar concept mapping materials.
RV	Review Vocabulary	Students click the vocabulary button to read vocabulary and sentence examples.
AC	Answer Correct	Students answer correctly.
AW	Answer Wrong	Students answer incorrectly.

To understand the students' learning behavior patterns in the personal learning phase, the main behaviors are coded, including Review Key learning material, Review Vocabulary, Answer Correct, and Answer Wrong, as shown in Table 1. To understand the students' discussion patterns in the Collaborative Learning phase, the main dimensions of discussion are coded, including Question, Answer, Share, and Other, as shown in Table 2.

Table 2. Coding scheme for discussion

Code	Definition	Description
Q	Question	Students ask questions.
A	Answer	Students answer classmates' questions.
S	Share	Students present their ideas during the discussion.
O	Other	Students divert attention from the course.

4. Experimental results

4.1. Analysis of students' learning achievement

To analyze the effectiveness of the proposed grammar concept-mapping based collaborative English gaming approach on the learning achievement of the students with different levels of pre-test scores, students in each group were divided into two subgroups, "high-achieving" and "low-achieving" students, based on their pre-test scores. The students with scores ranked in the bottom 1/2 of the class were grouped as low-achieving students, and the top 1/2 of the class were grouped as high-achieving students. The descriptive data of the learning achievements for the sub-groups are shown in Table 3.

Table 3. The descriptive data of the learning achievements for the sub-groups

Groups		Pretest			Posttest	
		N	Mean	*SD*	Adjusted mean	Std. Error
Experimental group (n = 68)	High-achieving	34	98.59	1.94	71.28	2.85
	Low-achieving	34	88.82	6.66	74.27	2.64
Control group (n = 62)	High-achieving	31	98.97	1.78	70.64	3.00
	Low-achieving	31	83.10	9.78	63.28	3.33

In this study, two-way ANCOVA was performed using the students' pre-test as a covariate, while the grammar English gaming approaches and different levels of learning achievements (high and low) were the independent variables, and the post-test scores were the dependent variable. The assumptions of homogeneity of regression were assessed, and the F value for the different learning strategies and different levels of learning achievements was 3.77 (p = .06 > .05). Therefore, it was acceptable to execute two-way analysis of covariance (two-way ANCOVA) to evaluate the different levels of pre-test and gaming approaches.

Table 4 shows the post-test scores examined by the main effect analysis for the experimental group and the control group. The post-test of the experimental group was significantly better than that of the control group (F = 4.84, p = .03, η^2 = 0.37). The adjusted mean and standard error of the experimental group was 72.77 and 1.89, while the adjusted mean and standard error of the control group was 66.96 and 1.80. Therefore, it implies that the grammar concept mapping-based collaborative English gaming strategy can improve students' learning achievement more than the collaborative English gaming approach. Furthermore, the effect size (η^2) for the ANCOVA results of the proposed game-based learning model indicated a large effect size (η^2 > 0.14) on the basis of the propositions developed by Cohen (1988).

Table 4. Results of ANCOVA on students' learning achievement

Groups	*N*	Mean	*SD*	Adjusted mean	Std. Error	*F*	η^2
EG	68	73.97	12.80	72.77	1.89	4.84*	0.37
CG	62	65.65	21.55	66.96	1.80		
High-achieving in EG	34	77.06	13.09	71.28	2.85	0.09	
High-achieving in CG	32	76.77	14.23	70.64	2.98		
Low-achieving in EG	34	70.88	11.90	74.27	2.64	7.18**	0.10
Low-achieving in CG	32	54.52	22.04	63.28	3.33		

Note. $^*p$ < .05. Experimental Group (EG: the grammar concept mapping-based collaborative English gaming approach). Control group (CG: the collaborative English gaming approach).

Moreover, the high-achieving students of the two groups showed no significant difference in the post-test (F = 0.09, p = .77). On the contrary, the post-test score of the low-achieving students in the experimental group was significantly higher than that of the low-achieving students in the control group (F = 7.18, p = .009, η^2 = 0.10). The adjusted mean and standard error of the experimental group were 72.77 and 1.89, while those of the control group were 66.96 and 1.80. The effect size (η^2) for the ANCOVA results of the grammar concept mapping-based collaborative English gaming approach indicated a moderate to large effect size (η^2 > 0.14) on the basis of the propositions developed by Cohen (1988).

