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Single loop or double loop learning: English vocabulary learning performance and behavior of students in situated computer games with different guiding strategies

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A B S T R A C T

In this study, a situated computer game was implemented for engaging students in English vocabulary contexts. Furthermore, two test-item guiding approaches, the cloze and multiple-choice guiding strategies, were embedded in the game to serve as guidance for the students. To investigate the students' performance and behaviors of learning English vocabulary with different guiding strategies, two classes of students were included to learn with the two approaches. The experimental results showed that the students using the game with the cloze guiding strategy had significantly better learning achievement with higher cognitive load than those learning with the multiple-choice guiding strategy. Moreover, from the behavioral pattern sequential analysis, it was found that the game with cloze item guidance engaged the students in both single loop situated learning (i.e., repeatedly trying to deal with the same set of learning tasks) and double-loop situated learning (i.e., trying to deal with the same learning tasks after reviewing relevant materials and adjusting their learning strategies). On the other hand, those using the game with multiple-choice item guidance only performed single-loop situated learning during the gaming process, meaning that they seldom reviewed relevant materials or adjusted their learning strategies before trying to solve the same learning tasks again. The findings imply that it is worth considering different test-item guiding approaches when developing English vocabulary games for future studies and applications.

1. Introduction

Globalization is considered as one of the important issues in education (National Education Association, 2010; Wan Yee, 2010). In order to achieve this goal, the global language, English, has become an essential ability, which is the reason why nations around the world are eager to develop children's English ability from an early age. In Taiwan, children start taking formal English courses from 3rd grade according to the education curriculum outline published by the Ministry of Education (National Academy for Education Research, 2014). In English courses, vocabulary has a crucial influence on students' learning outcomes. As indicated by August, Carlo, Dressler, and Snow (2005), who compared the learning performances of English

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language learners and English-only students, English language learners often suffer from a lack of vocabulary, which significantly influences their comprehension of texts as well as their learning motivation.

Besides, previous studies have reported that there is usually a gap between a student's "active vocabulary knowledge" and "passive vocabulary knowledge" (Fan, 2000; Schmitt, 2014), where the former refers to the knowledge that enables students to express their thoughts on their own with the vocabulary learned, while the latter refers to the knowledge that only enables students to comprehend the meanings of the vocabulary. With low active knowledge, students might experience difficulties conveying their opinions. Those learners who study English as a second or foreign language usually have double, triple, or even more passive than active vocabulary knowledge; therefore, they may know and understand what they read or see, but it is uncertain that they have the ability to express or form the same statements as they read in an article. One of the purposes of learning a language is to develop students' ability to convey their thoughts (Schmitt, 2014). Therefore, it is essential to cultivate their active vocabulary knowledge to assist them to communicate.

One important factor to stimulate students' language learning is to provide them with a learning context which lets them engage in an environment full of the learning targets. Collentine and Freed (2004) stated the importance of context for language learning. However, it is difficult to provide enough context for students to learn in the classroom. Therefore, to create an environment for students to learn has become an alternative option, and digital games can fulfill this need. In digital games, any situation can be created. Besides, digital games have also been confirmed as being an effective learning tool, and can improve students' learning performance as well as their motivation (Hung, Huang, & Hwang, 2014).

Laufer and Paribakht (1998) indicated that most vocabulary tests adopt multiple-choice items as a way of testing students' ability. It is even more common to see this kind of test item in an educational game. However, using multiple-choice items might make students get used to this way of learning, which may hinder the expression of their ideas because they do not have enough active vocabulary knowledge. Therefore, in this study, another assessment method, cloze test items, was also provided to serve as a guiding strategy. Cloze test items can prevent students from guessing to earn points, and can cultivate their active vocabulary knowledge since no candidate answers are provided for them to choose from. Therefore, in cloze test item-based learning activities, although certain learning materials are provided for the students to learn within the gaming context, it is possible that they would respond to the questions with answers that are not included in the provided learning materials.

To evaluate the effectiveness of the proposed approach, a situated computer game with different test-item guiding strategies has been developed and applied to an elementary school English course to explore the effects of the game on the learning performance and behavior of the students who are guided with the different strategies.

2. Literature review

2.1. Situated learning

Situated learning, as defined by Lave and Wenger (1991), aims to transfer the learning that might happen in the classroom to real scenes, and to put students in certain situations. Herrington and Oliver (1995) also stated that the critical characteristic of employing situated learning in teaching is to offer a real context, which means an authentic environment. Brown, Collins, and Duguid (1989) also pointed out that the authentic environment is not limited to outdoor learning activities; on the contrary, if an indoor learning activity can bring the same effects as an outdoor learning activity, it can also be seen as an authentic environment.

Due to the time and space constraints, it would be easier for teachers to create a learning environment with authentic contexts in which students are allowed to practice and apply the knowledge they have learned. Eventually, through situated learning, it is expected that the students would be able to connect their prior knowledge with newly gained knowledge and further apply it in real-world environments (Sung, Hwang, & Yen, 2015). Therefore, the purpose of situated learning is to develop students' ability of applying the knowledge gained in school in real-world contexts, and so the provision of learning contexts has become an essential way of enabling students to experience what they might encounter in their daily lives.

In the past decades, the situated learning approach has been widely adopted by many researchers. Anderson, Reder, and Simon (1996) mentioned in their review study that much research has used situated learning in mathematics for improving students' learning experience by combining what is learned in class with real world applications to assist them in using their knowledge in the workplace. In recent years, owing to the advancements in computer and multimedia technologies, situated learning has also been used in other courses. For instance, Chou et al. (2012) developed an educational computer game to situate elementary school students in an earthquake situation to instruct them how to react when faced with an earthquake. Most of the students felt that through the game, they knew more about the escape procedures and what should be noted in an earthquake, compared to only textbook instruction. Besides, Chen and Lin (2015) adopted situated learning and applied it in a game to teach Chinese poetry to engage the students in the situation and to let them feel what the poets felt while writing the poems. The students using the game performed much better than those students receiving traditional narrative instruction, implying that situated learning is beneficial for students' learning.

On the other hand, scholars have indicated that situating students in authentic contexts is very important for language education (Collentine & Freed, 2004). People generally learn their mother tongue better than second or foreign languages since it is not learned via instruction from books, but rather from environmental contexts. In the language learning activity conducted by Piirainen–Marsh and Tainio (2009), the learning context was provided as a collaborative game. In the game, the students learned how to organize, construct, and actively engage in vocabulary learning. Nagy (1995) also indicated the importance of context in vocabulary learning. A word needs context for the meaning to be precisely understood, and people usually learn a word from its context. Sternberg (1987) stressed that the best way to improve people's vocabulary learning is to let them learn in context. The study of Huang and Eslami (2013) further confirmed this point. They observed the learning approaches of students with advanced English proficiency and found that those students usually learned word usage from the relevant contexts instead of from dictionaries.

