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The Impacts of Digital Games on Learning Academic English: A Prior Knowledge Perspective

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Abstract: In order to help learners improve the grammar concept of academic English, we developed an Academic English Competitive Solitaire Game (AECSG) where learners developed the understanding English academic writing via a problem-solving process. In addition, an empirical study was conduct to investigate how high prior knowledge (HPK)learners and low prior knowledge (LPK)learners reacted to the AECSG. The results indicated that HPK learners had better task scores and got fewer answer card errors in Task 1. Additionally, HPK learners favored to collect large-scaled information with the sentence hint so while LPK learners were keen to collect small-scaled information with the Chinese hint. On the other hand, no significant differences between HPK learners and LPK learners were found for the scores of Task 2. These finding suggested that practice could reduce the gap between LPK learners and HPK learners. In summary, the findings from this study contribute the understandings of how to develop personalized AECSG.

Keywords: competitive digital game-based learning, prior knowledge, experience

1. Introduction

Game-based learning (GBL) has been commonly used to improve English learning in educational settings (Hung, Yang, Hwang, Chu and Wang, 2018). In the meanwhile, most of scholars claimed that GBL was useful for student learning (Qian & Clark, 2016). For example, Zhonggen(2018) used a mixed-design research method to explore the impacts of serious game in English learning. Their results indicated that students who used an interactive serious game had significantly higher motivation than those who used the less interactive serious game and those who used a traditional approach. In addition, Fu , Lin, Hwang and Zhang (2019) proposed a mind mapping-based contextual gaming approach to improve university students' English writing performance. Their results indicated that their writing performance in English learning was indeed improved by this approach. Moreover, Hao, Lee, Chen and Sim(2019) developed a language learning mobile games to support seven-graders to learn English as a foreign language (EFL). Their results showed that this mobile game could make students have enjoyment and that their confidence in English learning could also be improved.

In spite of the aforementioned advantages, GBL is not always beneficial to students. For instance, DeHaan, Reed & Kuwanda (2010) found that students with a video game demonstrated poor performance. This is because video game caused cognitive load, which reduced their learning performance. In addition to cognitive load, past scholars also found that GBL had other disadvantages. For example, Koh, Kin, Wadhwa and Lim (2012) examined teachers' perception for GBL and problems with the use of GBL. Their results indicated that teachers were worry about game addiction because students lacked self-discipline in playing games. Additionally, Lai and Wen(2012) adopted an online role-playing game for elementary school students to learn English speaking. Their results showed that teachers were worried about the fact that students' eye-sight would get worse and that they spent too much time for using computers. Thus, GBL also had negative impacts.

The aforesaid conflicting results suggested that GBL may not suitable for all learners. Therefore, there is a need to examine the effects of individual differences in GBL, especially the impact of prior knowledge. For instance, Chen and Huang(2013) investigated how prior knowledge affected university students to use two GBL systems. One system provided procedural knowledge to help students learn

problem solving while the other system provided declarative knowledge to teach students to learn forensic science. Their result indicated that prior knowledge had positive influences on learning declarative knowledge while prior knowledge had negative effects on learning procedural knowledge. Furthermore, Zambrano, Kirschner, Sweller & Kirschner (2019) aimed to determine how prior knowledge affected student problem-solving, including individual learners and collaborative groups. Their results showed that high prior knowledge learners had better learning performance than low prior knowledge learners, regardless of individual or collaborative groups. On the other hands, Lee, Donkers, Jarodzka, & van Merriënboer (2019) used a medical simulation game to support medical professionals and medical students and investigated whether prior knowledge was an influential factor. Their results showed that their high prior knowledge students had relatively high accuracy in visual selection and lower cognitive load. In addition, they performed tasks faster than low prior knowledge students.

The results from aforementioned studies demonstrated that prior knowledge played an important role in GBL. Therefore, it is necessary to investigate the impact of prior knowledge on student learning in GBL. Consequently, this study had two aims. One aim was to develop an Academic English Competitive Solitaire Game (AECSG), which was applied to help students learn how to make meaningful English sentences while the other aim was to explore how prior knowledge affected student learning in the context of GBL.