Figure 7 shows that there is no interaction between the two variables, but it can be observed that there is a learning achievement gap between the learning strategy factor and the different levels of learning achievement factor. The difference in learning achievement of the high- and low-achieving students in the experimental group is small, but the difference in the control group is large. This indicates that the grammar concept mapping-based collaborative English gaming approach was very helpful to the students whose pre-test learning achievement was low. Therefore, this study explores the learning achievement of the two groups with different levels of English learning achievement.

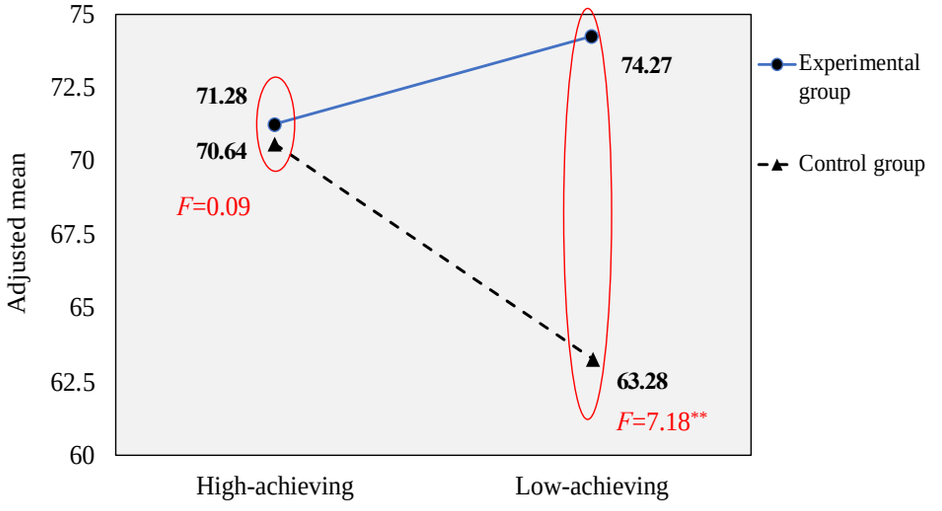


Figure 7. The post-test results of different learning strategies for high- and low-level learning achievement
Note. Experimental Group (The grammar concept mapping-based collaborative English gaming approach); Control group (The collaborative English gaming approach).

4.2. Analysis of students' cognitive load

In order to evaluate students' cognitive load which includes mental load and mental effort, the one-way analysis of variance (ANOVA) was employed. The purpose of measuring cognitive load was to evaluate what affect the students' loading in the learning process had on their learning achievements. Researchers have indicated that if all of the information, elements and their interactions need to be processed simultaneously, it will impose a load on the learner's working memory capacity (Hwang, Kuo, Chen, & Ho, 2014; Paas, Renkl, & Sweller, 2004). The assumption of homogeneity of regression was not violated (F = 0.85, p = .36); therefore, the assumption was tenable and the ANOVA was performed.

Table 5 shows the students' cognitive load results. It was found that for the students in the experimental group, the mean value and standard deviation of the high-achieving students' cognitive load were 2.72 and 1.03, while those of the low-achieving students' cognitive load were 3.15 and 0.95. There was no significant difference in the cognitive load of the high- and low-achieving students in the experimental group (F = 3.12, p > .05). On the contrary, the cognitive load of the high-achieving students is significantly higher than that of the low-achieving students in the control group (F = 20.63, p < .001). This means that the low-achieving students perceived heavier cognitive load than the high-achieving students in the control group. Furthermore, the effect size (Cohen's f) was 0.58. According to Cohen (1998), Cohen's f expresses the effect size in standard deviation when conducting one-way ANOVA for two or more groups. For two groups, f = 1/2d; therefore, f is 0.58, representing a large effect size (f = 0.40) (Cohen, 1998; Grove & Cipher, 2019).