2.2. Digital game-based learning

As Prensky (2007) defined, digital game-based learning combines education and games, and uses a digital platform as the medium. While using this approach, people are situated in the gaming contexts, which could be quite real or totally fantasy, and would be more willing to spend time playing the game. Such engagement and motivation are what researchers and educators hope that students can experience in learning (Prensky, 2003). Chen and Hwang (2014) also pointed out the importance of motivation in learning, and digital game-based learning can motivate students to play games.

According to a review study by Hwang and Wu (2012), digital game-based learning has been applied in many different subjects and can indeed improve students' learning results in some aspects. Romero, Usart, Ott, Earp, and de Freitas (2012) not only adopted digital game-based learning, but also incorporated collaborative learning in their experiments to improve students' learning. In Papastergiou's research (2009), digital game-based learning was used to teach students computer science, and it was found that the students using this form of learning performed much better than those students learning with the traditional way in terms of both their learning achievement and learning motivation. Besides, Hung et al. (2014) also applied digital game-based learning to instruct students in mathematics within a game-based learning environment, and the results showed that it can effectively promote students' learning achievement and motivation.

Digital game-based learning has been widely adopted in the field of language learning. By integrating the advantages of digital game-based learning, most research has reported positive results. For example, Neville, Shelton, and McInnis (2009) integrated the role-playing feature to immerse players in learning German vocabulary, reading, and culture, and found that the approach benefited the learners' learning achievement. Yip and Kwan (2006) also reported the positive effects of digital game-based learning by comparing the learning performances of the students who learned with an educational computer game and those who learned with transitional instruction in an English vocabulary learning course.

While digital games have long been praised as an effective way for students to learn, it should be noted that not all games with educational content benefit students' learning (Van Eck, 2006). They need to be carefully designed with a certain degree of educational purpose, not just purely for entertainment (Johnson, Vilhjálmsson, & Marsella, 2005). More importantly, it would benefit students more if instructional strategies could be integrated into digital games to bring better learning effects and learning behaviors (Hsiao, Chang, Lin, & Hu, 2014; Sung & Hwang, 2013). Thus, in this study, a digital game was developed by integrating different test item-based guiding strategies to engage students in situated English vocabulary learning.

3. Development of the english situated computer game

3.1. Situated computer game learning model

The purpose of implementing situated computer games is to situate students in the gaming contexts that are related to the learning content so that they are able to learn meaningfully and enjoyably. In this study, a situated computer game-based learning model is proposed by considering possible behaviors students might perform while learning with situated computer games, as shown in Fig. 1. The model has been modified from the problem-based gaming model proposed by Kiili (2007) by adding the theory of "double loop learning" proposed by Argyris (1991). "Single-loop learning" refers to the repeated attempt to deal with the same problem without trying to find better methods or to know more about the learning task, while

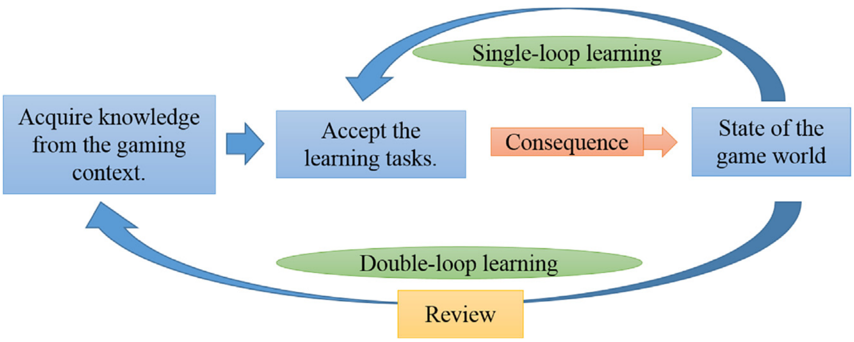

Fig. 1. Situated computer game learning model.

"double loop learning" emphasizes the use of an additional learning stage to acquire more knowledge or find better problem-solving methods during the learning process.

In a situated computer game, students might learn through the following process. Initially, they might acquire the knowledge embedded in the learning environment. Later, they might face some challenges, which can bring a sense of excitement to the game. As Van Eck (2006) indicated, what makes game-based learning effective is the provision of opportunities for students to practice what they have learned when they are situated in the gaming contexts that might lead to various gaming results. The students might successfully complete the gaming tasks or fail to deal with the gaming missions. When facing the same gaming tasks, students could have diverse learning behaviors; for example, they might try a task repeatedly with or without attempting to seek help.

The process of looking for help in a situated computer game is usually relevant to students' reviewing behavior. Review can be seen as a part of the learning cycle. The importance of reviewing is investigated by many researchers trying to find a better way for students to review the knowledge gained in class more efficiently (Hwang, Chen, Shadiev, & Li, 2011). For example, Kobayashi (2006) compared the students learning with an integrated note-taking and reviewing strategy, and those learning with only note-taking. It turned out that the former performed much better than the latter, implying how crucial reviewing behaviors are in the learning process.

Experiencing the process of reviewing has effects on students' behavior in a game. Before performing the reviewing action, students can choose to keep using the same learning strategy and accept the learning tasks again, which does not yield any change in behavior and is categorized as single-loop learning. On the other hand, after going through the review process, students might take their learning tasks into consideration to alter their learning strategies or answers, which is categorized as double-loop learning, as indicated by Kiili (2007).

In order to promote students' double-loop situated computer game learning behavior, two different test-item guiding strategies were used in the English situated computer game. Among various types of test items, only cloze and multiple-choice items were chosen to serve as the learning guidance. Multiple-choice items are the most common type of test item adopted in educational games, while cloze has received great attention due to its effects for second language learners, which researchers have made efforts to evaluate (Rankin & Culhane, 1969). The following sections introduce in more detail how these two types of guiding strategies were embedded in the game.

3.2. Structure of the learning system

The English situated computer game was created using the role-playing game development software, RPG Maker XP, developed by Enterbrain Incorporation. Two different test-item guiding strategies were adopted in the games to investigate if the different strategies would affect the students' learning and bring about deeper learning behaviors. Moreover, the vocabulary embedded in the game was discussed and consensus was reached with an experienced teacher who had taught the participants for at least one semester.

When playing the game, the students' learning behaviors were automatically recorded by the learning system. The structure of the learning system is shown in Fig. 2.

