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Balancing cognitive complexity and gaming level: Effects of a cognitive complexity-based competition game on EFL students' English vocabulary learning performance, anxiety and behaviors

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ABSTRACT

Digital game-based language learning promotes motivation and enables learners to immerse themselves in learning. However, some gaming elements (e.g., competition and challenge) or learning content (e.g., difficulty levels) may have different influences on different learners, especially those with low self-efficacy or academic achievement, as competitive games may lead to frustration. It is therefore important to take students' cognitive capacities into consideration when designing a competitive learning environment, and to provide them with learning content of appropriate cognitive complexity. In the current study, a game-based situational vocabulary learning system that integrated a cognitive complexity-based competition strategy was developed to provide learners with appropriate tasks. A quasi-experiment was conducted in a high school English course to evaluate the effectiveness of the proposed approach. It was found that, compared to the conventional situational gaming approach, the situational game with the cognitive complexity-based competition strategy significantly improved the participants' learning performance (in particular, that of the low-achieving students), but it also increased their anxiety. Furthermore, the behavioral analysis showed that the students who learned with the proposed approach accomplished the tasks more smoothly, because the system could take into account players' learning performance and adjust the cognitive complexity of the following tasks through upgrading or downgrading the learners' gaming levels to ensure that individual students learned with tasks at appropriate levels for them. On the other hand, the participants who learned with the conventional game-based learning approach had a greater tendency to fail the game repeatedly. Based on the findings and relevant studies, we also discuss suggestions for future research.

1. Introduction

Over the past decades, digital game-based learning has aroused considerable attention in the academic community, with the literature indicating that integration of learning content into digital games improves learner motivation, engagement, and

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performance (Dede, 2011; Dickey, 2011; Hamari et al., 2016; Miller, Chang, Wang, Beier, & Klisch, 2011). Digital game-based language learning is considered advantageous in providing immersion experiences, reducing anxiety and emotional obstacles, contextualizing learning, and increasing opportunities for knowledge application in game environments (Cornillie, Thorne, & Desmet, 2012; Hwang & Chen, 2013; Yang, Quadir, & Chen, 2016). However, such benefits are conditional upon appropriate game design with effective use of learning strategies (Ke, 2008). Chapelle's (2001) framework for evaluating the appropriateness of computer-assisted language learning tasks proposes six aspects (i.e., language learning potential, learner fit, meaning focus, authenticity, impact, and practicality) that ought to be considered when designing digital games (Chapelle, 2001). Among the six, *learner fit*, which refers to the amount of opportunity for learners to engage in language learning under appropriate conditions, and *practicality*, which refers to the adequacy of resources to support learners' completion of the learning activities, highlight the importance of designing tasks that are suitable for learners' needs and academic levels, and which encourage their language use attempts. Gibbons's (2009) interpretation of sociocultural rationales for language pedagogy also suggests that learning tasks with low challenge and low support cause boredom, whereas tasks with high challenge but low support cause frustration and anxiety. Tasks with low challenge and high support situate learners in a comfort zone, but we should create a learning and engagement zone for learners through providing them with tasks of high challenge and high support (also known as scaffolding) (Gibbons, 2009).

Competition has always been regarded as an effective strategy to create challenges and stimulate improvement. Setting up competitive objectives in games can help learners play games and learn target knowledge more purposefully and actively, and thus achieve better performance (Julian & Perry, 1967; Karakostas & Demetriadis, 2011; Vandercruysse, Vandewaetere, Cornillie, & Clarebout, 2013; Yu, 2001). However, competition provokes different perceptions from learners with different backgrounds, and may have negative influences on students with low achievement by placing cognitive overload on them (Chen & Huang, 2013; Cropper, 1998; Kohn, 1986; Lam, Yim, Law, & Cheung, 2004). It is also possible that the competitive mechanism in games may affect the performance and motivation of novice learners and learners with low self-efficacy (Bandura & Locke, 2003; Carreira, 2006; MacIntyre, Baker, Clément, & Donovan, 2002). As students who learn English as a foreign language tend to encounter new vocabulary and concepts in learning tasks, it is important for them to adopt effective strategies to reduce their anxiety and cognitive load during the learning processes (Lin & Chen, 2006; Tsai & Tsai, 2018; Zou, Huang, & Xie, 2019).

Learners' cognitive load is closely related to the cognitive complexity of the learning tasks, and tasks of greater cognitive complexity tend to induce higher cognitive load (Robinson, 2001). The cognition hypothesis indicates that language learning tasks should be sequenced on the basis of increases in learners' cognitive complexity (Robinson, 2001). That is, effective language learning occurs when the cognitive complexity of language learning tasks is appropriate and increases gradually. However, few studies have applied the cognition hypothesis in the contexts of digital game-based learning, and few digital games for language learning are designed in a way that takes cognitive complexity levels into account and can assist learners' gradual language development at different stages. As it is crucial to assist students with low achievement to catch up with those with high achievement in terms of their learning motivation and achievement (Hung, Young, & Lin, 2015), our research aimed to develop a digital game that can enhance language learning at different stages with tasks of diverse cognitive complexity levels. Furthermore, considering that it is necessary to design a competitive learning environment that takes into account individual differences such as prior knowledge or cognitive capacities and avoids negative influences of cognitive overload (Chang, Yang, & Yu, 2003; Wang, Chen, Chang, & Chan, 2016), we developed a situational English vocabulary learning game with three levels of cognitive complexity. Our game design integrated a cognitive complexity-based competition strategy in the hope of assisting learners' gradual language development at different stages. The research questions are as follows.

(1) Could the cognitive complexity-based situational English vocabulary gaming approach enhance students' learning performance more than the conventional situational English vocabulary gaming approach? Did learners' domain knowledge influence their performance while learning through the cognitive complexity-based situational gaming approach and the conventional situational gaming approach?
(2) Could the cognitive complexity-based situational English vocabulary gaming approach improve students' learning motivation more than the conventional situational English vocabulary gaming approach?
(3) Could the cognitive complexity-based situational English vocabulary gaming approach reduce students' English anxiety more than the conventional situational English vocabulary gaming approach?
(4) Could the cognitive complexity-based situational English vocabulary gaming approach reduce students' cognitive load more than the conventional situational English vocabulary gaming approach?
(5) Are there any differences in the learning behaviors of the learners using the cognitive complexity-based situational English vocabulary gaming approach and the conventional situational English vocabulary gaming approach?

2. Literature review

2.1. Game-based language learning

Educational technologies play an important role in providing students with more practicing opportunities and reducing their anxiety (Yen, Hou, & Chang, 2015). In the field of language learning, many researchers have reported positive effects of the digital game-based learning strategy on language development (Reinders & Wattana, 2014; Sandberg, Maris, & Hoogendoorn, 2014), and digital game-based language learning has become a popular approach to increasing students' participation and learning motivation (Dickey, 2006; Griffiths & Davies, 2002; Miller et al., 2011). It is also found that digital game-based learning can reduce learners' anxiety as it immerses learners in relaxing learning activities (Mavridis & Tsiatsos, 2017). Moreover, researchers believe that digital game-based learning is the process of learners' interaction with virtual characters or tasks in the virtual learning environment (Peterson, 2012), and that it provides learners with greater autonomy (Chik, 2011), awards and encouragement (Ronimus, Kujala, Tolvanen, & Lyytinen, 2014). These features can offer language learners less stressful environments, enabling them to be more relaxed and confident, and motivating them to conduct better language learning practice (Chiu, Kao, & Reynolds, 2012; Franciosi, 2017).

Digital games have great potential for promoting effective vocabulary learning through abundant animation, complex scenes, and interactivity (Yu, 2018). The rich background in games can also provide learners with a virtual language learning environment, which is another stimulating factor that enhances the efficiency of language learning (Ranalli, 2008). Moreover, situating learners in game-based learning contexts is conducive to their memorization and recall of the learning content related to the gaming scenarios, which could further help them learn other knowledge or skills after the game-based learning activities (Whitton, 2010). Situated learning and contextualized learning are considered beneficial for language learners' autonomy and facilitative for their transfer of the acquired vocabulary knowledge to new contexts (Prince, 1996). Specifically, there are three benefits of contextual learning: (1) understanding word meanings in contexts enables learners to adopt effective strategies for learning development; (2) applying new vocabulary in contexts assists learners in mastering authentic uses and purposes of the vocabulary; and (3) contexts provide guidance for vocabulary usage. Situated learning highlights active cognition processes and social interactions in authentic learning environments (Brown, Collins, & Duguid, 1989). It has been extensively applied in language education, and its positive effects have been widely found, including assisting learners' development of knowledge (Franciosi, 2017), problem-solving abilities (Huang, Lubin, & Ge, 2011), higher order thinking (Herrington & Oliver, 1999), project performance (Zheng, 2010), and cooperative learning (Taylor, 2003).

2.2. *Competition in game-based language learning*

Numerous studies have reported influences of competitions on learning, many of which focused on motivation (e.g., Admiraal, Huizenga, Akkerman, & Ten Dam, 2011; Dolgov, Graves, Nearents, Schwark, & Volkman, 2014; Pe-Than, Goh, & Lee, 2014). Several studies have also found positive effects of competitions on other aspects of learning. Burguillo (2010) found that competitions could stimulate students' willingness to participate actively in learning so as to overcome challenges, which further improved their learning performance and increased their motivation. It is also believed that competitions have positive effects on learning as they are associated with challenges and intrinsic motivation (Malone & Lepper, 1987). Specifically, competitions are accompanied by additional challenges, and learners tend to pay more attention to the learning content and feel more excited when they are challenged (Cheng, Wu, Liao, & Chan, 2009). Moreover, it is found that competitions play positive roles in increasing motivation, participation, interest, interaction, as well as improved teamwork (Burguillo, 2010). In game environments, competitions can stimulate players and improve their gaming focus (Wu, Liao, Chen, & Chan, 2010).

However, the literature indicated that competitions do not always lead to preferable learning outcomes. For instance, Vandercruysse et al. (2013) compared the effects of competition and non-competition on English learners' motivation and learning concept while playing a 3D individual role-play game, but found no significant difference between the two mechanisms. Some researchers argued that for students with low self-efficacy and for novice learners, competitions may negatively affect their performance (Bandura & Locke, 2003), making them more depressed (Cheng et al., 2009). Competitions tend to make these students nervous, anxious and stressed, leading to low efficiency (Wu et al., 2010). That is, competitions do not necessarily promote learning, especially for learners with low self-efficacy or domain knowledge. Nevertheless, if these students can obtain some assistance or support from teachers or scaffolding, they can achieve better performance (Van Eck & Dempsey, 2002). Thus it is important to take into account students' knowledge levels or personal factors when designing competitive tasks in digital game-based learning systems (Vandercruysse et al., 2013). Some researchers also suggested that influences of external factors on students should be minimized to maintain the advantages of competitions in competitive learning environments (ter Vrugte, Vandercruysse, Wouters, van Oostendorp, & Elen, 2015).

In DGBL (Digital game-based learning), through the processes of solving problems and dealing with challenges, students keep trying to derive more information and reconstruct knowledge, which is the key to transforming fragmented knowledge into learning experience and structured knowledge (Jonassen, Beissner, & Yacci, 2013). According to Csikszentmihalyi (1975), the balance between challenges and skills is the key factor that puts players into a flow state. Players with low-level skills would fail and experience depression or anxiety if the difficulty level of the game is too high for them. However, players with high-level skills may feel bored if the challenges are too easy for them. Some studies have summarized three structures of the game challenge and individual skill: high flow (when the challenge is high, and players have high-level skills), boredom or relaxing (when the challenge is low, and players have high-level skills), and anxiety (when the challenge is high, but players have low-level skills) (Csikszentmihalyi, 1975; Deitcher, 2011; Fong, Zaleski, & Leach, 2015). If there is a mismatch between the challenge level of a learning activity and an individual's cognitive and skill level, the individual's flow experience would be weak, resulting in learning obstacles. When learners experience an adequate flow state, they feel challenged and confident. Therefore, it is necessary to provide learners with challenges and tasks of difficulty levels that appropriately fit their knowledge and skill levels, so as to achieve good learning performance for students who experience flow in gaming processes.