The mental load and mental effort were further analyzed. In the experimental group, the mean value and standard deviation of the high-achieving students' mental load were 2.69 and 0.99, while those of the low-achieving students' mental load were 3.17 and 0.97. The mental load of the high-achieving students is significantly higher than that of the low-achieving students (F = 4.08, p = .04). In the control group, the mean value and standard deviation of high-achieving students' mental load were 2.19 and 1.01, while those of the low-achieving students' mental load were 3.21 and 0.92. The mental load of the high-achieving students was also significantly higher than that of the low-achieving students (F = 17.29, p < .001). The Cohen's f values of mental load and overall cognitive load were 0.245 and 0.528, respectively, indicating median and large effect sizes (f = 0.25, median; f = 0.40, large) (Cohen, 1988). Therefore, it is inferred that the low-achieving students perceived higher intrinsic cognitive load in both groups while learning with the two approaches. It is possible that the amount of learning material was slightly excessive, so the complexity of the learning content was increased for the low-achieving students. However, for students, 3.21 is a reasonable mental load value.

Meanwhile, considering the post-test results, it was found that the low-achieving students in the experimental group showed significantly better learning achievement than those in the control group, implying that the challenges of the learning tasks and the increased complexity of the learning materials were at an appropriate level and were within the zone of proximal development (ZPD) proposed by Vygotsky (1978). This finding complies with what has been reported by Hwang, Kuo, Chen, and Ho (2014) and Sweller et al. (1998), namely that reasonable mental load can encourage students to learn.

On the other hand, there was no significant difference in the mental effort of the high- and low-achieving students in the experimental group (F = 1.77, p = .19), with a mean value below 4, while the low-achieving students showed significantly higher mental effort in the control group (F = 20.38, p < .001). This implies that the students in the experimental group used this proposed approach to learn, and that both high- and low-achieving students had the same level of mental effort. Therefore, using the grammar concept mapping-based collaborative English gaming approach could reduce students' load.

Table 5. Results of ANOVA on students' cognitive load for all four groups

Dimension	Groups		*N*	Mean	*SD*	*F*	Cohen's *f*
Cognitive load	EG	High-achieving	34	2.72	1.03	3.12	
		Low-achieving	34	3.15	0.95		
	CG	High-achieving	31	2.17	0.99	20.63***	0.58
		Low-achieving	31	3.23	0.83		
Mental load	EG	High-achieving	34	2.69	0.99	4.08*	0.245
		Low-achieving	34	3.17	0.97		
	CG	High-achieving	31	2.19	1.01	17.29***	0.528
		Low-achieving	31	3.21	0.92		
Mental effort	EG	High-achieving	34	2.79	1.12	1.77	
		Low-achieving	34	3.18	0.98		
	CG	High-achieving	31	2.14	1.07	20.38***	0.577
		Low-achieving	31	3.26	0.86		

Note. EG = Experimental group; CG = Control group. *p < .05.

4.3. Analysis of students' learning behavioral patterns

4.3.1. Phase 1: Personal Learning stage

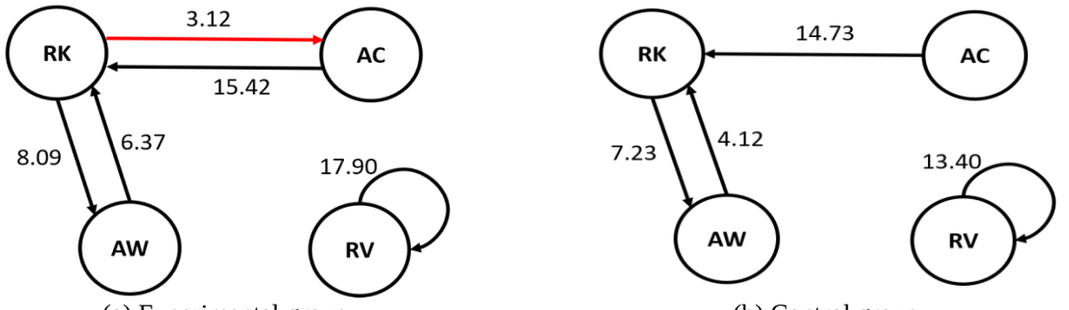
According to the frequency of learning behaviors in the Personal Learning phase, it was found that "Review Key learning material" (RK) was the most frequent behavior in the experimental group and control group, with 55% and 53% respectively; that is, reviewing key learning materials is the most important learning source for both groups of students. In addition, a total of 2,414 behaviors in the experimental group were recorded, and 2,062 in the control group, as shown in Table 6. Therefore, it is inferred that the grammar concept mapping-based collaborative English gaming approach can promote students' operating behavior.