2. Academic English Competitive Solitaire Game

The AECSG was implemented with the Unity3D and was applied to support students to learn Academic English. Accordingly, each learner and a virtual opponent needed to take turn make meaningful academic English sentences according to grammatical rules. More specifically, the learner and the virtual opponent were provided three academic sentences. Initially, only the middle word was visible in each sentence. For instance, there were 17 words in a sentence and the ninth word was visible. By doing so, learners could fill in English words by moving forward or backward (Figure 1). The AECSG possessed five major design features, which are presented below:

- Fair Treatment: There were two sets of cards, one of which could be selected by a learner while the other set was assigned to a virtual opponent. In each set, there were answer cards and non-answer cards (Table 1). The former presented a word associated with sentences that they made while the latter showed a reductant words unrelated to sentences that they made. Either the answer cards and non-answer cards were equally allotted into the learner and the virtual opponent so that there was fair treatment. On the other hand, the learner and the virtual opponent were equally provided 3000 points as basic task scores.
- Scaffolding Hints: During the gaming process, the AECSG provided a variety of scaffolding hints in order to reduce the learner's frustration, including the Chinese hint, Sentence hints and form of the Words. However, the learner's scores could be deducted (Table 2) when they used the scaffolding hints so that the reliance of the hints and tools could be minimized.
- Playing by Helping: To help learners solve problems during the gaming process, the AECSG provided two types of tools, which were the Helper and Exchange Cards. The Helper provided five cards, one of which presented a correct answer. By doing so, the range of the answer could be minimized and learners could get additional support. On the other hand, the Exchange Cards allowed the learner to swap a card with the virtual opponent when he/she thought that he/she did not have an answer card. These two types of tools allowed learners to get help in time so that their interest and motivation could be promoted. However, the learner's scores could be deducted (Table 2) so that he/she could not rely on them too much (Table 3).
- Learner Control: Learners were given freedom to control the order of the learning tasks. More specifically, they could decide which sentence they would like to start and where they would like to start based on their preferences. In addition, they could decide whether they would like to use hints and tools provided by the AECSG and which hints or tools they would like to use. By doing so, the AECSG could accommodate the preferences of various learners.
- Sense of competition: To make learners have the sense of competition during the gaming process, there were leaderboard and punishment mechanisms to enhance learner's motivation. The

leaderboard was applied to constantly show the scores that the learner and virtual opponent possessed (Figure 4). The punishment mechanism was that learners' scores could be deducted when they gave a wrong answer. In particular, their scores would have been deducted more if an answer card were not properly selected.

Table 1

The punishment mechanism in the AECSG.

Project	**Deduction**
Answer card error	-20 points
Non-answer card error	-10 points

Table 2

The costed points of each Scaffolding Hint in the AECSG.

Scaffolding Hints	**Costed Points**
Chinese translation	10 points
Ford of the word	10 points
Sentence hints	30 points

Table 3

The costed points of each tool in the AECSG.

Tools	**Costed Points**
Helper	50 points
Exchange cards	20 points

Figure 1. Overview of the AECSG

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3. Methodology Design

This study took s a quasi-experimental research method. The independent variables were students' prior knowledge and the dependent variables were learning performance and learning behavior.

3.1 Experimental subject

In this study, the participants were 14 research students from a university in the north Taiwan and all of them had computing skills and basic English skills.

3.2 Experimental procedure

The experiment was conducted once a week and lasted four weeks. At the beginning of the experiment, students were asked to use a laptop computer to connect to the wireless network to play with the AECSG. Subsequently, each student competed with a virtual opponent. More specifically, either the student or the virtual opponent needed to compete two tasks. Task 1 was conducted in the first week and the second week, and Task 2 was conducted in the third week and fourth week. In each task, they needed to take turn to make three meaningful academic English sentences without grammatical errors. Each sentence included 17 words. When students performed the task, their behavior was recorded in log files.