3. The development of a situational English vocabulary learning game based on the cognitive complexity-based competition strategy

Our situational English vocabulary learning game involved three cognitive complexity levels, the design of which was based on

Robinson's cognition hypothesis of task-based language learning and second language development (2001). The cognition hypothesis suggests that pedagogic tasks should be sequenced on the basis of increases in learners' cognitive complexity (Robinson, 2001). Such task sequences aim to approximate the full complexity of task demands to assist learners' language development from program-entry levels to program-exit levels gradually and continuously (Robinson, 2011). The cognition hypothesis is a triadic componential framework for task classification and design, including task complexity, task conditions, and task difficulty (Robinson, 2001). Specifically, task complexity refers to the intrinsic cognitive demands of the task and is associated with cognitive factors (e.g., whether the task involves the use of prior knowledge; whether the task demands spatial, causal, or intentional reasoning; whether the task requires a single step to be performed, or multiple simultaneous steps; etc.). Task difficulty relates to learners' perceptions of the task demands and is dependent on learner differences in the cognitive factors (e.g., working memory, reasoning, aptitude, etc.) and affective variables (e.g., processing anxiety, motivation, self-efficacy, etc.). Learners with different working memory capacities therefore tend to perceive the same task with different levels of difficulty and perform differently (Robinson, 2007). Task conditions concern the interactive demands of task performance and are associated with interactive factors, including participation variables (e.g., whether the information is equally distributed as in a two-way task, or is passed from one person to another as in a one-way task, etc.) and participant variables (e.g., whether the participants have shared content knowledge or the same proficiency, etc.) (Robinson, 2001).

Following Robinson's cognition hypothesis, our game was designed in a way that learners' cognitive complexity increased as they entered different levels of learning. Compared to the task of level a, the task of level b was of greater complexity and difficulty, because reasoning was necessary for the completion of the level b task as learners needed to understand the given context and evaluate which candidate answer best fit the context, but no reasoning was required for the completion of the level a task. The level c task was of greater complexity and difficulty than the level b task because more reasoning was involved for the completion of the level c task as learners needed to understand the situation and decide which candidate answer could be appropriately applied to the situational dialogue. Thus, our gaming system was designed according to the cognition hypothesis, and our three levels of learning tasks were sequenced based on the task complexity and difficulty.

We developed this situational vocabulary learning game using the RPG maker MV (Role-Playing Game maker, Multi-View) and integrated the cognitive complexity-based competition strategy in the game design. As shown in Fig. 1, the gaming system consists of the proposed competition mechanism and the English vocabulary learning mechanism. In the cognitive complexity-based competition mechanism, a learning performance evaluation module is used to measure players' learning performance, based on which, the players' gaming levels are upgraded and downgraded. In the English vocabulary learning mechanism, the task module is used to propose corresponding questions and give awards based on learners' learning performance while doing different tasks. The learning resource usage module enables learners to use or play back the dialogue video resources and vocabulary learning cards. The gaming behaviors of each learner are recorded in the learning process database.

In the cognitive complexity-based English vocabulary learning game, students played the game individually. Fig. 2 shows the whole map of game-based vocabulary learning and the locations of the corresponding gaming tasks in the map.

Fig. 3 illustrates the process of the cognitive complexity-based gaming approach. At the beginning of the game, the story background and gaming goals are presented. Following these, the learners are situated in English vocabulary learning scenarios. Through a

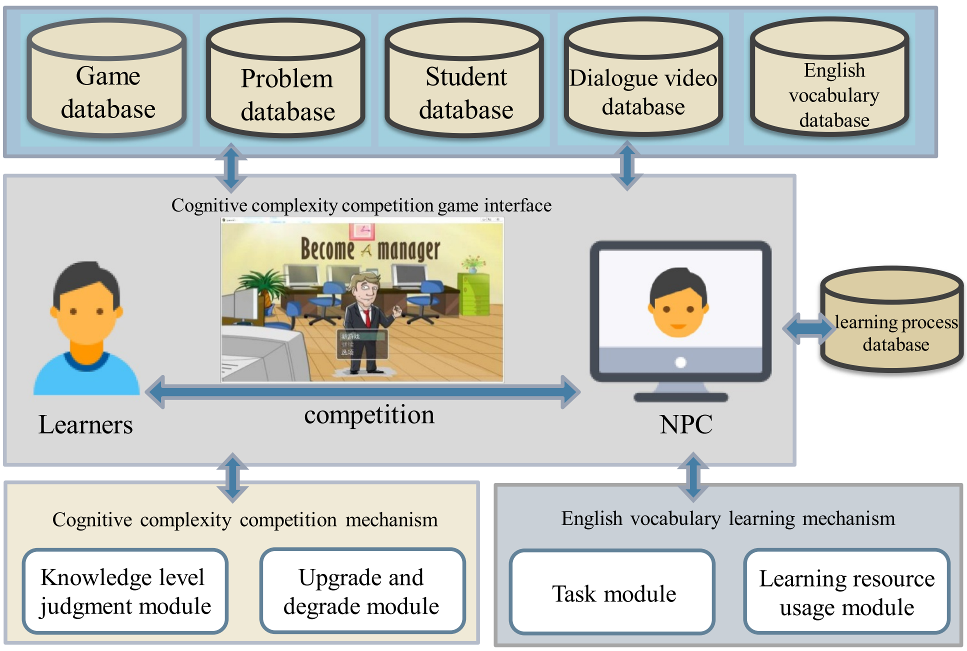

Fig. 1. The system structure of the situational English vocabulary learning game with the cognitive complexity competition strategy.

relevant storyline and character conversation in the game, students are guided to learn the target vocabulary and its usage.

Players enter the three levels sequentially. At level a, the level of the lowest cognitive complexity, Chinese meanings of target words and their parts of speech are presented in the interface, and learners are asked to provide forms of the words by spelling them. At level b, the level of middle cognitive complexity, English contexts of target words are presented, and learners are asked to understand the contexts and fill in the blanks with target words or phrases that fit the given contexts appropriately. At level c, the level of highest cognitive complexity, situational contexts of target words are presented, and learners need to understand the situations and choose the right responses that fit the situational dialogues best. In summary, the cognitive complexity of the three levels increases in sequence. The tasks of level a focus on the forms of the target words and are learning at the vocabulary level; the tasks of level b mainly focus on the meanings of the target words and are learning at the sentence level; and the tasks of level c focus on the uses of the target words and are learning at the paragraph level. Also, the three main aspects of word knowledge (i.e., form, meaning, and use), as proposed by Nation (2001), are all well covered by the learning activities of the three levels of the game in this way.

Initially, a = 0, b = 0, and c = 0 for all players. When a learner completes the tasks at level a, the scoring mechanism is used to check whether the total score is greater than 90. If yes, the player will be upgraded to the a+1 task level. Afterwards, the system judges whether the score of the level is greater than or equal to 1. If yes, the learner upgrades to level b. If no, the learner needs to stay at level a to keep doing the tasks at the original challenge level. Levels b and c also use this judgment mechanism. After the learners complete

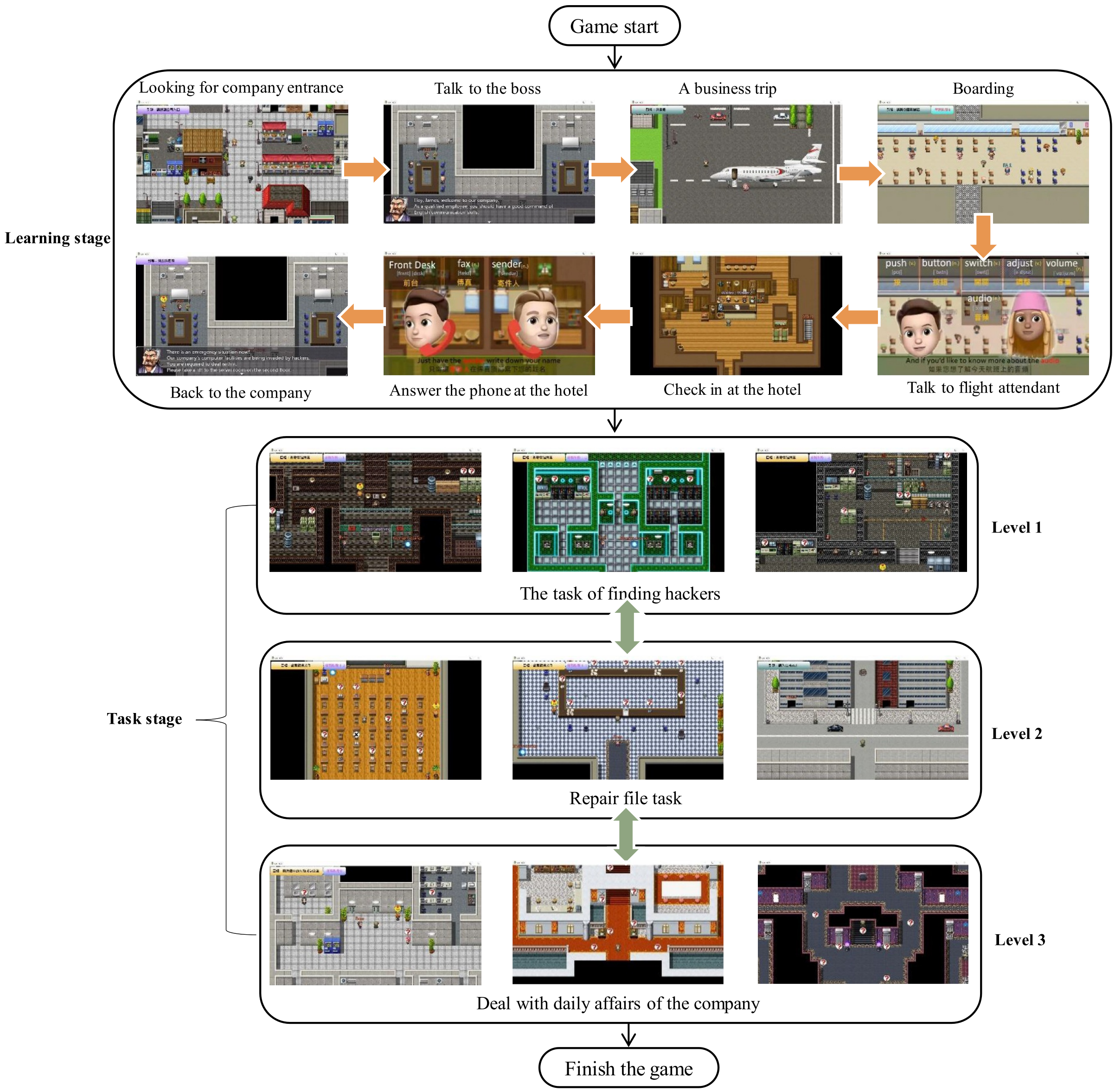

Fig. 2. The whole map of the digital gaming content.