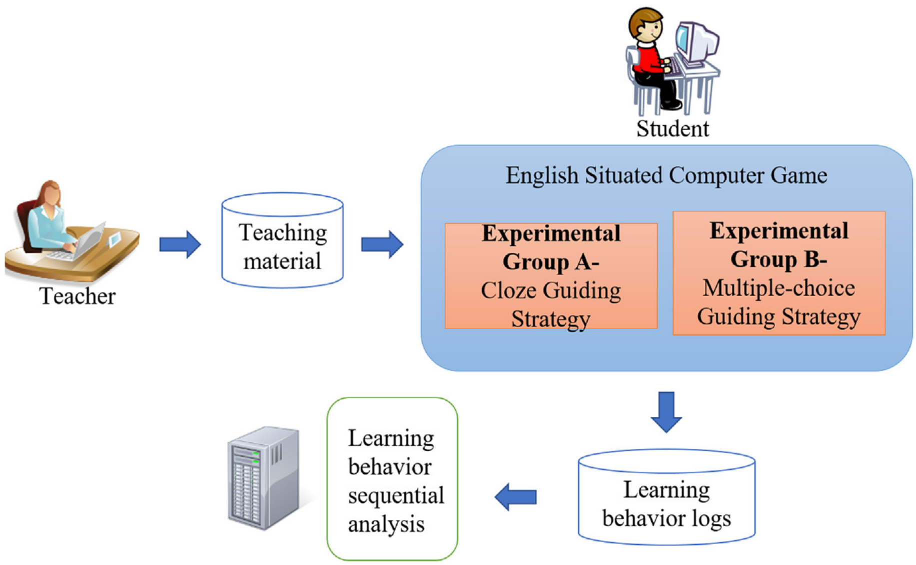

Fig. 2. Structure of the learning system.

3.3. Storyline and interface of the situated computer game

The players were first given the background story of the game to lead them into the gaming context. They were told that their parents were out for the whole day and they needed to do some household chores and run some errands for them. In order to do those household chores, they needed to know what cleaning equipment they could use, which led them to learn the vocabulary in the corresponding context, as presented in Fig. 3 (a). Besides, they were asked to run some errands in the supermarket, which guided them to learn in the corresponding context, as illustrated in Fig. 3 (b). While they were exploring in the context, vocabulary flash cards were shown and pronunciation of the words was provided. Following the gaming storyline, the students were guided to deal with daily life problems, such as "Clean the desk" or "Prepare breakfast." Fig. 4 shows the interfaces of the cloze (upper) and multiple-choice (lower) guiding strategies.

Furthermore, the students could seek help if they needed some assistance. For example, when facing a new question raised by the gaming system or failing to answer the question, they were encouraged to find answers on their own by approaching certain non-player characters to derive information about the game or the supplementary materials of the learning targets, as Fig. 5 shows. In particular, in the cloze guiding mode, no candidate set of answers was provided during the gaming process; therefore, seeking help from the gaming context could be the best approach for the students.

Fig. 3. Learning contexts in the home setting and the supermarket setting (a) Home setting (b) Supermarket setting.

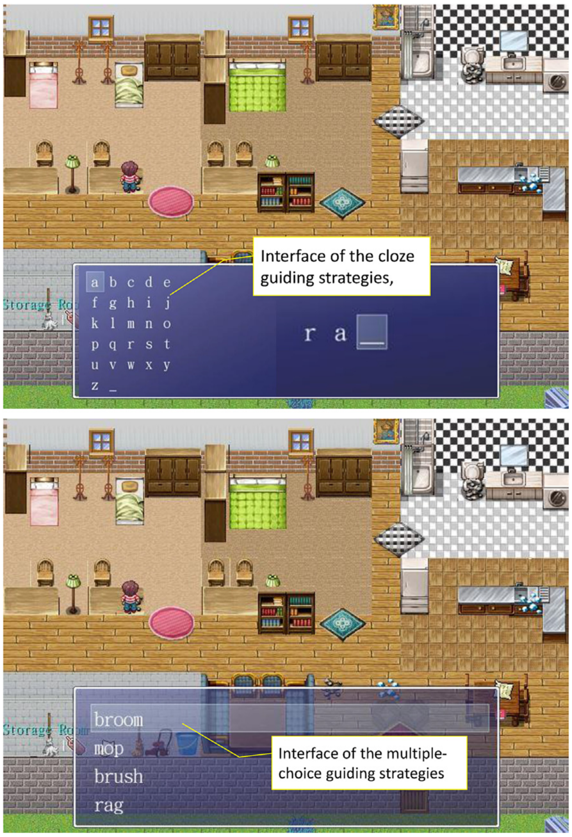

Fig. 4. Interfaces of the cloze and multiple-choice guiding strategies.

Fig. 5. Assistance embedded in the gaming system.

4. Experiment design

4.1. Participants

The subjects of this study were two classes of sixth graders of an elementary school located in Taipei City. All of the students were taught by the same instructor who had taught them for at least one semester. Before the experiment, they had no experience of using digital computer games as an approach to learning. One class with 23 students (10 females and 13 males) was assigned to use the English situated computer game with the cloze guiding strategy, while the other class with 27 students (14 females and 13 males) learned with the English situated computer game with the multiple-choice guiding strategy.

4.2. Experimental process

The overall procedure of this study is presented in Fig. 6. One class of students was assigned to experimental group A, while the other was experimental group B. Before the learning activity, the students took the pre-test. Then, they were instructed to play the game, and the vocabulary was demonstrated in the gaming scenes to provide them with the necessary prior knowledge. Each student was equipped with one computer to explore the learning content for 50 min. The vocabulary embedded in the game was designed with the function of pronouncing the words so the students would hear the word every time they learned a new word in the context in order to reinforce their memory.

During the learning activity, the students in experimental group A learned with the English situated computer game with cloze guiding strategy, which provides fewer clues for the learning tasks, and hence the students needed to explore to find the answers to the questions because of the test item design. That is, they needed to observe the context of the game, such as the goods for sale in the supermarket, to fully understand the usage of the words. On the other hand, the students in experimental group B learned with the English situated computer game with the multiple-choice guiding strategy, which provided a set of possible answers to the questions raised in the learning tasks, and hence the students could focus more on the candidate solutions when searching for the answers. During the gaming process, the game automatically recorded the students' learning behaviors, which could then be used for later behavioral pattern analysis.

After the learning activities, the two groups of students were asked to complete the cognitive load questionnaire. Besides, three students with different learning achievement levels (i.e., low, medium and high English listening achievements) were chosen from each class for in-depth interviews in order to understand their perceptions of this way of learning, and to see what students with different levels of learning achievement would feel while playing.