Figure 8 shows the comparison of the students' behavioral patterns in the different groups. It was found that students in the experimental group were inclined to "Review the key learning material" and "Answer the questions correctly" (RK→AC). That is, reading the English grammar concept mapping materials helped the students understand the concepts of English grammar and find the correct answers.

Table 6. The frequency of learning behaviors

Groups	RK	RV	AC	AW	Total
Experimental group	1329 (55%)	630 (26%)	232 (10%)	223 (9%)	2414
Control group	1084 (53%)	597 (29%)	193 (9%)	188 (9%)	2062

Note. RK = Review key learning material; RV = Review vocabulary; AC = Answer correct; AW = Answer wrong.



(a) Experimental group (b) Control group

Figure 8. Comparison of students' behavioral patterns in the different groups

Note. RK = Review key learning material; RV = Review vocabulary; AC = Answer correct; AW = Answer wrong.

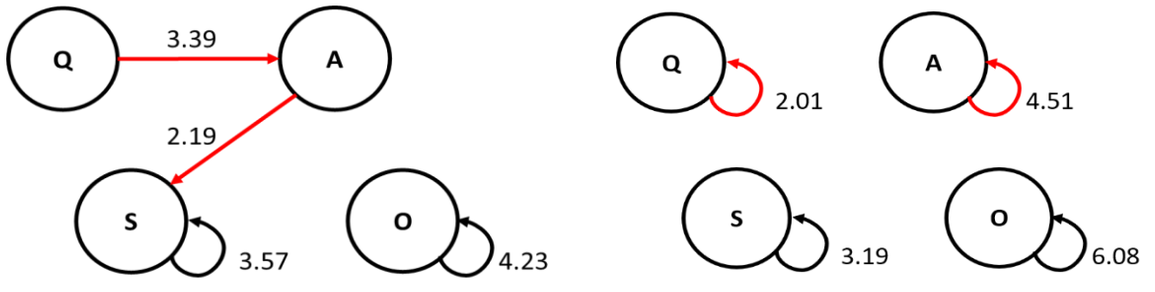
4.3.2. Phase 2: Collaborative Learning stage

According to the frequency of discussion in the Collaborative Learning phase, it was found that the frequency of "Question" and "Answer" of the experimental group was lower than that of the control group (as shown in Table 7). It is indicated that students in the experimental group learning with the English grammar concept mapping materials raised fewer questions. Besides, they were also more accurate in answering classmates' questions. On the other hand, students in the control group may not learn the concepts of grammar clearly, so they had many problems and could not accurately answer their classmates' questions. Therefore, many records of "Question" and "Answer" were generated. In addition, "Other" was the most frequent discussion content in both groups, especially in the experimental group (75%). It is inferred that because the students had built a good foundation of English grammar at the Personal Learning phase, most problems in the Collaborative Learning phase could be completed by themselves.

Table 7. The frequency of discussion

Groups	Q	A	S	O	Total
Experimental group	23 (13%)	6 (3%)	15 (9%)	130 (75%)	174
Control group	57 (30%)	20 (10%)	26 (13%)	90 (47%)	193

Note. Q = Question; A = Answer; S = Share; O = Other.



(a) Experimental group (b) Control group

Figure 9. Comparison of the different groups' discussion patterns. *Note*. Q = Question; A = Answer; S = Share; O = Other.

Figure 9 shows the comparison of students' discussion patterns in the different groups. It was found that students in the experimental group tended to answer questions after peers asked questions (Q→A), and they shared meaningful ideas after answering others' questions (A→S). This indicates that the students had internalized the knowledge. They could teach others what they had learned and share their ideas. On the other hand, students in the control group would ask questions (Q→Q) and answer questions (A→A) continuously. This means that they

only had superficial memory and understanding, so they could not ask the key questions and provide an accurate explanation when answering, leading to the discussion lacking focus.