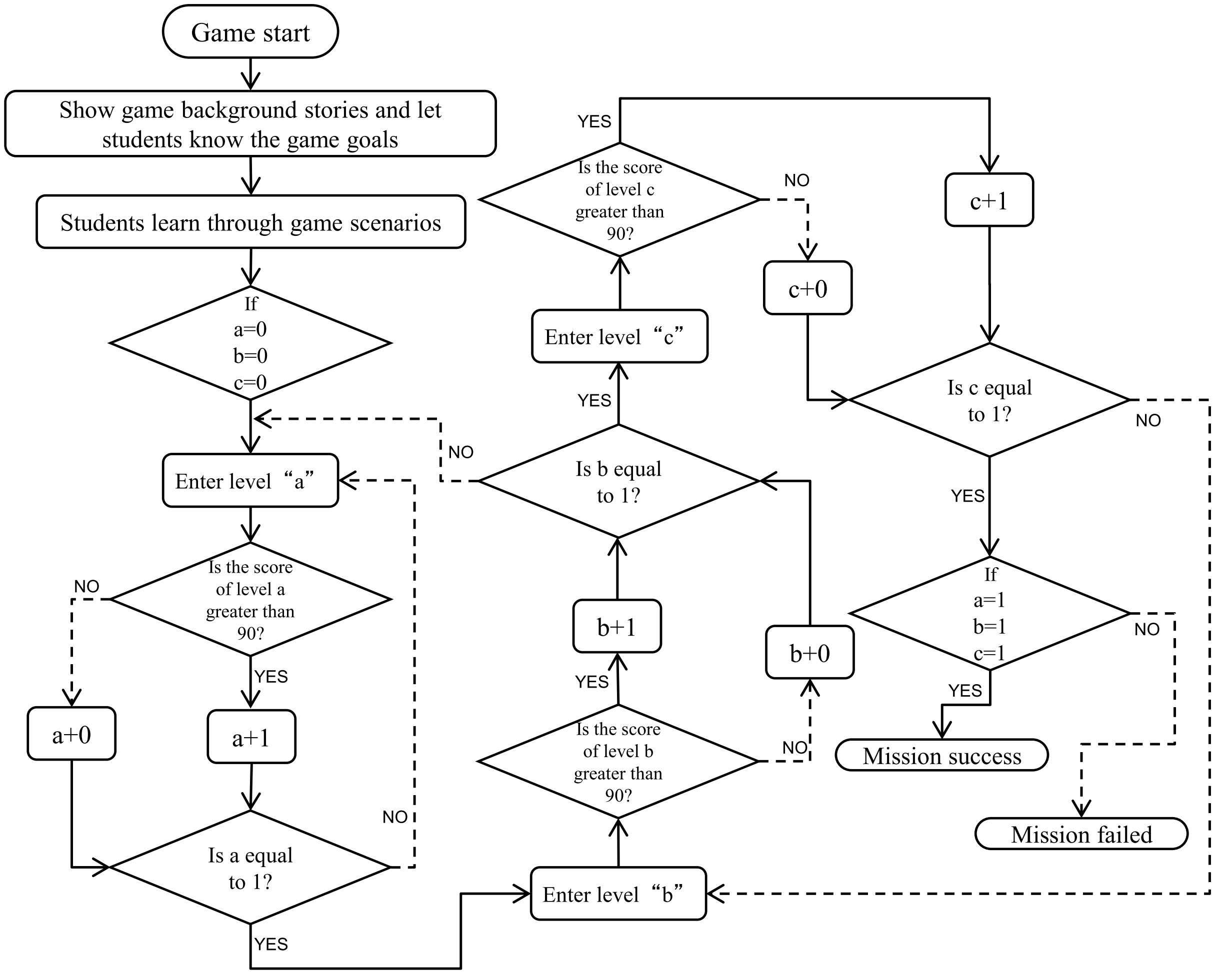

Fig. 3. Flowchart of the cognitive complexity-based competition strategy for developing situational English vocabulary learning games.

all of the tasks at each level, the system examines whether the score reached a = 1, b = 1, and c = 1. If yes, the gaming mission ends.

At each level, there are three gaming versions, all of which share similar learning content but have different storylines. Each gaming version consists of a set of tasks, each of which relates to a list of target words. When a learner enters a cognitive complexity level of the game, one of the gaming versions at that level is randomly assigned. If the learner completes a learning task by correctly answering the corresponding questions, her/his gaming score increases by 10; otherwise, the score decreases by 5. If the learner's gaming score is higher than the "pass" threshold as defined by the teacher (i.e., 90), s/he is allowed to enter the next cognitive complexity level. If her/his score is lower than the "fail" threshold, s/he needs to return to the previous cognitive complexity level and do more learning tasks at that level before s/he is allowed to be upgraded to the higher cognitive complexity level.

When the game starts, the system introduces the background stories, rules, and ultimate goal of the game. The game uses "Become a Manager" as the story background (see Fig. 4). The learner plays the role of a newcomer "James" in the workplace. On a business trip, he must interact with the NPCs (Non-Player Characters) in the game, watch the dialogue videos, learn relevant target words, and finish a series of tasks given by his boss. The left hand corner of the interface guides players to learn based on the designed content. The characters in the dialogue use voices, facial expressions and mouths to assist students to learn the forms, meanings, and uses of the target words. Flashcards in the upper part of the video are also used to help students consolidate the knowledge of the target vocabulary. There are also Chinese and English subtitles of the dialogues at the bottom of the videos. During the tasks, a NPC played by the computer competes with the players to create the atmosphere of workplace competition.

Fig. 5 demonstrates the main function of the game and the interface of a sample task. Students choose the task they want to complete; the game in each level consists of several tasks, which require students to solve all the missions in order to complete the goal in each stage. When students carry out the learning tasks, they can apply their knowledge of the target vocabulary as learned previously from the dialogue videos to complete the tasks. As they learn from the materials, finish the learning tasks, and correctly answer the questions proposed by the system, the boss becomes friendlier, and vice versa. During the process of answering questions, students can choose not to answer immediately, but to watch the dialogue videos again to make sure that their answers are correct. However, watching videos again requires students to spend the corresponding amount of money. During the time, players could move among

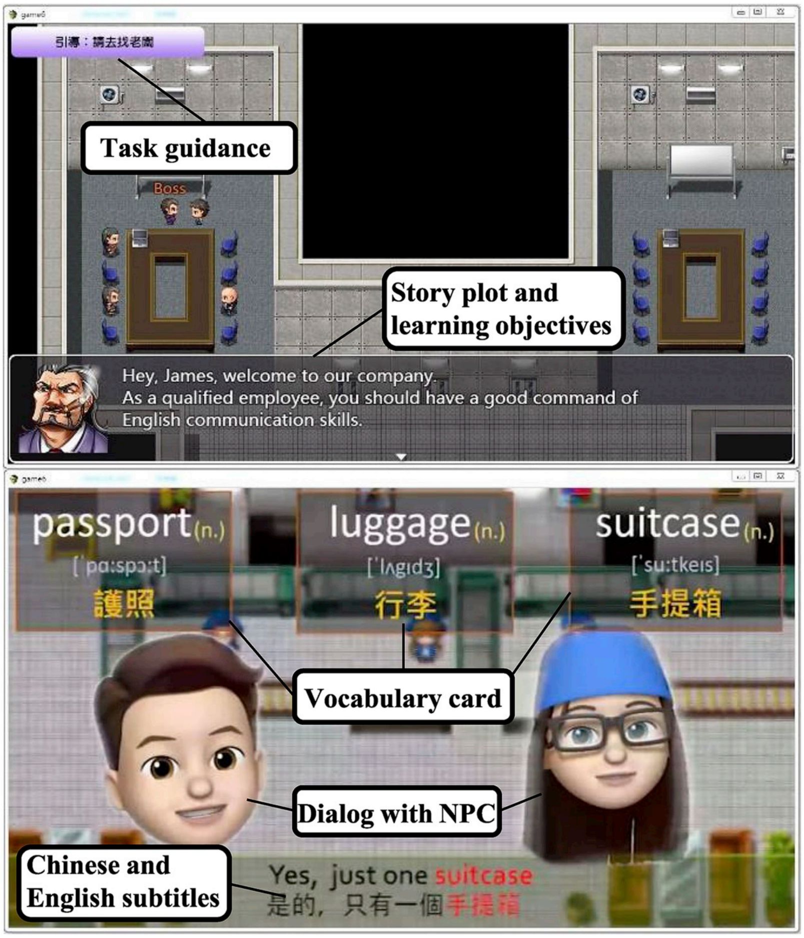

Fig. 4. Game background stories and the interface of learning stages.

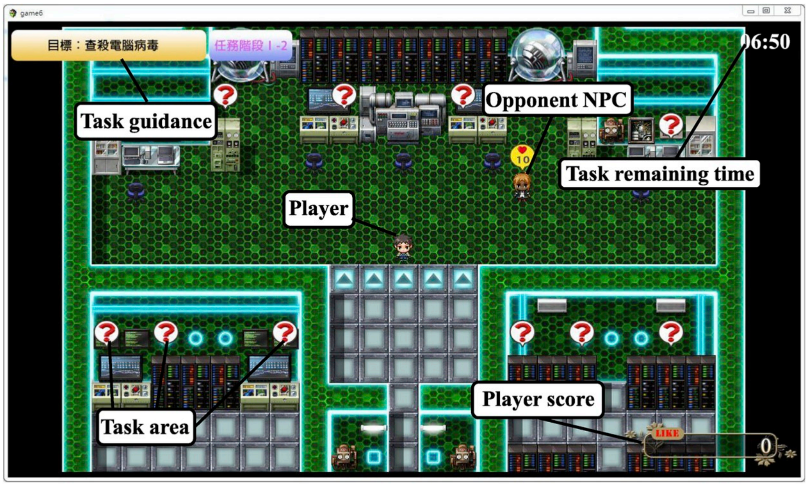

Fig. 5. The main functions of the game and task interface.

scenes and search for the task area, but they have to finish the task at each level within the designated time, or they will "fail." In addition, players can focus on the counterparts' scores and their own scores (degree of friendliness from the boss) at any time, which creates the competitive environment. The left corner of the interface also shows the current task goals so as to instruct players to carry out the tasks smoothly.

The task interface is shown in Fig. 6. The present study divided the game tasks into three levels, as explained previously. The questions at level a are presented in the fill-in-the-blank format; and students need to completely spell the vocabulary to obtain the score. The questions at level b are in the format of multiple-choice questions with four to six candidate answers. There is only one correct answer. When players answer questions correctly, their scores increase accordingly. At level c, players are required to have a conversation with the NPC. It aims to examine whether the learners are able to apply their acquired vocabulary in different contexts. Students could choose to engage in a conversation with the NPC. The conversation consists of a set of questions in the format of multiple-choice questions with four to six candidate answers. There is only one correct answer to each question. Only when the interaction completes could players continue the task.

The learning content of the game was designed based on the vocabulary of the "Money and Travel" unit of the 11th-grade English course. The gaming content was consistent with the existing curriculum of the selected high school. The English vocabulary learning game was developed based on the Situated Learning Theory proposed by Lave (1988), who indicated that learning is unintentional and situated within authentic activity, context, and culture. In addition, the English vocabulary learning tasks were designed by referring to Nation's (2007) four strands of vocabulary teaching and learning, that is, meaning-focused input, meaning-focused output, language-focused learning, and fluency development. Based on the four standards, in each learning task in the game, students are guided to learn via relevant contexts of the vocabulary to be learned and to complete the learning task through comprehensible input following the gaming contexts presented with multimedia, including sounds, images, videos, animation and text. Following that, they are situated in gaming contexts to apply the vocabulary. In each cognitive complexity of the game, students are guided to provide answers in different forms following the gaming contexts; that is, they have opportunities to produce output in a variety of appropriate genres. In addition, by guiding individual students to practice in gaming tasks with different cognitive complexity levels based on their learning status, it is expected that their vocabulary fluency level can be developed.

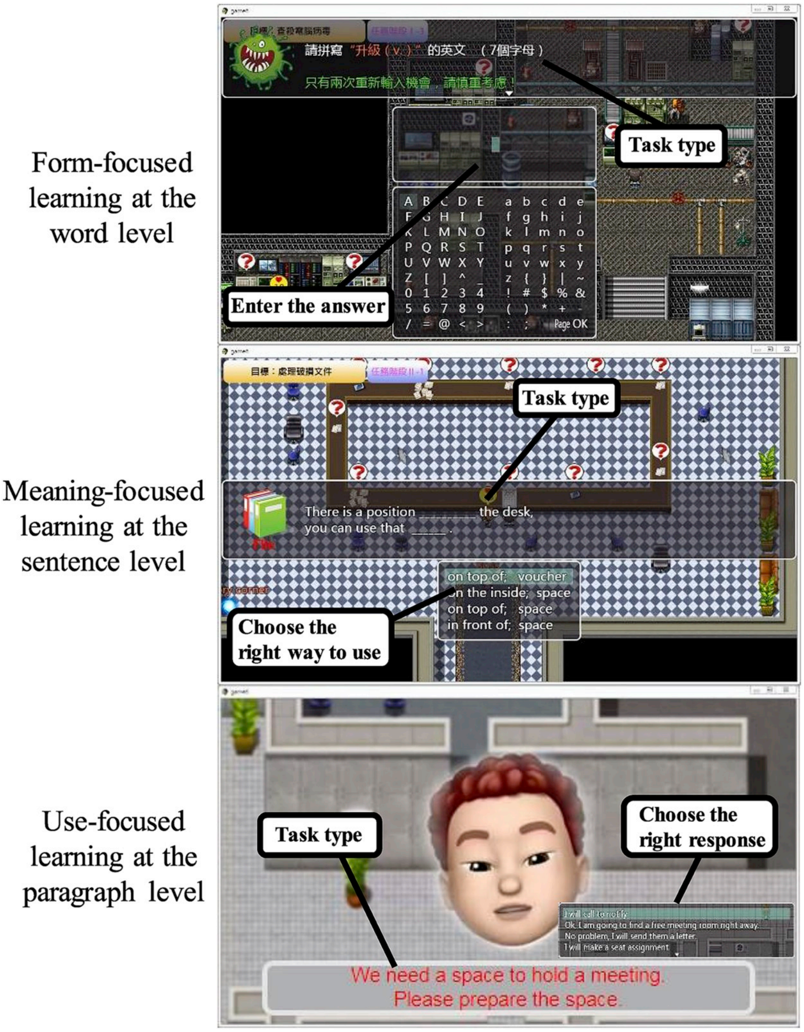

Fig. 6. Interfaces of task types.