4.3. Measuring tools

The pre-test was designed by an experienced teacher with over five years of teaching experience and was used in the students' midterm exam. The purpose of the test was to evaluate their prior knowledge. The pre-test consisted of 6 listen and check items, 5 listen and number items, 6 listen and mark items, 8 listen and match items, 14 look, read, and write items, 3 unscramble the word items, 4 read and check items, 2 write the answer items, 6 read and match items, and 3 look and write items. For instance, in the look, read, and write items, the students were asked to fill in the verb according to the gaming context by referring to a set of candidate verbs. In the unscramble the words items, the students were asked to make a sentence based on the given components of the sentence. As for the post-test, there were two parts in the English achievement post-test, including 10 selection items and 10 fill-in-the-blank items. For instance, the students were given a

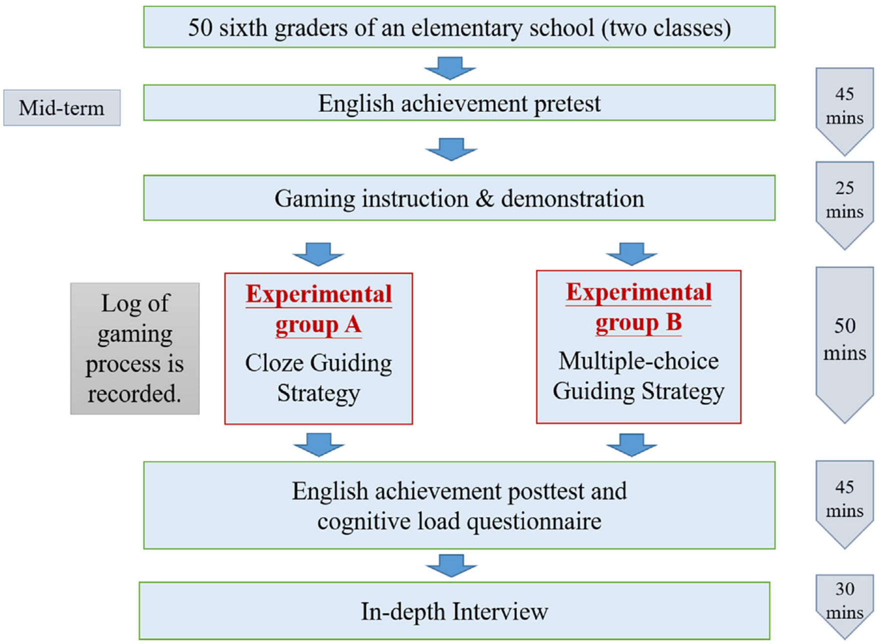

Fig. 6. Experimental procedure.

picture and were asked to select the vocabulary corresponding to the picture from the candidate items. Both the pre-test and post-test had a perfect score of 100.

The cognitive load questionnaire proposed by Hwang, Yang, and Wang (2013) was adopted, with a total of 8 items, of which 5 were for mental load and 3 for mental effort. For example, one of the items is "The learning content in this learning activity was difficult for me", and for mental effort, one of the items was "During the learning activity, I need to put much effort into following the way of instruction or learning content presentation." A 6-point Likert scale was adopted, where 1 represented "Strongly disagree" and "6" represented "Strongly agree." The Cronbach's alpha value of mental load was 0.86 and for mental effort it was 0.85.

In addition, to explore whether the different guiding approaches affected the students' learning behaviors, certain learning behaviors were automatically coded and recorded in the game. The code, its definition, and the examples are all presented in Table 1. In order to ensure the validity of the coding scheme, three experts who had experience of adopting game-based learning in teaching and learning behavioral pattern analysis were asked to examine the suitability of the codes and definitions in the proposed games.

5. Experimental results

5.1. Learning achievement

The one-way analysis of covariance (ANCOVA) was employed using the pre-test scores of learning achievement as the covariate, the learning approach (cloze guiding strategy or multiple-choice guiding strategy) as the independent variable, and the post-test scores of learning achievement as the dependent variable.

Before conducting the analysis of covariance (ANCOVA), it was necessary to check that there was no violation of the assumption of homogeneity of regression. There was no significant difference in the homogeneity of regression ($F = 1.64$, $p = 0.21 > 0.05$), indicating that the two groups of students had equivalent prior knowledge of the vocabulary before the learning activity.

After the experiment, the two groups of students took a post-test of English vocabulary in order to explore the learning differences as a result of the two different treatments. Then, the analysis of covariance (ANCOVA) was performed on the post-test scores. As shown in Table 2, the results show that the mean score and adjusted mean score of the cloze guiding strategy group are 88.91 and 89.63 respectively, while the mean score and adjusted mean score of the multiple-choice guiding strategy group are 83.33 and 82.73 respectively. Excluding the impact of the pre-test score on the post-test, there was a significant difference between the two groups ($F = 11.69$, $p = 0.001 < 0.01$). The eta squared effect size is 0.2, meaning a small to medium effect size. The students learning with the cloze guiding strategy showed better learning results than those learning with the multiple-choice guiding strategy. This implies that giving adequate practice during the learning process can help students learn better.

5.2. Cognitive load

To investigate the effects of incorporating different guiding strategies into the English situated computer game on the students' cognitive load, the independent sample *t*-test was adopted. As shown in Table 3, the mean values and standard deviations of the cognitive load in the game with the cloze guiding strategy are 2.29 and 0.79, while those in the game with the multiple-choice guiding strategy are 1.53 and 0.49. The *t*-test result ($t = 4.17$, $p < 0.001$) shows that there was a significant difference between the cognitive load of the two groups of students. From the statistics, it is indicated that students learning with the game with the cloze guiding strategy felt that the learning content and the way to complete the learning tasks were more difficult. This may be because they had to go through the process of reviewing the learning contents in the context, which, compared to the game with the multiple-choice guiding strategy, required much more effort. Furthermore, Cohen (1988) indicated that a Cohen's d value greater than 0.8 represents a large effect size, indicating that the experimental result is reliable.

Table 1
The coding scheme and the definition for learning behaviors in the game.

Code	Phase	Description
L	Read the learning contents.	Students learn the vocabulary from the corresponding contexts.
I	Read the gaming information.	Students read the information about how to play the game.
A	Accept the learning missions.	Students agree to answer the question.
S	Reject the learning missions.	Students reject to answer the question.
O	Complete the learning missions.	Students correctly answer the question.
X	Fail the learning missions.	Students give the wrong answer.
G	Look for gaming hints.	Students ask and read how to play the game.
H	Look for learning help.	Students read the summary of the learning contents.
T	Change the scenes.	Students go to another scene.
M	Take the props in the game.	Students fetch those props needed in the game.

Table 2
ANCOVA result of the learning achievement post-test of the two groups.

Group	*N*	Mean	S.D.	Adjusted mean	Std error	F
Cloze guiding strategy	23	88.91	14.92	89.63	1.48	11.69**
Multiple-choice guiding strategy	27	83.33	11.60	82.73	1.37	

**$p<0.01$.

Table 3
The *t*-test result of the cognitive load scores of the two groups.