4. Results and Discussions

4.1 Task performance

In this study, we used an independent t-test to analyze task scores, which pertained to scores obtained from Task 1 and Task 2 (Table 4). More specifically, differences of the task scores between HPK learners and LPK learners were analyzed. The results indicated that there were significant score differences between HPK learners and LPK learners, including the Overview and Task 1. More specifically, the task scores of LPK learners were significantly lower than those of HPK learners. It might be due to the fact that reorganizing sentences was difficult for LPK learners, who did not have sufficient prior English knowledge. Thus, they might need some practices to improve their English abilities. After doing such practice, they could make some improvement. This might be the reason why no significant differences existed between HPK learners and LPK learners for the scores of Task 2. These results implied that the practice could reduce gap between LPK learners and HPK learners.

Table 4

Task scores between the HPK and the LPK

		M	**SD**	**t**	**p**
Overview	LPK	509.28	284.10	-3.531	.0009***
	HPK	762.85	252.28		
Task 1	LPK	475.00	302.98	-3.267	.003**
	HPK	766.43	139.92		
Task 2	LPK	543.57	270.74	-1.872	.0725
	HPK	759.29	335.52		

**p<.01, ***p<.001

4.2 Task Behavior

We used an independent t-test to analyze the number of hints used by the HPK learners and that by the LPK learners. The results indicated that there were significant differences, including the Overview or Chinese translation (Table 5). Regarding the Overview, the LPK learners used more hints than the HPK learners. This might be because the LPK learners encountered more difficulties than the HPK learners. Furthermore, the LPK learners more frequently used the Chinese hint than the HPK learners. This finding suggested that LPK learners did not know sufficient vocabulary so that they needed to use the Chinese hint to understand the meaning of words presented in each sentence However, no significant differences were found for remaining hints.

In addition, we also used an independent t-test to analyze the error frequencies of the answer and non-answer card. The results (t=3.043, p=.0036**) indicated that LPK learners (Mean=34.35, SD=25.56) significantly had more errors for the answer cards than HPK learners (Mean=17.39,

SD=14.71). In addition, the results (t= 4.227, p=.0001**) also showed that LPK learners (Mean= 5.82, SD=3.67) significantly had more errors for the non-answer cards than HPK learners (Mean=2.42, SD=2.13).

Table 5

Hints use between the HPK and the LPK

		M	SD	t	p
Overview	LPK	52	28.999	2.061	.0440*
	HPK	37.96	21.365		
Chinese translation	LPK	12.82	12.362	3.227	.0021*
	HPK	4.35	6.302		
Helper hint	LPK	10.07	6.164	0.910	.3669
	HPK	8.39	7.568		
Exchange cards	LPK	14.28	20.531	1.714	.0922
	HPK	7.28	6.726		
Form of the Words	LPK	0.10	0.315	1.029	.3081
	HPK	0.03	0.189		
Sentence hints	LPK	14.71	7.980	-1.245	.2184
	HPK	17.89	10.894		

*p<.05

4.3 Behavior Sequences:

The LSA was employed to explore behavior sequences that HPK learners and LPK learners demonstrated. Table 6 shows the behavioral coding of the sequence analysis, thereby generating the results of two sets of sequence analysis (Figure 2). More specifically, Figure 1 shows (a) behavior sequences that learners showed when performing Task 1, and (b) behavior sequences that learners showed when performing Task 2.

Table 12

The coding scheme of learning behavior.

Behavior	Codes	Description
Game Start	B	Start the game.
Correct	Y	Get the correct answer.
Wrong	W	Get the wrong answer.
Send cards	S	Send the selected card to the selected sentence position
Use sentence hints	L	Use the hint for display Chinese sentences in English
Use Exchange cards	Q	Use the hint for selected a card to exchange with a random answer card of the computer.
Use Helper hint	H	Use the hint for display a correct answer and four wrong answers, and have a chance to answer the error without penalty points
Use Chinese translation hint	D	Use the hint for explain the meaning and form of each word.
Use Form of the Words	R	Use the hint for explain the Form of the Words and form of each word.
Game Over	E	All of sentences are completely filled.