4. Experiment design

4.1. Participants

The participants were 51 students from two classes of a high school in Northern Taiwan. Their average age was 17. Class A with 25 students was the CLBG (Cognitive complexity Level-Based Gaming) group who learned with the game based on the cognitive complexity-based competition strategy, while Class B with 26 students was the CG (Conventional Gaming) group who learned with the game based on the common competition strategy. The participants had received the same computer skill training courses. In addition, they were all instructed by the same English teacher who had more than 10 years of teaching experience. Additionally, the students voluntarily participated in the experiment, and knew that it would not influence their course grades. They were able to quit the experiment at any time. Their personal information was concealed in order to protect their privacy.

4.2. Instruments

The instruments in the current study included pre- and post-tests on learning performance and measures for learning motivation, cognitive load and English anxiety.

The pre-test aimed to evaluate the students' prior knowledge, that is, their learning status of basic English vocabulary. It consisted of 10 fill-in-the-blank items (20%), 15 multiple-choice items for vocabulary comprehension (55%), and five multiple-choice items for applying vocabulary (25%) with a perfect score of 100. The post-test aimed to evaluate the students' learning achievements in the activity. It consisted of 10 fill-in-the-blank items (20%), 10 multiple-choice items for vocabulary comprehension (40%), and 10 multiple-choice items for applying vocabulary (40%) with a perfect score of 100. The tests were both developed by two English teachers with more than 10 years' experience of teaching the English course. In addition, two experts of English education were invited to ensure the pre- and post-test were sufficient to evaluate the students' learning achievements for the selected unit. The KR-20 of the pre- and post-test was 0.79 and 0.84, respectively, indicating an acceptable internal consistency (Cortina, 1993).

The learning motivation measure was developed by Wang and Chen (2010) based on the measure proposed by Pintrich, Smith, García, and McKeachie (1991). The measure included six items with a 5-point Likert scale (1 = *strongly disagree*; 5 = *strongly agree*). The measure was divided into intrinsic and extrinsic motivation. The learning motivation measure was administered before and after the course to observe the change in students' motivation before and after the experiment, and had a Cronbach's α value of 0.79. In addition, the validity of the measure was examined by two experts who had more than 10 years' experience of developing questionnaires. Example items of this measure are "In a class like this, I prefer course material that really challenges me so I can learn new things" and "If I can, I want to get better grades in this class than most of the other students."

The English anxiety measure was adapted from the foreign language anxiety scale developed by Horwitz, Horwitz, and Cope (1986). The measure included 11 items with a 5-point Likert scale (1 = *extremely disagree*; 5 = *extremely agree*). The Cronbach's α of the English anxiety measure was 0.90. The high Kaiser-Meyer-Olkin measure (0.89), a significant Bartlett's test of sphericity (Chi-square = 411.28, $df = 55$, $p < 0.001$), and a 60.24% total variance explanation indicated the appropriateness of the instrument. Example items of this measure are "I never feel confident when I take the foreign language class" and "I am always thinking that other students' language proficiency level is higher than mine."

The cognitive load measure was adopted from the cognitive load scale by Hwang, Yang, and Wang (2013) to understand the effects of this learning approach on students' learning. The measure consisted of eight items, with a 5-point Likert scale (1 = *extremely disagree*; 5 = *extremely agree*). There were five items for mental load, and three for mental effort. The Cronbach's alpha values of the two dimensions are 0.86 and 0.85, respectively. Example items of this measure are "The learning content in this learning activity was difficult for me" and "I need to put lots of effort into completing the learning tasks or achieving the learning objectives in this learning activity."

Table 1
The coding table of learning behavior.

Code	Phase	Description
L1	Learning the vocabulary	Students learn vocabulary in the corresponding language contexts.
L2	Read game message	Students read the messages about how to play the game.
L3	Start	Students finish learning and start to carry out game tasks.
L4	Seek learning assistance	Students seek help when they encounter difficulties.
L5	Skip learning content	Students skip learning vocabulary.
G1	Finish game tasks	Students finish the game tasks.
G2	Game tasks fail	Students do not finish the game tasks.
G3	Give up game tasks	Students give up the game tasks.
G4	Irrelevant behavior	Students have behavior irrelevant to the game content.
C1	Competition process (enhance difficulty)	Students finish the learning objectives in the first level, and are guided to enter the next (higher) objective.
C2	Competition process (reduce difficulty)	Students finish the learning objectives in the first level, and are guided to enter the next (lower) objective.

4.3. Coding scheme of gaming behaviors

To examine the relationship between students' learning behavior and learning achievement during the game-based learning process, the current study generalized the possible learning behavior into learning behavior and gaming behavior. The coding scheme referred to English vocabulary learning coding by Hwang and Wang (2016) and English game-based learning coding by Hwang, Hsu, Lai, and Hsueh (2017). The learning behavior coding represented that students had such behavior as choose, seek assistance, watch repeatedly, and skip learning tasks. In addition, the current study also referred to the competition process coding developed by Chen, Liu, and Shou (2018) to explore students' learning process during the competition. The coding table of learning behavior is given in Table 1. During the gaming process, students' learning behaviors are automatically recorded by the gaming system. For example, if students read the messages announced on the noticeboard about how to play this game, L2 (i.e., Read game message) is recorded by the gaming system; if students have conversations with the flight attendants regarding the vocabulary to be learned or read the dictionary provided in the gaming contexts, L1 (i.e., Learning the vocabulary) is recorded; if they start a new gaming mission, L3 (i.e., Start) is recorded. They can also seek help when failing to complete a learning task by "calling the information desk," whereby L4 (i.e., Seek learning assistance) is recorded. The learning behaviors were recorded following the time sequence in which they occurred.

4.4. Experimental procedure

In order to investigate the differences in the learning performance, motivation, cognitive load, English anxiety, and learning behavior of students learning with the different game mechanisms, a situational English vocabulary learning game based on the cognitive complexity-based competition strategy was developed in this study for students to learn from. Moreover, an experiment was carried out to ensure that the game benefited students' learning. Fig. 7 illustrates the experiment design of the present study. Before the experiment, the two groups had a 3-week course. It mainly instructed English vocabulary learning skills and basic learning knowledge, which was part of the existing English course. Later, the pre-test and the pre-questionnaires of learning motivation and English anxiety were administered. The teacher carried out 10-min guidance on the learning activities for the two groups, including the introduction of the required learning tasks and the game interfaces. After the introduction, the two groups conducted the 90-min experiment. During the game, the CLBG group adopted the cognitive complexity-based situational English vocabulary gaming approach, while the CG group adopted the conventional situational English vocabulary gaming approach. During the gaming process, the students learned individually with a personal computer, which completely recorded their learning behavior. After the learning activity, all the students took the post-test and completed the surveys of learning motivation, English anxiety, and cognitive load.

4.5. Data analysis

Such results are likely because SPSS24 was used to conduct the ANCOVA analysis.

In addition, the students' gaming logs were analyzed using behavioral sequence analysis by employing GSEQ 5.1 developed by

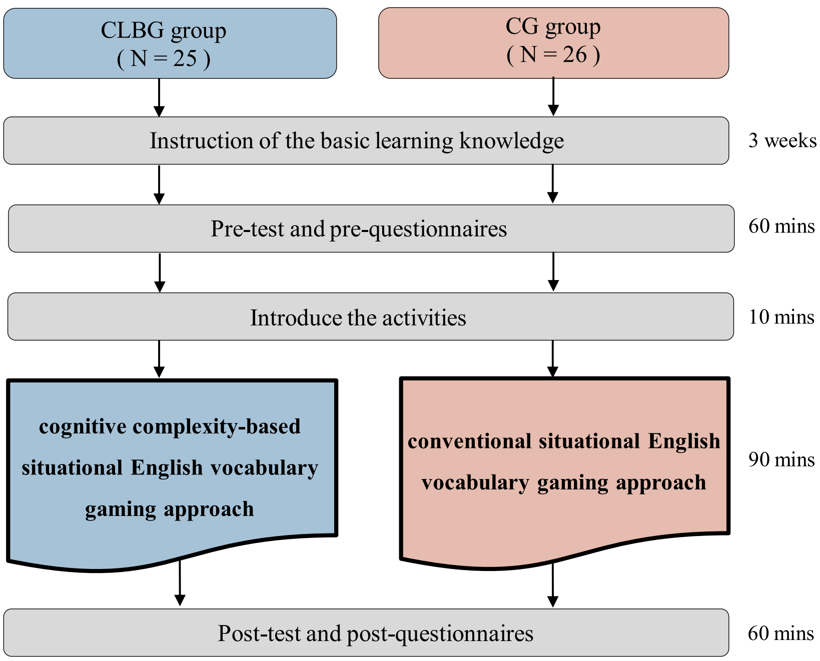

Fig. 7. Diagram of the experiment design.

Quera, Bakeman, and Gnisci (2007).

5. Experimental results

5.1. Analysis of learning performance

The one-way analysis of covariance (ANCOVA) was employed to evaluate students' learning achievement in the CLBG group and the CG group. Before using the ANCOVA, the independent *t*-test was employed to examine the internal consistency between the CLBG group and the CG group. As shown in Fig. 8, the residual values of the CLBG group of dependent variables are evenly distributed above and below 0, indicating that the variable of the CLBG group has independence; likewise, the residual value of the variable of the CG group is evenly distributed above and below 0, showing that the dependent variable of the CG group also has independence. Therefore, it can be shown that the CLBG group and the CG group have internal consistency (Hahs-Vaughn & Lomax, 2013).

The Shapiro-Wilk test results were between 0.96 and 0.97 ($p > 0.05$), showing that all of the data sets had a normal distribution. In addition, the Levene's test of determining homogeneity of variance was not violated ($F = 2.102$, $p > 0.05$), indicating that the assumption is tenable and that ANCOVA can be used to interpret the relationships between the students' prior knowledge and their learning achievement in the post-test. Table 2 shows the ANCOVA results of the learning achievement according to the post-tests of the two groups. The adjusted means and standard error were 72.97 and 2.40 for the CLBG group, and 64.87 and 2.36 for the CG group. It was found that the post-test scores of the two groups were significantly different ($F = 5.79$, $p < 0.05$, $\eta^2 = 0.11$). The findings indicated that the students who learned with the cognitive complexity-based situational English vocabulary gaming approach had better learning performance than those who learned with the conventional situational English vocabulary gaming approach.

This study further used two-way ANCOVA to investigate the effects of the cognitive complexity-based situational English vocabulary gaming approach on the students with different learning achievement levels. By referring to Lai and Hwang (2016), the students with the top 50% pre-test scores were regarded as high-achievers, while the others were low-achievers. The independent variables were the two game modes and two learning achievement levels (i.e., higher and lower), while the dependent variable is the students' learning achievement in the post-test scores. The Levene's test was not violated ($F = 2.54$, $p > 0.05$), suggesting that a common regression coefficient was appropriate for the two-way ANCOVA.

Table 3 shows the two-way ANCOVA results. It was found that significant effects were observed for the game modes ($F = 4.21$, $p < 0.05$), and learning achievement levels ($F = 14.15$, $p < 0.01$). In addition, the interaction between the game modes and learning achievement levels on the students' learning achievements was also significant ($F = 5.87$, $p < 0.05$).

The simple main-effect analysis was further employed to explore the effects of students' learning achievement levels on their learning achievements when learning with different game learning modes, as shown in Table 4. It was found that there was no significant difference between the post-test scores of the students with different learning achievement levels in the CLBG group ($F = 0.88$, $p > 0.05$, $\eta^2 = 0.02$), while a significant difference was found in the CG group ($F = 19.47$, $p < 0.001$). The results indicated that using the cognitive complexity-based situational English vocabulary gaming approach benefited the low-achievers more than the high-achievers.