Group	*N*	Mean	S.D.	*t*	*d*
Cloze test items	23	2.29	0.79	4.17***	1.16
Multiple-choice test items	27	1.53	0.49		

***$p<0.001$.

5.3. Behavioral pattern analysis

During the learning activity, the students' learning behaviors were all recorded automatically in the learning system. Besides, sequential analysis was adopted to explore if the students' learning behaviors would be affected by different test-item guiding strategies in the same English situated computer game design.

After the sequential analysis, the significance of which behavior is followed by another can be determined. There were 23 students who performed a total of 2340 behaviors in the game with the cloze guiding strategy group, and 27 students who performed a total of 2349 behaviors in the game with the multiple-choice guiding strategy group. All the behaviors were processed with sequential transition matrix calculations, which are presented in Tables 4 and 5. In these two tables, the row means the starting behavior and the column means the consequent behavior. A Z-score greater than 1.96 implying that the consequent relationship between the two behaviors is significant (Bakeman & Gottman, 1997; Bakeman & Quera, 2011). For example, for the starting behavior L (i.e., "Read the learning content"), the Z-scores for L A (i.e., "Accept the learning missions") and L M (i.e., "Take the props in the game") are larger than 1.96, and hence are marked with a "*" to point out the significance of the sequential relationship.

Table 4 shows the Z-score results of the sequential analysis of behavior in the game with the cloze test item group. There are 29 behaviors reaching a significant difference. Fig. 7 presents a transition diagram of the learning behaviors with significant consequent relationships in the game with the cloze guiding strategy.

Table 5 shows the Z-score results of the sequential analysis of behavior in the game with the multiple-choice guiding strategy group. There are 25 behaviors reaching a significant difference. Fig. 8 presents a transition diagram of the learning behaviors with significant consequent relationships in the game with the multiple-choice guiding strategy.

To further investigate the effects of different guiding strategies on the students' gaming behaviors, the significant behavioral transitions of the two groups were compared. Fig. 9 shows those significant behavioral transitions in the game with the cloze guiding strategy but not in that with the multiple-choice guiding strategy. It is found that when the students encountered a learning task they answered wrongly (X), they would seek help (H). Then, after getting help (H), they would accept the learning task again (A). As the cloze guiding strategy prevents students from guessing the answers, they are forced to try to find the right answer.

On the other hand, Fig. 10 shows those significant behavioral transitions in the game with the multiple-choice guiding strategy but not in that with the cloze guiding strategy. When the students faced the situation of wrongly answering a

Table 4
The results of sequential analysis of behaviors in the game with the cloze guiding strategy.

Z-score	L	I	A	S	O	X	G	H	T	M
L	0.84	−1.74	7.89*	−0.26	−10.59	−5.80	−1.67	−3.12	−1.95	15.10*
I	−1.53	32.17*	−5.42	−1.29	−4.88	−2.68	4.13*	−0.49	1.61	0.85
A	−10.80	−5.72	−22.14	−4.29	35.59*	19.51*	−3.71	−6.98	−7.09	−5.94
S	0.61	−1.16	−0.03	2.07*	−3.83	−2.10	−0.80	12.67*	−0.01	−1.70
O	5.20*	−2.50	15.90*	0.07	−14.25	−7.81	1.43	−3.20	0.24	−2.04
X	10.41*	−2.41	−1.68	9.56*	−7.93	−4.35	1.02	10.04*	−3.03	−2.55
G	2.62*	−0.92	−2.18	−0.80	−3.02	−1.65	5.91*	4.82*	1.60	1.06
H	1.46	−0.18	3.74*	0.22	−5.11	−2.80	1.90	6.50*	−1.40	−2.27
T	1.99*	0.34	−4.61	−1.42	−5.35	−2.93	−0.17	−0.19	26.63*	−2.38
M	−3.97	−1.98	13.43*	−1.10	−6.52	−3.57	−0.57	−1.84	−2.49	0.19

*$p<0.05$.
L: Read the learning contents; I: Read the gaming information; A: Accept the learning missions; S: Reject the learning missions.
O: Complete the learning missions; X: Fail the learning missions; G: Look for gaming hints; H: Look for learning help.
T: Change the scenes; M: Take the props in the game.

learning task (X), they just accepted the same learning task again (A). The behavior of searching for help (H) only followed the transition of the gaming scene (T), which is quite irrelevant to the learning part of the game. This shows that the students in the game with the multiple-choice guiding strategy focused on the gaming part more than on the learning part.

Furthermore, to explore the single-loop and double-loop situated computer game learning, only the relevant behaviors, L, A, S, X, O, and H, were chosen to investigate if the two different test-item guiding strategies affected the students' learning behaviors. Fig. 11 presents the transition diagram of those learning-related behaviors. In the game with the cloze guiding strategy, the students tended to learn the learning contents first (L), and then they would accept the learning tasks (A), which would lead to either a correct answer (O) or a wrong answer (X). If they correctly answered the task (O), they might continue on to the next one (A↔O) and this would result in single-loop situated computer game learning. On the other hand, if the students gave the wrong answer (X), they might look for help (H), which forms double-loop situated computer game learning. The students' learning strategy was changed by reviewing the learning contents again. If they wrongly answered a task (X), they might also choose not to accept the learning task (S) and later they would also seek help to let them better understand the contents (H). Besides, their repeated behaviors of reviewing the learning contents were also observed in the learning process (H↔H).

In the game with the cloze guiding strategy, the students' single-loop situated computer game learning behaviors only happened when they correctly answered the learning tasks (A). Otherwise, they would prefer to review or read the learning contents again (H) to reinforce their memory of the learning content.

Fig. 12 shows the transition diagram of those learning-related behaviors which happened in the game with the multiple-choice guiding strategy. In this game, only students' single-loop situated computer game learning behaviors were observed. They tended to accept the learning tasks first (A) and then, no matter whether their results were wrong (X) or right (O), they would take the learning tasks again (A↔X) (A↔O). They might go back to the start and read the learning contents again but after that there was no significance found between the actions of reading the learning contents (L) and accepting the learning tasks (A), which means that the relation of these two actions is low.