5. Discussion and conclusions

This study developed a two-phase grammar concept mapping-based collaborative English game and analyzed the gameplay experience of the students with different levels of learning achievement. The learning achievement of the grammar concept mapping-based collaborative English gaming group was significantly better than that of the collaborative English gaming group. It was indicated that the grammar concept mapping material can help students understand and enhance their English grammar learning performance.

In addition, this study compared the students with different levels of learning achievement using different learning strategies. It was found that the high-achieving students using the grammar concept mapping-based collaborative English gaming approach was significantly better than that of those using the collaborative English gaming approach. There was no significant difference in the learning achievement of the two groups of high-achieving students, but significant help to the low-achieving students in the experimental group was shown. That is, the grammar concept mapping-based collaborative English gaming strategy can promote the learning achievement of low-achieving students.

In the grammar concept mapping-based collaborative English gaming group, there was no significant difference in the cognitive load of the high- and low-achieving students; however, in the collaborative English gaming group, the cognitive load of the low-achieving students was significantly higher than that of the high-achieving students, which indicates that the proposed approach could let the students learn with less pressure. The analysis of mental load shows that the mental load of the low-achieving students in the experimental group was significantly higher than that of the low-achieving students in the control group, but they also showed better learning achievement. As indicated by Chu (2014), “mental load” refers to the element interactivity among the task, subject characteristics and learning materials; it can be considered to be the load which is imposed by the task (Paas, van Merriënboer, & Adam, 1994). Hwang, Kuo, Chen, and Ho (2014) further indicated that suitable challenges in the learning tasks could improve students’ learning performances. In this study, by integrating the proposed grammar concept mapping-based collaborative English gaming approach into the digital games, the students were situated in more challenging contexts that engaged them in organizing what they had learned during the gaming process. The better learning performances of the experimental group students showed that the challenge in the concept mapping tasks was suitable and hence helpful, and the activity was at an adequately challenging level for the low-achieving students (lower than 4).

This experiment also examined students’ learning behavior. According to the results of the system records, it was found that in the grammar concept mapping-based collaborative English gaming group and the collaborative English gaming group, reading key learning materials is the most frequent behavior, indicating that the students mainly relied on the grammar learning materials to learn in the learning system. Thus, the content and design of the learning materials are very important and might affect the students’ learning and absorption of the content. The grammar concept mapping materials help students easily understand the structure and classification rules of English grammar.

Moreover, through the records of discussion in the collaborative learning phase, students’ discussion patterns were analyzed. It was found that the collaborative English gaming group preferred to question and respond continuously. It is inferred that these students only learned English grammar by rote without actual understanding, so they could not focus on the key point during discussion. On the other hand, the students in the grammar concept mapping-based collaborative English gaming group were able to teach peers using the knowledge they had learned, and share their ideas, representing that the grammar concept mapping-based collaborative English gaming strategy can help students internalize knowledge and present their own interpretations. It can be seen that the reason that the learning achievement of the grammar concept mapping-based collaborative English gaming group is better than that of the collaborative English gaming group.

However, this study has some limitations that should be noted. First, the results cannot be generalized to all students of all regions or ages. Second, the teaching content of this research is mainly based on the grammatical concepts of English nouns, so the effects of other grammar units should be verified. Last, the system of this study has a chat room function to record the students’ discussion. However, since the students were all studying in the same classroom at the same time, some students tended to talk and discuss directly with their peers. This

may have resulted in some of the discussion content being unrecorded, leading to unpredictable errors in the research results.

In future studies, for low-achieving students, the concept mapping pre-guiding should be provided before the class in order to reduce their mental load and involve them more in the learning. In addition, it is recommended that providing topics or adding the role of the teacher for the discussion in the system might encourage students to focus on the discussion. Finally, the main contribution of this study is that the proposed approach, the grammar concept mapping-based collaborative English gaming approach, can enhance students' learning outcomes, especially for the low-achieving students. Therefore, the grammar concept mapping strategy can be integrated into other units in English or in different fields to explore the positive influence of the grammar concept mapping strategy on students.

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