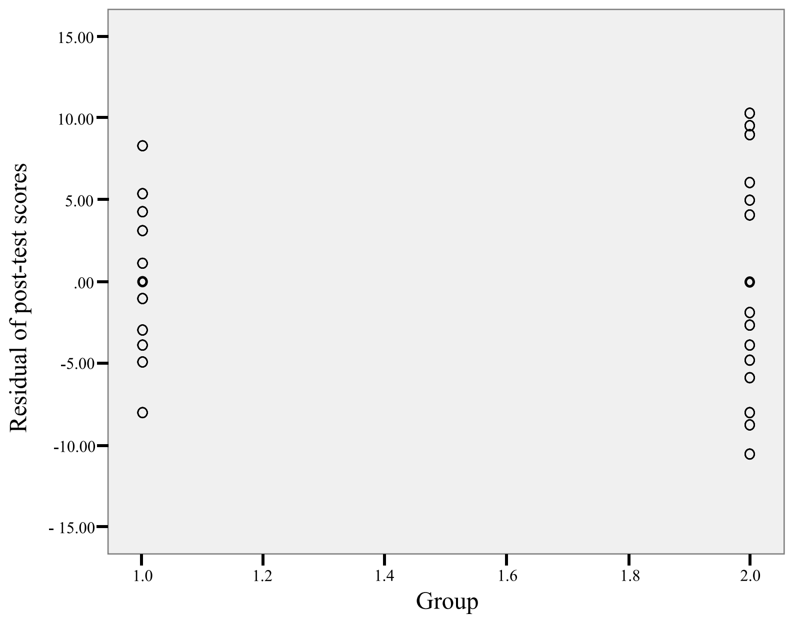

Fig. 8. Residuals plot of the independent variable of the two groups.

Table 2
Summary of ANCOVA on the learning achievement post-test.

Group	N	Mean	SD	Adjusted mean	Adjusted SD	*F*	η^2
CLBG group	25	72.24	12.72	72.97	2.40	5.79*	0.11
CG group	26	65.58	17.88	64.87	2.36		

$*p < .05$.

Table 3
The two way ANCOVA result of the learning achievement.

Variables	*SS*	*df*	*MS*	*F*	η^2
Game mode	742.96	1	742.96	4.21*	.082
Learning-achievement level	2494.93	1	2494.93	14.15**	.231
Game mode*Learning achievement level	1035.43	1	1035.43	5.87*	.111
Error	8287.38	47	176.33		
Total	12,560.7	50			

$**p < .01$, $*p < .05$.

Table 4
Simple main-effect analysis results of learning achievement levels on students' learning achievement.

Variables		*SS*	*df*	*MS*	*F*	η^2
CLBG group	Between groups	155.2	1	155.2	.88	.02
	Within groups	8287.38	47	176.33		
	Total	8442.58	48			
CG group	Between groups	3432.32	1	3432.32	19.47***	.293
	Within groups	8287.38	47	176.33		
	Total	11,719.7	48			

$***p < .001$.

Table 5 shows the simple main-effect analysis results of the effects of the game modes on the learning achievements of the students with different learning achievement levels. No significant difference was found between the learning achievements of the high-achievers in the two different gaming groups ($F = 0.07$, $p > 0.05$, $\eta^2 = 0.001$), while a significant difference was found between those of low-achievers in the two gaming modes ($F = 9.85$, $p < 0.01$). This implies that the cognitive complexity-based situational English vocabulary gaming mode benefited the low-achievers more than the high-achievers, as shown in Fig. 9.

5.2. Analysis of learning motivation

The Shapiro-Wilk test results were between 0.96 and 0.97 ($p > 0.05$), showing that all of the datasets had a normal distribution. The Levene's test on the two groups' test scores shows the equality of variances assumed of the two groups with $F = 1.22$. In addition, the test of homogeneity of the regression coefficient on the two groups' learning motivation ratings was $F = 3.483$ ($p > 0.05$), revealing that ANCOVA can be adopted to analyze the learning motivation ratings.

The ANCOVA findings are provided in Table 6, revealing that there was no significant difference between the two groups' learning motivation ($F = 0.00$, $p = 0.997$). The findings showed that the students who learned with the cognitive complexity-based situational English vocabulary gaming approach had no better learning motivation than those who learned with the conventional situational English vocabulary gaming approach.

Table 5
Simple main-effect analysis results of game modes on students' learning achievement.

Variables		*SS*	*df*	*MS*	*F*	η^2
High achievement	Between groups	12.32	1	12.32	.07	.001
	Within groups	8287.38	47	176.33		
	Total	8299.7	48			
Low achievement	Between groups	1736	1	1736	9.85**	.173
	Within groups	8287.38	47	176.33		
	Total	100,023.38	48			

$**p < .01$.

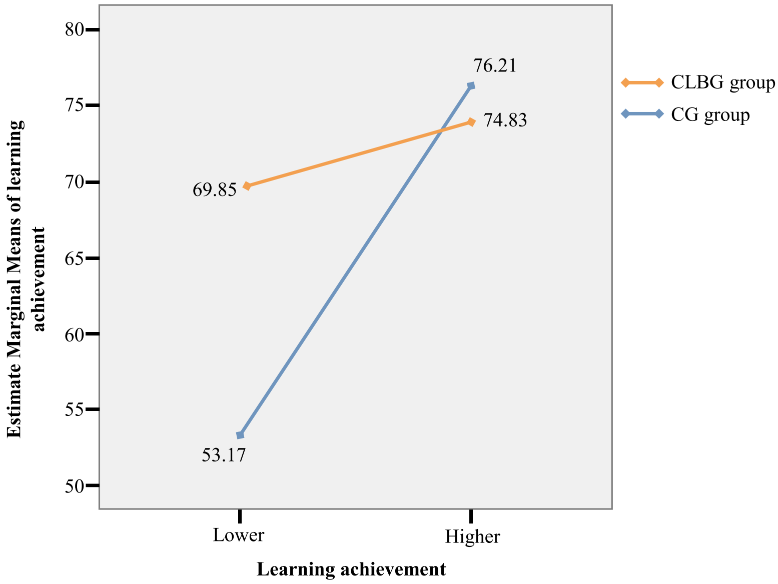

Fig. 9. Interaction between level of learning achievement and game mode.

Table 6
The one-way ANCOVA result of the learning motivation of the two groups.

Group	N	Mean	SD	Adjusted mean	Adjusted SD	*F*	η^2
CLBG group	25	3.55	0.56	3.47	0.87	0.00	0.00
CG group	26	3.40	0.52	3.47	0.86		

5.3. Analysis of English anxiety

The Shapiro-Wilk test results were between 0.97 and 0.98 ($p > 0.05$), showing that all of the datasets had a normal distribution. The Levene's test on the two groups' test scores shows the equality of variances assumed of the two groups with $F = 1.24$. In addition, the test of homogeneity of the regression coefficient on the two groups' English anxiety ratings was $F = 2.717$ ($p > 0.05$), revealing that ANCOVA could be adopted to analyze the English anxiety ratings.

The ANCOVA results are shown in Table 7. The adjusted mean and adjusted standard deviation of the post-English anxiety measure for the CLBG group were 2.99 and 0.84, respectively, and those of the CG group were 2.57 and 0.83. Furthermore, the findings showed that the CLBG group scored significantly higher than the CG group on English anxiety ($F = 12.84$, $p < 0.05$, $\eta^2 = 0.21$). The results revealed that students who learned with the cognitive complexity-based situational English vocabulary gaming approach had higher English anxiety than the students who learned with the conventional situational English vocabulary gaming approach.

5.4. Analysis of cognitive load

Table 8 shows the *t*-test result of the cognitive load of the two groups. The average score of the CLBG group was 2.55, and that of the CG group was 2.45, with a t value of 0.44. Therefore, there was no significant difference in the cognitive load of the students adopting the cognitive complexity-based situational English vocabulary gaming approach and of those adopting the conventional situational English vocabulary gaming approach.

Table 7
The one-way ANCOVA result of the English anxiety of the two groups.

Group	N	Mean	SD	Adjusted mean	Adjusted SD	*F*	η^2
CLBG group	25	3.00	0.63	2.99	0.84	12.84**	0.21
CG group	26	2.57	0.68	2.57	0.83		

**p <.01.

Table 8
The independent *t*-test analysis of cognitive load.

	Group	N	Mean	SD	*t*
Cognitive load	CLBG group	25	2.55	0.87	0.44
	CG group	26	2.45	0.63	
Mental load	CLBG group	25	2.57	0.90	0.14
	CG group	26	2.54	0.63	
Mental effort	CLBG group	25	2.50	0.85	0.90
	CG group	26	2.30	0.73	

5.5. Analysis of learning behavior patterns

To investigate the differences in the learning behavior of the students in the two groups, behavioral sequence analysis was conducted. The z score was calculated to evaluate the coding data of each group, and generated the adjusted residual table for students' behavior patterns. Table 9 shows the adjusted residual table of the CLBG group. If the z value is larger than 1.96, it means that the sequence has statistical meaning (Bakeman & Gottman, 1997). The sequence analysis of the present study was performed using GSEQ 5.1 developed by Quera et al. (2007).

The behavioral patterns of the CLBG group are demonstrated in Fig. 10; the number on each line is the z value of the sequence, and the direction of each line represents the transfer direction. In addition, the thicker line shows that the z value of behavior was larger than 8.00, while the thinner line shows that the z value of behavior is smaller than 8.00, which was to distinguish the significance level of the sequence. In the figure, L1↔ L1 shows that students were in the learning stage and repeatedly conducted vocabulary learning in the contexts provided in the game; L1→L5 shows that students skipped a part of the learning content; L5→ L1 shows that students came back to the learning content after skipping it; L1→ L3 shows that students finished the learning stage and entered the next stage to carry out the tasks; L3→ L2 shows that students read messages and understood how to complete tasks before conducting them; L2↔ L2 shows that students read the messages provided in the game repeatedly; L2→G1 and L2→G2 show that students completed the task or failed, respectively, after they finished reading the required messages; G1→C1 shows that students finished the task and entered the next level; C1→G1 shows that students finished tasks continually after upgrading; C1→G2 shows that students failed in the next level after upgrading; G2→C2 shows that students failed and returned to the previous level; N→H shows that students failed continually after downgrading; C2→G1 shows that students finished the task in the next level after downgrading; L4↔L4 shows that students repeatedly asked to read the learning content when encountering difficulties. Based on the aforementioned content, the cycle of G1↔C1→G2↔C2→G1 represents the change of level after students win or fail.

As can be seen from Fig. 9, the CLBG group followed the game designs in the learning stage. After the game started, the students entered the learning stage. During their learning process, they skipped a part of the content. After finishing the learning tasks, they started to play the game, and repeatedly read the message (L5↔L1↔L1→L3→L2↔L2). Later, they used their acquired vocabulary to complete the tasks; if they completed the tasks, they were guided to the next level. If not, they were downgraded to the previous level (L2→G1→C1 or L2→G2→C2). Furthermore, it was found that the students had higher failure rates after upgrading (C1→G2, z = 13.43). On the other hand, the success rate was greatly enhanced after the students conducted more practice when they were downgraded (C2→G1, z = 17.54). This phenomenon illustrates that employing the cognitive complexity-based situational English vocabulary gaming approach enabled the students to obtain better game process after understanding their cognitive complexity and having appropriate practice to improve their vocabulary level.

Table 10 is the adjusted residual table of the CG group. Among all of the patterns, L1↔ L1, L1→L5, L5→ L1, L1→L3, L3→L2, L2→L2, L2→G1, L2→G2, L4↔L4, G1↔C1 and C1→G2 were identical to the CLBG group. Its z value was also similar to that of the CLBG group. The behavior patterns of the CG group are shown in Fig. 8. Except for the same patterns as the CLBG group, L2→L4 showed that the students actively returned to the learning materials after checking the message; G2→G1 shows that the students tried again after

Table 9
Adjusted residual table of the CLBG group.

Z	L1	L2	L3	G1	L4	G2	L5	C1	C2
L1	10.29*	−3.85	15.21*	−7.59	−8.12	−7.23	6.50*	−7.87	−7.23
L2	−4.46	12.57*	−2.55	1.97*	−0.04	4.38*	−1.04	−1.79	−1.65
L3	1.64	3.98*	−5.24	−2.65	−3.02	−1.94	−2.14	−3.69	−3.39
G1	−7.66	−1.76	−3.60	−2.51	−3.05	−2.32	−1.47	34.36*	−2.32
L4	−6.67	−1.59	−4.35	1.64	23.48*	0.11	−1.78	−3.06	−2.81
G2	−7.08	−1.62	−3.33	−2.32	−2.83	−2.15	−1.36	−2.34	34.58*
L5	6.64*	−1.03	−2.10	−1.47	−1.79	−1.36	−0.86	−1.48	−1.36
C1	−6.92	−1.59	−3.25	7.74*	1.06	13.43*	−1.33	−1.79	−2.10
C2	−6.64	−1.52	−3.12	17.54*	0.43	7.43*	−1.27	−2.19	−2.02

*$p < .05$.