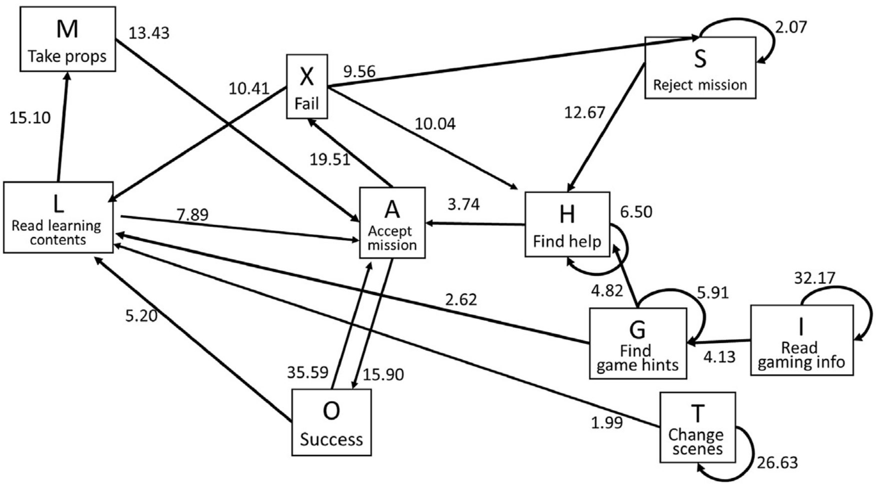

Fig. 7. The behavioral transition diagram of the students in the game with the cloze guiding strategy.

Table 5
The results of the sequential analysis of behaviors in the game with the multiple-choice guiding strategy.

Z-score	L	I	A	S	O	X	G	H	T	M
L	7.94*	−3.46	−1.10	−0.48	−9.13	−4.64	−2.14	−1.90	−2.46	20.71*
I	1.77	36.58*	−8.41	−1.02	−7.04	−3.58	0.98	1.47	−1.29	−0.58
A	−10.00	−7.60	−26.09	−2.54	38.78*	19.71*	−4.62	−4.40	−8.39	−8.32
S	1.22	−0.93	1.54	2.52*	−2.44	−1.24	1.22	1.50	−0.99	0.72
O	1.67	−4.49	22.39*	−1.83	−16.55	−8.41	1.74	−0.30	0.82	−3.42
X	4.74*	−2.55	9.84*	4.95*	−8.58	−4.36	−0.90	−1.79	−3.16	0.28
G	1.16	0.00	0.07	1.28	−3.86	−1.96	3.69*	6.91*	1.86	−0.02
H	−0.80	−1.37	−2.44	−0.52	−3.62	−1.84	6.49*	15.66*	5.10*	−0.43
T	0.30	−1.21	−3.44	1.24	−6.67	−3.39	3.26*	0.92	25.25*	−2.79
M	−0.71	−2.66	12.53*	1.66	−7.99	−4.06	−0.11	−1.01	−3.25	0.52

*$p<0.05$.
L: Read the learning contents; I: Read the gaming information; A: Accept the learning missions; S: Reject the learning missions.
O: Complete the learning missions; X: Fail the learning missions; G: Look for gaming hints; H: Look for learning help.
T: Change the scenes; M: Take the props in the game.

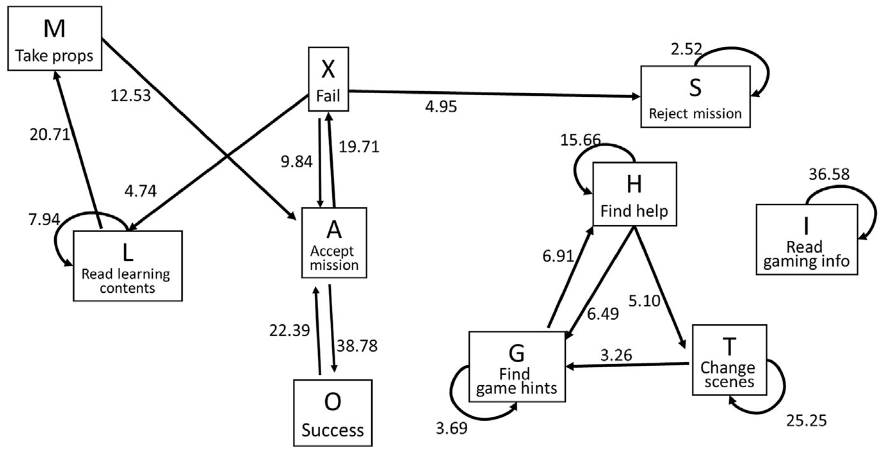

Fig. 8. The behavioral transition diagram of the students in the game with the multiple-choice guiding strategy.

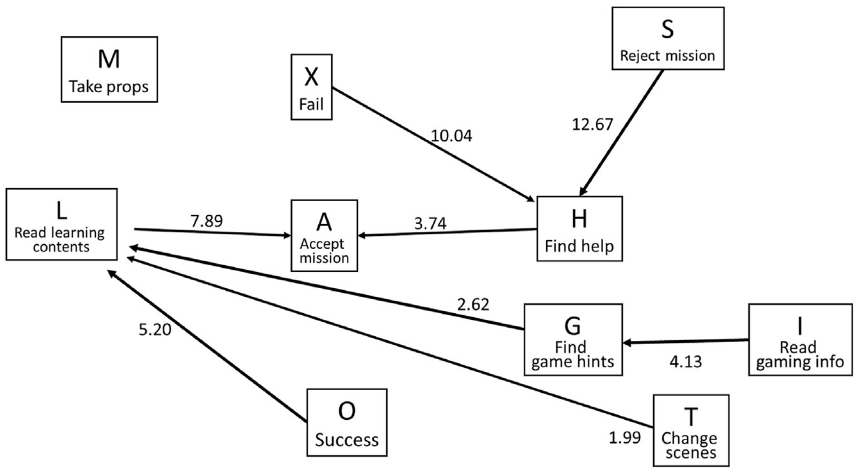

Fig. 9. Significant behavioral transitions in the cloze guiding strategy group not found in the multiple-choice guiding strategy group.

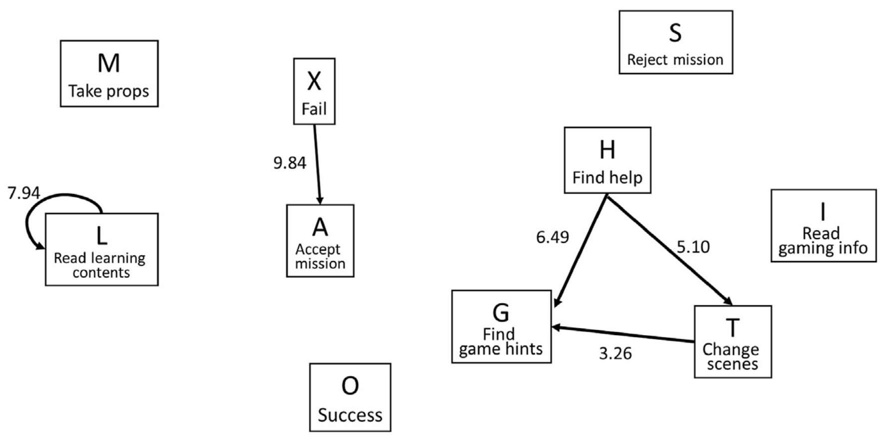

Fig. 10. Significant behavioral transitions in the game with the multiple-choice guiding strategy not found in that with the cloze guiding strategy.