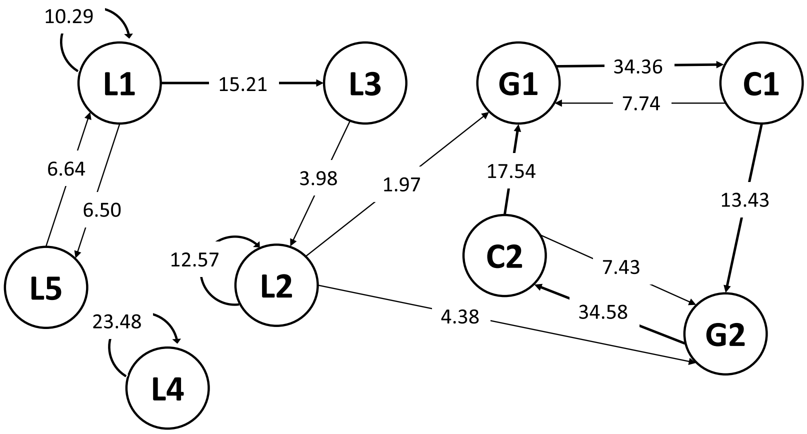

Fig. 10. Behavioral patterns of the CLBG group.

Table 10
Adjusted residual table of the CG group.

Z	L1	L2	L3	G1	L4	G2	L5	C1	C2
L1	11.35*	−4.97	14.52*	−7.94	−7.10	−12.00	5.21*	−7.81	0.00
L2	−4.38	6.32*	−2.42	4.03*	2.72*	6.94*	−0.79	−1.58	0.00
L3	0.19	5.35*	−5.61	−2.80	−2.18	−4.93	−1.84	−3.68	0.00
G1	−7.73	−1.53	−3.68	−2.65	−2.34	−3.37	−1.21	33.75*	0.00
L4	−5.92	−0.13	−3.52	1.09	22.57*	−2.15	−1.15	−2.31	0.00
G2	−11.12	1.46	−5.37	9.00*	0.17	17.64*	−1.76	−3.52	0.00
L5	5.34*	−0.76	−1.81	−1.31	−1.15	−1.83	−0.59	−1.19	0.00
C1	−7.46	−1.48	−3.55	9.18*	0.26	11.02*	−1.16	−2.32	0.00
C2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$^{*}p < .05$.

failure, and completed the level successfully; G2↔G2 shows that the students failed in the consecutive levels. According to the aforementioned content, the pattern of the CG group in the task was G1↔C1→G2→G1; the students followed the levels designed by the game, and were not downgraded.

Based on the behavioral patterns of the CG group in Fig. 11, their behavior in the learning stage was identical to that of the CLBG group (L5↔L1↔L1→L3→L2↔L2). After reading the information before the level, the students mostly went back to the learning content to learn further (L2→L4). Moreover, based on the task level, the students' failure rate was higher than their success rate after upgrading (C1→G1, z = 9.18; C1→G2, z = 11.02); there was a significant increase in students' continued failure rate (G2↔G2, z =

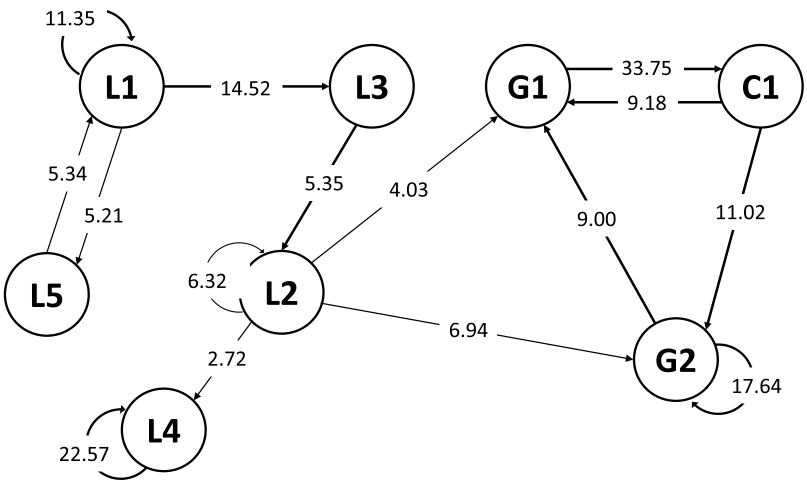

Fig. 11. Behavioral patterns of the CG group.

17.64). This phenomenon explained that if they lacked the adjustment of the cognitive complexity, the students who learned with the conventional situational English vocabulary gaming approach had significantly higher failure rates than those of the CLBG group no matter whether they were upgraded or tried repeatedly.

The differences between the two groups' behavioral patterns with the two competition strategies are demonstrated in Fig. 12. In the figure, the red lines represent the specific behaviors of the experimental and CG groups in the behavioral sequential figure. Based on the figure, the behavioral differences between the two groups appear in the task level. The game for the CLBG group conducted cognitive complexity judgement according to students' situations; when they reached a certain score in the learning tasks, they were upgraded to the next cognitive complexity (the score >90). In contrast, if they did not reach this score, they were requested to return to the previous level (the score <90). The behavioral sequence of the CLBG group in the task level was G1↔C1→G2↔C2→G1. An explanation for this is that when the students reached the score in the learning tasks after the game started, they upgraded to the next level (G1↔C1). If not, they had to return to the previous level (G2↔C2). Only when they reached the score of tasks in each level could they finish the level. It can be seen that the students would integrate their vocabulary knowledge and learn again in the level that fits their current cognitive complexity through the cognitive complexity competition mechanism. Through the tasks, they repeatedly learned what their deficiencies were or the vocabulary items that they did not control well. In this situation, the CLBG group had better task success rates than the CG group. The system provided more appropriate learning objectives based on the students' cognitive complexity. Also, it enabled them to have more opportunities to practice the tasks to avoid situating them in the status of high cognitive load owing to overly challenging tasks or feeling bored owing to challenges that were not sufficiently demanding.

The CG group used the conventional situational English vocabulary gaming approach; the mechanism provided the students with different levels of tasks and competition difficulty levels. They finished the tasks in each level based on the difficulty level of the tasks, which followed the process of cognitive complexity (Remembering→Understanding→Applying). As shown in Fig. 12, the learning behavior sequence of the CG group's learning behavior was G1↔C1→G2→G1. An explanation for this was that when the students reached the score in the level after the game started, they could upgrade to the next level (G1↔C1), which was the same as the CLBG group. If not, they were required to complete the tasks in this level until they reached the score. Consequently, the system did not support shifting the task level and competition difficulty level based on the students' cognitive complexity in the game with the common competition strategy. Moreover, it was found that the CG group had higher failure rates when trying repeatedly in the game (G2↔G2). Since the task difficulty level and students' individual learning performance could not strike a balance, it resulted in the decreasing completion rate and success rate in the tasks, which further indicated why the CLBG group outperformed the CG group on their learning performance.

6. Discussion and conclusions

In the present study, a situational English vocabulary learning game-based learning system was developed based on a cognitive complexity-based competition strategy. The approach has been applied to the English course in a junior college to examine its effects on the students' learning performance, learning motivation, cognitive load, English anxiety, and learning behavior. The findings revealed that the system significantly enhanced students' learning performance, in particular for the low-achieving students. It was also found that, with the cognitive complexity-based competition strategy, the students had better game-based learning behavioral patterns.

Based on the experiment, the research questions proposed in the present study could be answered. Research question 1 was to explore the effects of the cognitive complexity-based situational English vocabulary gaming approach on students' learning performance. The findings indicated that students with that proposed game mechanism significantly outperformed those with a conventional situational English vocabulary gaming approach. When using this system and conducting vocabulary learning in the game contexts, they started a series of tasks in the following level. During the tasks, the system judged the cognitive complexity and provided students with different levels of task difficulty and competition degree. The students had better learning performance due to this experience. These findings provide further support to Lee and Chen's (2009) study on cognitive complexity and Burguillo's (2010) study on competition. The major difference between the present study and previous studies is that a cognitive complexity-based competition mechanism for designing educational games is proposed. Although competition is a frequently adopted approach in digital game-based learning, previous studies generally engaged students in gaming scenarios with fixed cognitive complexity levels, or situated them in the same gaming contexts to compete with peers with different cognitive capacities. By engaging students in proper gaming contexts that met their cognitive capacities, it was found that the students' learning performances were significantly improved. Moreover, importantly, the approach proposed in the present study is able to help low-achieving students, who are likely to feel frustrated in conventional competitive contexts, to learn in a more effective manner. Such results are likely because all students in the control group followed the same procedure of learning, some of whom may have been stuck at learning levels with inappropriate cognitive complexity for a long time and consequently felt frustrated, while the cognitive complexity-based gaming approach could make adjustments according to students' learning performance so that all students in the experiment group learned with tasks at cognitive complexity levels that were appropriate for them. That is, the students in the control group may have been in a state of high anxiety and had low learning effectiveness, whereas the cognitive complexity-based gaming approach assisted the students in the experiment group to learn at appropriate complexity levels, so they achieved better learning performance.

Research question 2 was related to the effects of the cognitive complexity-based situational English vocabulary gaming approach on students' learning motivation. The results indicated that the CLBG group's learning motivation was not enhanced by using the situational English vocabulary learning game-based learning system based on the cognitive complexity-based competition strategy. A possible explanation is that the two groups both used the game to learn vocabulary. In the previous research, Vandercruysse et al.

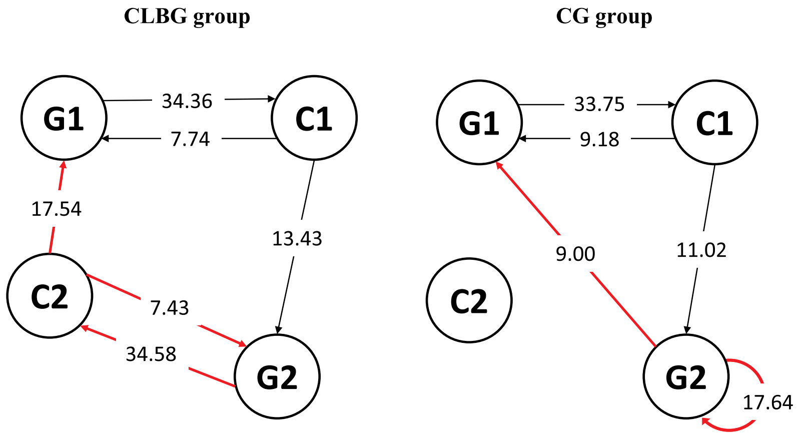

Fig. 12. The differences in the behavioral patterns of the two groups.

(2013) indicated that the competition in a game did not affect students' motivation. In the context of game-based learning, most students have better motivation. It could increase their motivation when compared with the traditional class, which is in accordance with the results of previous relevant studies (Lan, 2015; Reinders & Wattana, 2014).

Research question 3 was to explore the differences in the English anxiety of the experimental and CG groups. The results indicated that using the cognitive complexity-based situational English vocabulary gaming approach increased students' English anxiety. As illustrated in Fig. 13, Csikszentmihalyi (1990) believed there was a change in learners' immersion based on different contexts; learners might think their skill was equal to the challenge at the beginning, so they immersed themselves in the activity (F). Mastery of the skill made learners feel bored (G) or anxious (I). As a result, the reason that led to students' English anxiety might be relevant to the difficulty level of the task set by the game mechanism. In the current study, the CG group adopted the level shifting from easy to difficult, which was similar to the feature of previous games or learning tasks. On the other hand, the game adopted by the CLBG group adjusted the difficulty level based on students' scores in each level. According to Csikszentmihalyi's (1990) theory, if students could upgrade from the previous level based on their scores, they would encounter challenges and tasks at a higher difficulty level until the end of the level. Therefore, if students' cognitive complexity could not deal with the tasks at the new difficulty level, they had to wait until the end of the level to downgrade. However, because there were almost 10 questions to be solved in each level, it might lead to students' English learning anxiety in this period. On the contrary, the game adopted by the CG group raised the difficulty level of the learning content little by little, which corresponded to their previous game experiences. Therefore, there was no increase in their anxiety. The findings are in accordance with Chen and Sun (2016) and Martyastiadi (2018): when there is a balance with the challenge and skill based on self-perception, there is an increasing possibility of entering the flow state, which then encourages students to participate in more complicated activities to pursue greater learning interest. When the challenge is too difficult, it causes anxiety. Most important of all, the flow state is never stationary. With the change in difficulty level, the anxiety level and flow state change accordingly. Thus, there is room for improvement to the design of this game in the future.

Research question 4 examined the difference in the cognitive load of the experimental and CG groups. The findings revealed that there was no significant difference between the two groups' cognitive load. Previous studies also reported that game strategy allowed students to learn happily, which then decreased their cognitive load and encouraged them to learn knowledge more actively (Beylefeld & Struwig, 2007). Since the two groups both used games to learn unit vocabulary items, there was no noticeable difference in the content or strategy. As a result, no difference was found in the cognitive load in the process of game-based learning.

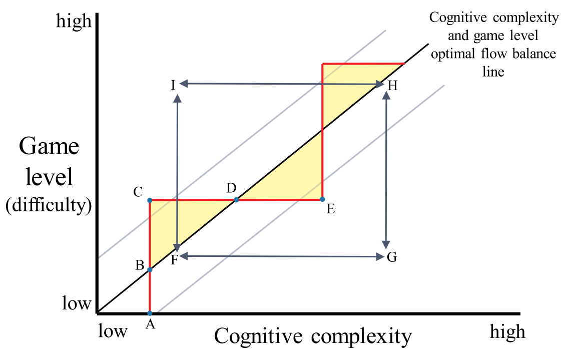

Fig. 13. The balance between cognitive complexity and game level.

Research question 5 analyzed the difference in the learning behaviors of the experimental and CG groups. The results showed that the CLBG group accumulated their vocabulary items and learned in the learning stage based on the cognitive complexity competition mechanism. After they finished the learning content, they entered the game task level. During the tasks, if they reached the required score of the level, they could upgrade to the next level. If not, they had to downgrade to the previous level. Only when students met the requirements of each level could they complete the game. This also indicated that the students fully understood the vocabulary items in each level. The behavioral patterns of the CLBG group corresponded to the goal set by the system. With the adjustment of the difficulty level in the game, it adjusted the balance between students' cognitive complexity and game level back to meet their learning flow to avoid situating them in an anxious or boring state for too long. This also echoes the balanced framework between challenge and skill proposed by Csikszentmihalyi (1990). In addition, the CG group learned vocabulary through the game with the common competition mechanism. After they finished the learning content, they entered the game task level. During the game, the system provided the tasks and competition with different difficulty levels progressively. Students finished each level based on the cognitive complexity (Remembering→ Understanding→ Applying). Above all, the main difference between the two groups' behaviors was found in the game level; the different game mechanisms formulated different learning behaviors. The results were also in line with previous studies which specified the importance of balancing students' cognitive complexity and game level (Barr, 2018; Fullagar, Knight, & Sovern, 2013).

The current study summarized the balance between the cognitive complexity and game level based on the balanced framework between challenge and skill proposed by Csikzentmihalyi (1975) (see Fig. 10). Suppose that the middle tangent 1 was the best cognitive complexity and game level optimal flow balance line. When students were at any point on this line, they reached the ideal situation; that is, their cognitive complexity corresponded to the game level. However, it was impossible to precisely predict the cognitive complexity and control the game level. Thus, maintaining the best balance line was ideal. The current study shifted the game level to assist students in learning effectively in the game. As illustrated in the figure, point A means the learners' preliminary cognitive complexity; A→B means the game level starting from 0 to the game level that corresponded to the learners' cognitive complexity; B→C represents that learners were using the game to learn. Learners faced the game level that was above their cognitive complexity during this time, and learned via the tasks. After the learning process, their cognitive complexity was enhanced. In this way, it could not only stimulate the appropriate anxiety of learners about the unknown game, but also promoted them to actively seek solutions to problems. C→D represents that the learners' cognitive complexity increased through game inquiry and learning. Point D was the best balance; D→E means the process whereby learners practice, consolidate and master newly acquired knowledge after their cognitive complexity was improved. F↔G↔H↔I↔F represents the change in students' flow state based on the change in game level (Chen & Sun, 2016). The pattern of students' learning process circulated based on this cycle until they reached the learning objectives. Students' flow state would exceed the adequate range in some situations; nonetheless, the system could adjust in time and enable students to get accustomed to the game level so as to prevent anxiety and boredom and obtain better immersion. The effects of this game mechanism were in line with the findings from previous research (Chen, Wigand, & Nilan, 2000; Hrabec & Chrz, 2015; Scoresby & Shelton, 2011).

The current study also had some limitations that should be noted. First of all, the sample size was small, so the results could not be generalized to students' cognition in all circumstances. Second, we did not conduct a delayed posttest to measure the students' retention of the target vocabulary knowledge, so the effects of the digital game on students' long-term retention were not investigated. Third, the coding content was not detailed enough in the Behavior Sequential Analysis. Additionally, as game design and development were very time-consuming, our game included a comparatively limited amount of learning content, and students completed the learning of this one unit in 90 min. If more learning sessions could be provided in the game, and students could spend a longer time learning with the situational vocabulary learning game, the research would be largely improved.

Moreover, based on the discussion and the limitations of the present study, we propose several suggestions here. In the current study, three cognitive complexity levels were used to adjust the difficulty level of the competition based on students' situations. However, the adjustment was performed after the students finished each level. Consequently, it might have caused the students' English anxiety to a certain degree before the system adjusted the difficulty level. It is suggested that a more thorough adjusting mechanism be designed in the future, for instance, a competition mechanism with formative assessment (Tsai, Tsai, & Lin, 2015) that would reduce the task time and the number of questions in each level. In this way, it can help students adjust the game level in a timely fashion, which would then decrease their English learning anxiety while using the system. Providing a knowledge map or other graphical presentation to enable individual students to have a whole picture of their own learning process could also be a good way to reduce students' learning anxiety, as suggested by several scholars. Additionally, the provision of immediate guidance or assistance can also reduce their learning anxiety, as suggested by Chen and Lee (2011). Furthermore, although scholars have pointed out that the game-based learning approach can generally improve both students' short- and long-term knowledge retention (Rondon, Sassi, & de Andrade, 2013), it is suggested that a large-scale and longitudinal experiment be conducted based on this study to improve the internal validity as well as to examine the impacts of the approach on students' knowledge retention. As for the coding content, it is suggested that future researchers increase the detail of the coding of students' behavior in order to perform in-depth investigation of the change in students' behavior patterns; moreover, they can also further explore the behavior patterns from students with different levels of learning achievement to reveal in-depth differences (Hou, 2012). Also, future studies can change the competition mechanism of the game into a competition between students to attain a better sense of competition and learning effects. Lastly, in an effort to more reliably investigate students' English anxiety, it would be worth trying to explore individuals' perceptions using other research methods such as in-depth interviews or the think aloud method (Hwang et al., 2017).

CRediT authorship contribution statement

Qi-Fan Yang: Software, Formal analysis, Investigation, Data curation, Writing - original draft. **Shao-Chen Chang:** Software, Formal analysis, Investigation, Writing - original draft. **Gwo-Jen Hwang:** Conceptualization, Methodology, Writing - review & editing. **Di Zou:** Conceptualization, Methodology, Writing - review & editing.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.compedu.2020.103808.

References

Admiraal, W., Huizenga, J., Akkerman, S., & Ten Dam, G. (2011). The concept of flow in collaborative game-based learning. *Computers in Human Behavior, 27*(3), 1185–1194.
Bakeman, R., & Gottman, J. M. (1997). *Observing interaction: An introduction to sequential analysis*. London, England: Cambridge university press.
Bandura, A., & Locke, E. A. (2003). Negative self-efficacy and goal effects revisited. *Journal of Applied Psychology, 88*(1), 87.
Barr, M. (2018). Student attitudes to games-based skills development: Learning from video games in higher education. *Computers in Human Behavior, 80*, 283–294.
Beylefeld, A. A., & Struwig, M. C. (2007). A gaming approach to learning medical microbiology: Students' experiences of flow. *Medical Teacher, 29*(9–10), 933–940.
Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18*(1), 32–42.
Burguillo, J. C. (2010). Using game theory and competition-based learning to stimulate student motivation and performance. *Computers & Education, 55*(2), 566–575.
Carreira, J. M. (2006). Motivation for learning English as a foreign language in Japanese elementary schools. *JALT Journal, 28*(2), 135.
Chang, L. J., Yang, J. C., & Yu, F. Y. (2003). Development and evaluation of multiple competitive activities in a synchronous quiz game system. *Innovations in Education and Teaching International, 40*(1), 16–26.
Chapelle, C. A. (2001). *Computer applications in second language acquisition: Foundations for teaching, testing and research*. Cambridge: Cambridge University Press.
Cheng, H. N., Wu, W. M., Liao, C. C., & Chan, T. W. (2009). Equal opportunity tactic: Redesigning and applying competition games in classrooms. *Computers & Education, 53*(3), 866–876.
Chen, S. Y., & Huang, P. R. (2013). The comparisons of the influences of prior knowledge on two game-based learning systems. *Computers & Education, 68*, 177–186.
Chen, C. H., Liu, J. H., & Shou, W. C. (2018). How Competition in a Game-based Science Learning Environment Influences Students. *Learning Achievement, Flow Experience, and Learning Behavioral Patterns. Journal of Educational Technology & Society, 21*(2), 164–176.
Chen, C. M., & Lee, T. H. (2011). Emotion recognition and communication for reducing second-language speaking anxiety in a web-based one-to-one synchronous learning environment. *British Journal of Educational Technology, 42*(3), 417–440.
Chen, L. X., & Sun, C. T. (2016). Self-regulation influence on game play flow state. *Computers in Human Behavior, 54*, 341–350.
Chen, H., Wigand, R. T., & Nilan, M. (2000). Exploring web users' optimal flow experiences. *Information Technology & People, 13*(4), 263–281.
Chik, H. H. (2011). Learner autonomy development through digital gameplay. *Digital culture & education, 3*(1), 30–45.
Chiu, Y. H., Kao, C. W., & Reynolds, B. L. (2012). The relative effectiveness of digital game-based learning types in English as a foreign language setting: A meta-analysis. *British Journal of Educational Technology, 43*(4), E104–E107.
Cornillie, F., Thorne, S. L., & Desmet, P. (2012). ReCALL special issue: Digital games for language learning: Challenges and opportunities: Editorial digital games for language learning: From hype to insight? *ReCALL, 24*(3), 243–256.
Cortina, J. M. (1993). What is coefficient alpha? An examination of theory and applications. *Journal of Applied Psychology, 78*(1), 98.
Cropper, C. (1998). Is competition an effective classroom tool for the gifted student? *The Gifted Child Today, 21*(3), 28–31.
Csikszentmihalyi, M. (1975). *Beyond boredom and anxiety*. San Francisco: Jossey-Bass.
Csikszentmihalyi, M. (1990). *Flow: The psychology of optimal experience*. New York: Harper & Row Publishers.
Dede, C. (2011). Developing a research agenda for educational games and simulations. *Computer games and instruction, 3*(2), 233–250.
Deitcher, J. (2011). *Facilitating flow at work: Analysis of the dispositional flow scale-2 in the workplace (ProQuest Dissertations and Theses)*. Halifax, NS: Saint Mary's University.
Dickey, M. D. (2006). Game design narrative for learning: Appropriating adventure game design narrative devices and techniques for the design of interactive learning environments. *Etr&D-Educational Technology Research and Development, 54*(3), 245e263.
Dickey, M. D. (2011). Murder on Grimm Isle: The impact of game narrative design in an educational game-based learning environment. *British Journal of Educational Technology, 42*(3), 456–469.
Dolgov, I., Graves, W. J., Nearents, M. R., Schwark, J. D., & Volkman, C. B. (2014). Effects of cooperative gaming and avatar customization on subsequent spontaneous helping behavior. *Computers in Human Behavior, 33*, 49–55.
Fong, C. J., Zaleski, D. J., & Leach, J. K. (2015). The challenge–skill balance and antecedents of flow: A meta-analytic investigation. *The Journal of Positive Psychology, 10*(5), 425–446.
Franciosi, S. J. (2017). The effect of computer game-based learning on FL vocabulary transferability. *Journal of Educational Technology & Society, 20*(1), 123.
Fullagar, C. J., Knight, P. A., & Sovern, H. S. (2013). Challenge/skill balance, flow, and performance anxiety. *Applied Psychology, 62*(2), 236–259.
Gibbons, P. (2009). *English learners, academic literacy, and thinking: Learning in the challenge zone*. Portsmouth, NH: Heinemann.
Griffiths, M. D., & Davies, M. N. O. (2002). Research note excessive online computer gaming: Implications for education. *Journal of Computer Assisted Learning, 18*(3), 379–380.
Hahs-Vaughn, D. L., & Lomax, R. G. (2013). *An introduction to statistical concepts*. New York, NY: Routledge.
Hamari, J., Shernoff, D. J., Rowe, E., Coller, B., Asbell-Clarke, J., & Edwards, T. (2016). Challenging games help students learn: An empirical study on engagement, flow and immersion in game-based learning. *Computers in Human Behavior, 54*, 170–179.
Herrington, J., & Oliver, R. (1999). Using situated learning and multimedia to investigate higher-order thinking. *Journal of Interactive Learning Research, 10*(1), 3–24.
Horwitz, E. K., Horwitz, M. B., & Cope, J. (1986). Foreign language classroom anxiety. *The Modern Language Journal, 70*(2), 125–132.
Hou, H. T. (2012). Exploring the behavioral patterns of learners in an educational massively multiple online role-playing game (MMORPG). *Computers & Education, 58*(4), 1225–1233.
Hrabec, O., & Chrz, V. (2015). Flow genres: The varieties of video game experience. *International Journal of Gaming and Computer-Mediated Simulations, 7*(1), 1–19.
Huang, K., Lubin, I. A., & Ge, X. (2011). Situated learning in an educational technology course for pre-service teachers. *Teaching and Teacher Education, 27*(8), 1200–1212.
Hung, H. C., Young, S. S. C., & Lin, C. P. (2015). No student left behind: A collaborative and competitive game-based learning environment to reduce the achievement gap of EFL students in Taiwan. *Technology, Pedagogy and Education, 24*(1), 35–49.