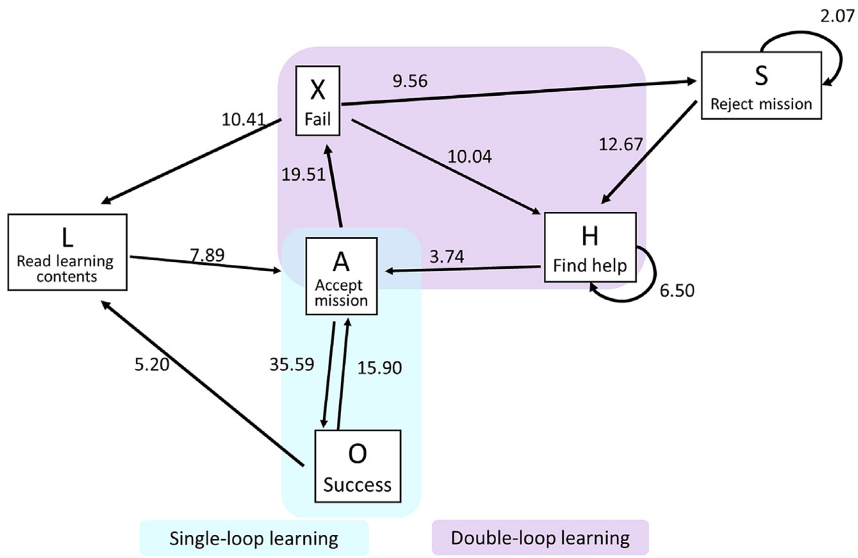

Fig. 11. The behavioral transition diagram of the students' learning situation analysis in the game with the cloze guiding strategy.

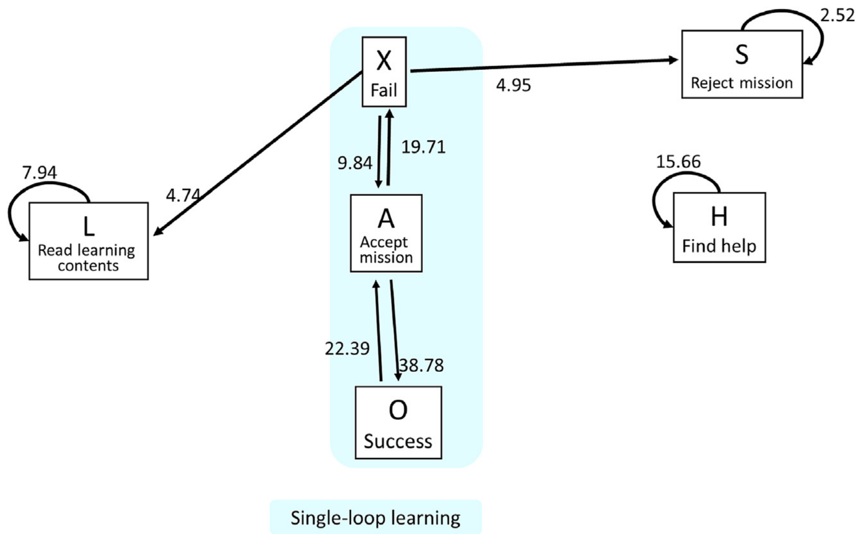

Fig. 12. The behavioral transition diagram of the students' learning situation analysis in the game with the multiple-choice guiding strategy.

In the game with the multiple-choice guiding strategy, the students might keep the "trial and error" loop because possible options were already provided for them to choose from. That is the reason why the behavioral patterns A↔X and A↔O were presented in the transitional diagram.

6. Discussion and conclusions

In the students' learning achievement, it was found that there was a significant difference between the effects of the two guiding strategies. Those students learning with the cloze guiding strategy outperformed those learning with the multiple-choice guiding strategy.

To further investigate the students' perceptions of the two different test-item guiding strategies, some students in both groups were selected for in-depth interviews. Several students learning with the multiple-choice guiding strategy pointed out that while answering the multiple-choice items, most of them just repeated guessing the answers until the task was completed, which is not that beneficial for learning. On the other hand, those learning with the cloze guiding strategy indicated that they would review what was learned in the context if they could not complete the task, which might reinforce their memory of the target vocabulary.

From the behavioral pattern sequential analysis, the learning behaviors of those students learning with the cloze guiding strategy did in fact coincide with what was said in the interviews. They reviewed the learning contents after they failed to correctly answer the learning tasks, which became the key point and which formed double-loop situated computer game learning. This is the crucial reason why they outperformed the other group. Besides, as was mentioned by the student learning with the multiple-choice guiding strategy, they just kept guessing the answers if they did not give the correct one. They would not review the learning contents again, which resulted in worse performance than the other group in terms of their learning achievement. Therefore, after analyzing the statistical and qualitative results, it can be inferred that a situated computer game for language learning with the cloze guiding strategy might be able to produce better learning achievement due to the feature of the test item guiding strategy.

However, the students learning with the cloze guiding strategy also showed higher cognitive load because such an approach requires more effort on the part of the students. Despite this fact, the students' learning achievement still improved. These results confirm the findings of several previous studies that engaged students in finding answers or solving problems on their own. For example, in the study of Hwang and Chang (2011), the students were asked to answer a series of questions on a field trip for a local culture course. Their experimental results revealed that those who received only hints during the learning activity showed higher cognitive load but better learning achievements than those who directly received the answers to the questions. On the other hand, Chu (2014) reported a quite different result in a similar learning activity; that is, the students who were asked to find answers to the questions on their own (i.e., receiving hints only) showed higher cognitive load and worse learning achievement than those who received help (i.e., the correct answer) after trying to answer a question. Chu (2014) further indicated the reason for the different results, that is, the different degrees of cognitive load caused by the number of learning tasks assigned to the students. The degrees of cognitive load were medium (around 4) and high (close to 7) on a 7-point rating scheme for the students in the studies of Hwang and Chang (2011) and Chu (2014), respectively. This suggests that, when using test item-based guiding strategies, it is critical to assign proper learning tasks with challenges that the students can manage.

For future studies, it is suggested that when designing digital game-based learning, designers can consider integrating diverse learning tasks to help students learn from different perspectives. Furthermore, whether the subject content is suitable to be presented in different kinds of test items is another issue worth discussing. To further investigate the effects of different test item-based guiding strategies, we plan to conduct follow-up experiments with larger sample sizes and subjects with different ages in diverse learning domains in the near future.

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References

Anderson, J. R., Reder, L. M., & Simon, H. A. (1996). Situated learning and education. *Educational Researcher, 25*(4), 5–11.
Argyris, C. (1991). Teaching smart people how to learn. *Harvard Business Review, 4*(2), 99–109.
August, D., Carlo, M., Dressler, C., & Snow, C. (2005). The critical role of vocabulary development for English language learners. *Learning Disabilities Research & Practice, 20*(1), 50–57.
Bakeman, R., & Gottman, J. M. (1997). *Observing interaction. An introduction to sequential analysis*. Cambridge, MA: Cambridge University Press.
Bakeman, R., & Quera, V. (2011). *Sequential analysis and observational methods for the behavioral sciences*. Cambridge, UK: Cambridge University Press.
Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18*(1), 32–42.
Chen, N. S., & Hwang, G. J. (2014). Transforming the classrooms: Innovative digital game-based learning designs and applications. *Educational Technology Research and Development, 62*(2), 125–128.
Chen, H. R., & Lin, Y. S. (2015). An examination of digital game-based situated learning applied to Chinese language poetry education. *Technology, Pedagogy and Education*, 1–16 (ahead-of-print).
Chou, Y. S., Hou, H. T., Yu, M. C., Lee, H. J., Wu, H. S., Yang, Y. T., et al. (2012, March). Running Tommy©: Developing a digital adventure game based on situated learning to promote learners' concepts of earthquake escape. In *Digital game and intelligent toy enhanced learning (DIGITEL), 2012 IEEE fourth international conference on* (pp. 156–158). IEEE.
Chu, H. C. (2014). Potential negative effects of mobile learning on students' learning achievement and cognitive load-a format assessment perspective. *Educational Technology & Society, 17*(1), 332–344.
Collentine, J., & Freed, B. F. (2004). Learning context and its effects on second language acquisition: Introduction. *Studies in Second Language Acquisition, 26*(02), 153–171.
Fan, M. (2000). How big is the gap and how to narrow it? an investigation into the active and passive vocabulary knowledge of L2 learners. *RELC Journal, 31*(2), 105–119.
Herrington, J., & Oliver, R. (1995). *Critical characteristics of situated learning: Implications for the instructional design of multimedia*.
Hsiao, H. S., Chang, C. S., Lin, C. Y., & Hu, P. M. (2014). Development of children's creativity and manual skills within digital game-based learning environment. *Journal of Computer Assisted Learning, 30*(4), 377–395.
Huang, S., & Eslami, Z. (2013). The use of dictionary and contextual guessing strategies for vocabulary learning by advanced English-language learners. *English Language and Literature Studies, 3*(3), 1.
Hung, C. M., Huang, I., & Hwang, G. J. (2014). Effects of digital game-based learning on students' self-efficacy, motivation, anxiety, and achievements in learning mathematics. *Journal of Computers in Education, 1*(2–3), 151–166.
Hwang, G. J., & Chang, H. F. (2011). A formative assessment-based mobile learning approach to improving the learning attitudes and achievements of students. *Computers & Education, 56*(4), 1023–1031.

Hwang, W. Y., Chen, N. S., Shadiev, R., & Li, J. S. (2011). Effects of reviewing annotations and homework solutions on math learning achievement. *British Journal of Educational Technology, 42*(6), 1016–1028.
Hwang, G. J., & Wu, P. H. (2012). Advancements and trends in digital game-based learning research: A review of publications in selected journals from 2001 to 2010. *British Journal of Educational Technology, 43*(1), E6–E10.
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.
Johnson, W. L., Vilhjálmsson, H. H., & Marsella, S. (2005, May)). Serious games for language learning: How much game, how much AI?. In *In AIED* (Vol. 125, pp. 306–313).
Kiili, K. (2007). Foundation for problem-based gaming. *British Journal of Educational Technology, 38*(3), 394–404.
Kobayashi, K. (2006). Combined effects of note-taking/-reviewing on learning and the enhancement through interventions: A meta-analytic review. *Educational Psychology, 26*(3), 459–477.
Laufer, B., & Paribakht, T. S. (1998). The relationship between passive and active vocabularies: Effects of languagelearning context. *Language Learning, 48*(3), 365–391.
Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge university press.
Nagy, W. E. (1995). *On the role of context in first-and second-language vocabulary learning*. Champaign, Ill: University of Illinois at Urbana-Champaign, Center for the Study of Reading.
National Academy for Education Research. (2014, November 12). *12-Year compulsory education curriculum outline*. Retrieved August 13, 2015, from Ministry of Education.
National Education Association. (2010). *Preparing 21st century students for a global society: An educator's guide to the "four Cs."*. Retrieved February 21, 2015, from the National Education Association.
Neville, D. O., Shelton, B. E., & McInnis, B. (2009). Cybertext redux: Using digital game-based learning to teach L2 vocabulary, reading, and culture. *Computer Assisted Language Learning, 22*(5), 409–424.
Papastergiou, M. (2009). Digital game-based learning in high school computer science education: Impact on educational effectiveness and student motivation. *Computers & Education, 52*(1), 1–12.
Piirainen–Marsh, A., & Tainio, L. (2009). Collaborative game-play as a site for participation and situated learning of a Second Language. *Scandinavian Journal of Educational Research, 53*(2), 167–183.
Prensky, M. (2003). Digital game-based learning. *Computers in Entertainment (CIE), 1*(1), 21. –21.
Prensky, M. (2007). *Digital game-based learning*. New York: McGraw-Hill.
Rankin, E. F., & Culhane, J. W. (1969). Comparable cloze and multiple-choice comprehension test scores. *Journal of Reading, 13*(3), 193–198.
Romero, M., Usart, M., Ott, M., Earp, J., & de Freitas, S. (2012). Learning through playing for or against each other? Promoting collaborative learning in digital game based learning. *Learning, 5*(2012), 15–2012.
Schmitt, N. (2014). Size and depth of vocabulary knowledge: What the research shows. *Language Learning, 64*(4), 913–951.
Sternberg, R. J. (1987). Most vocabulary is learned from context. *The Nature of Vocabulary Acquisition, 89105*.
Sung, H. Y., & Hwang, G. J. (2013). A collaborative game-based learning approach to improving students' learning performance in science courses. *Computers & Education, 63*, 43–51.
Sung, H. Y., Hwang, G. J., & Yen, Y. F. (2015). Development of a contextual decision-making game for improving students' learning performance in a health education course. *Computers & Education, 82*, 179–190.
Van Eck, R. (2006). Digital game-based learning: It's not just the digital natives who are restless. *EDUCAUSE Review, 41*(2), 16.
Wan Yee, C. (2010, November 2). *Teaching and learning of 21st century competencies in schools*. Retrieved August 13, 2015, from Ministry of Education, Singapore.
Yip, F. W., & Kwan, A. C. (2006). Online vocabulary games as a tool for teaching and learning English vocabulary. *Educational Media International, 43*(3), 233–249.