Hwang, W. Y., & Chen, H. S. (2013). Users' familiar situational contexts facilitate the practice of EFL in elementary schools with mobile devices. *Computer Assisted Language Learning, 26*(2), 101–125.
Hwang, G. J., Hsu, T. C., Lai, C. L., & Hsueh, C. J. (2017). Interaction of problem-based gaming and learning anxiety in language students' English listening performance and progressive behavioral patterns. *Computers & Education, 106*, 26–42.
Hwang, G. J., & Wang, S. Y. (2016). Single loop or double loop learning: English vocabulary learning performance and behavior of students in situated computer games with different guiding strategies. *Computers & Education, 102*, 188–201.
Hwang, G. J., Yang, L. H., & Wang, S. Y. (2013). A concept map-embedded educational computer game for improving students' learning performance in natural science courses. *Computers & Education, 69*, 121–130.
Jonassen, D. H., Beissner, K., & Yacci, M. (2013). *Structural knowledge: Techniques for representing, conveying, and acquiring structural knowledge*. New York, NY: Routledge.
Julian, J., & Perry, F. (1967). Cooperation contrasted with intra-group and intergroup competition. *Sociometry, 30*, 79–90.
Karakostas, A., & Demetriadis, S. (2011). Enhancing collaborative learning through dynamic forms of support: The impact of an adaptive domain-specific support strategy. *Journal of Computer Assisted Learning, 27*(3), 243–258.
Ke, F. (2008). Computer games application within alternative classroom goal structures: Cognitive, metacognitive, and affective evaluation. *Educational Technology Research & Development, 56*(5–6), 539–556.
Kohn, A. (1986). *No contest: The case against competition*. Boston, MA: Houghton Mifflin Company.
Lai, C. L., & Hwang, G. J. (2016). A self-regulated flipped classroom approach to improving students' learning performance in a mathematics course. *Computers & Education, 100*, 126–140.
Lam, S. F., Yim, P. S., Law, J. S., & Cheung, R. W. (2004). The effects of competition on achievement motivation in Chinese classrooms. *British Journal of Educational Psychology, 74*(2), 281–296.
Lan, Y. J. (2015). Contextual EFL learning in a 3D virtual environment. *Language, Learning and Technology, 19*(2), 16–31.
Lave, J. (1988). *Cognition in Practice: Mind, mathematics, and culture in everyday life*. Cambridge, UK: Cambridge University Press.
Lee, C. Y., & Chen, M. P. (2009). A computer game as a context for non-routine mathematical problem solving: The effects of type of question prompt and level of prior knowledge. *Computers & Education, 52*(3), 530–542.
Lin, H., & Chen, T. (2006). Decreasing cognitive load for novice EFL learners: Effects of question and descriptive advance organizers in facilitating EFL learners' comprehension of an animation-based content lesson. *System, 34*(3), 416–431.
MacIntyre, P. D., Baker, S. C., Clément, R., & Donovan, L. A. (2002). Sex and age effects on willingness to communicate, anxiety, perceived competence, and L2 motivation among junior high school French immersion students. *Language and Learning, 52*(3), 537–564.
Malone, T. W., & Lepper, M. R. (1987). Making learning fun: A taxonomy of intrinsic motivations for learning. In R. E. Snow, & M. J. Farr (Eds.)*, Vol. 3. Aptitude, learning and instruction:* (pp. 223–253). New York, NY: Guilford Press. Cognitive and affective process analysis.
Martyastiadi, Y. S. (2018). The paradox of control: Visual clue vs. Auditory instruction in game designing. *International Journal of Creative and Arts Studies, 5*(2), 35–47.
Mavridis, A., & Tsiatsos, T. (2017). Game-based assessment: Investigating the impact on test anxiety and exam performance. *Journal of Computer Assisted Learning, 33*(2), 137–150.
Miller, L. M., Chang, C. I., Wang, S., Beier, M. E., & Klisch, Y. (2011). Learning and motivational impacts of a multimedia science game. *Computers & Education, 57*(1), 1425–1433.
Nation, I. S. P. (2001). *Learning vocabulary in another language*. Cambridge: Cambridge University Press.
Nation, P. (2007). The four strands. *International Journal of Innovation in Language Learning and Teaching, 1*(1), 2–13.
Pe-Than, E. P. P., Goh, D. H. L., & Lee, C. S. (2014). Making work fun: Investigating antecedents of perceived enjoyment in human computation games for information sharing. *Computers in Human Behavior, 39*, 88–99.
Peterson, M. (2012). Learner interaction in a massively multiplayer online role playing game (MMORPG): A sociocultural discourse analysis. *ReCALL, 24*(3), 361–380.
Pintrich, P. R., Smith, D. A. F., García, T., & McKeachie, W. J. (1991). *A manual for the use of the Motivated Strategies for Learning Questionnaire (MSLQ)*. Ann Arbor: University of Michigan, National Center for Research to Improve Postsecondary Teaching and Learning.
Prince, P. (1996). Second language vocabulary learning: The role of context versus translations as a function of proficiency. *The Modern Language Journal, 80*(4), 478–493.
Quera, V., Bakeman, R., & Gnisci, A. (2007). Observer agreement for event sequences: Methods and software for sequence alignment and reliability estimates. *Behavior Research Methods, 39*(1), 39–49.
Ranalli, J. (2008). Learning English with the sims: Exploiting authentic computer simulation games for L2 learning. *Computer Assisted Language Learning, 21*(5), 441–455.
Reinders, H., & Wattana, S. (2014). Can I say something? The effects of digital game play on willingness to communicate. *Language, Learning and Technology, 18*(2), 101–123.
Robinson, P. (2001). Task complexity, task difficulty, and task production: Exploring interactions in a componential framework. *Applied Linguistics, 22*(1), 27–57.
Robinson, P. (2007). Criteria for classifying and sequencing pedagogic tasks. In M. P. Garcia–Mayo (Ed.), *Investigating tasks in formal language learning* (pp. 7–26). Clevedon, UK: Multilingual Matters.
Robinson, P. (2011). Second language task complexity, the Cognition Hypothesis, language learning and performance. In P. Robinson (Ed.), *Second language task complexity: Researching the Cognition Hypothesis of language learning and performance* (pp. 3–38). Philadelphia/Amsterdam: John Benjamins.
Rondon, S., Sassi, F. C., & de Andrade, C. R. F. (2013). Computer game-based and traditional learning method: A comparison regarding students' knowledge retention. *BMC Medical Education, 13*(1), 30.
Ronimus, M., Kujala, J., Tolvanen, A., & Lyytinen, H. (2014). Children's engagement during digital game-based learning of reading: The effects of time, rewards, and challenge. *Computers & Education, 71*, 237–246.
Sandberg, J., Maris, M., & Hoogendoorn, P. (2014). The added value of a gaming context and intelligent adaptation for a mobile learning application for vocabulary learning. *Computers & Education, 76*, 119–130.
Scoresby, J., & Shelton, B. E. (2011). Visual perspectives within educational computer games: Effects on presence and flow within virtual immersive learning environments. *Instructional Science, 39*(3), 227–254.
Taylor, J. A. (2003). Managing staff development for online education: A situated learning model. *Journal of Higher Education Policy and Management, 25*(1), 75–87.
Tsai, Y. L., & Tsai, C. C. (2018). Digital game-based second-language vocabulary learning and conditions of research designs: A meta-analysis study. *Computers & Education, 125*, 345–357.
Tsai, F. H., Tsai, C. C., & Lin, K. Y. (2015). The evaluation of different gaming modes and feedback types on game-based formative assessment in an online learning environment. *Computers & Education, 81*, 259–269.
Van Eck, R., & Dempsey, J. (2002). The effect of competition and contextualized advisement on the transfer of mathematics skills a computer-based instructional simulation game. *Educational Technology Research & Development, 50*(3), 23–41.
Vandercruysse, S., Vandewaetere, M., Cornillie, F., & Clarebout, G. (2013). Competition and students' perceptions in a game-based language learning environment. *Educational Technology Research & Development, 61*(6), 927–950.
ter Vrugte, J., de Jong, T., Vandercruysse, S., Wouters, P., van Oostendorp, H., & Elen, J. (2015). How competition and heterogeneous collaboration interact in prevocational game-based mathematics education. *Computers & Education, 89*, 42–52.
Wang, J. H., Chen, S. Y., Chang, B., & Chan, T. W. (2016). From integrative to game-based integrative peer response: high ability versus low ability. *Journal of Computer Assisted Learning, 32*(2), 170–185.
Wang, L. C., & Chen, M. P. (2010). The effects of game strategy and preference-matching on flow experience and programming performance in game-based learning. *Innovations in Education & Teaching International, 47*(1), 39–52.
Whitton, N. (2010). *Learning with digital games: A practical guide to engaging students in higher education*. New York, NY: Taylor & Francis.

Wu, M., Liao, C. C. Y., Chen, Z.-H., & Chan, T.-W. (2010). Designing a competitive game for promoting students' effort- making behavior by virtual pets. *International Conference on Digital Game and Intelligent Toy Enhanced Learning*, 234–236. https://doi.org/10.1109/DIGITEL.2010.51.

Yang, J. C., Quadir, B., & Chen, N. S. (2016). Effects of the badge mechanism on self-efficacy and learning performance in a game-based English learning environment. *Journal of Educational Computing Research, 54*(3), 371–394.

Yen, Y. C., Hou, H. T., & Chang, K. E. (2015). Applying role-playing strategy to enhance learners' writing and speaking skills in EFL courses using facebook and skype as learning tools: A case study in Taiwan. *Computer Assisted Language Learning, 28*(5), 383–406.

Yu, F. Y. (2001). Reflections upon cooperation-competition instructional strategy: Theoretical foundations and empirical evidence. *The National Chi Nan University Journal, 5*(1), 181–196.

Yu, Z. G. (2018). Differences in serious game-aided and traditional English vocabulary acquisition. *Computers & Education, 127*, 214–232.

Zheng, R. (2010). Effects of situated learning on students' knowledge acquisition: An individual differences perspective. *Journal of Educational Computing Research, 43*(4), 467–487.

Zou, D., Huang, Y., & Xie, H. (2019). Digital game-based vocabulary learning: Where are we and where are we going? *Computer Assisted Language Learning*. https://doi.org/10.1080/09588221.2019.1640745.