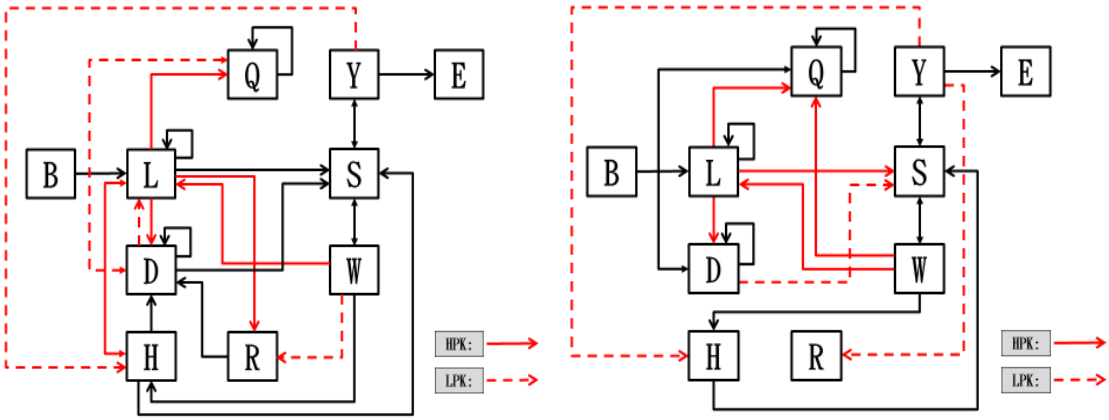

Figure 2. The behavioral transition diagram of Task 1 (left) and the diagram of Task 2 (right).

4.3.1 Task 1

The results from the LSA indicated that HPK learners and LPK learners demonstrated some similar behavior sequences when performing Task 1, i.e., B→L↔L, S↔Y→E, S↔W→H→S, R→D→S, and H→D↔D. The details are explained below.

- B→L↔L: When the game starts, learners repeatedly used the sentence hints.
- H→D↔D: Learners repeatedly used the Chinese translation hint after using the Helper hint.
- S↔W→H→S: Learners repeatedly sent the answer and got wrong answers before using Helper hint, and finally sent the answer.
- R→D→S: Learners used the form hint before using the Chinese translation hint, and finally sent the answer.
- S↔Y→E: Learners completed all of sentences after repeatedly getting correct answer.

The aforementioned findings suggested that learners were keen to use the sentence hint and the Chinese translation because they repeated used these two hints. The former was used at the beginning of doing the tasks (B→L↔L) while the latter was adopted after using the Helper (H→D↔D). In addition to combining with the Chinese hint, learners also used the Helper when they repeatedly sent the wrong answers(S↔W→H→S). On the other hand, they also used the Chinese hint and the form of the words together (R→D→S). Such findings implied that learners tended to use various hints together. The other interesting finding was that learners repeatedly got the correct answer when they nearly completed the tasks (S↔Y→E). In other words, time let them acquire some experience so that they could have better outcome in the end.

In addition to similarities, learners with the HPK and those with the LPK also demonstrated some different behavior sequences when performing Task 1. These different behavioral sequences are presented below.

- L→D (HPK) vs. D→L (LPK): HPK learners used the sentence hints before using the Chinese t hint while the LPK learners used the Chinese hint before using the sentence hints.
- L→Q (HPK) vs. D↔Q (LPK): HPK learners used the sentence hints before exchanging cards while LPK learners repeatedly switched between the Chinese hint and the card exchange.
- L→R (HPK) vs. None (LPK): HPK learners used the sentence hints before using the form of the words. Conversely, LPK learners did not have such behavior.
- W→L (HPK) vs. W→R (LPK): HPK learners got the wrong answer before using the sentence hints while LPK learners got the wrong answer before using the form of the words.
- L↔H (HPK) vs. Y→H (LPK): HPK learners repeatedly switched between the Helper hint and the sentence hints. However, LPK learners got the correct answer before using the Helper hint.

The aforementioned findings showed that HPK learners combined to use the sentence hint with various hints or tools, including the Chinese translation (L→D), form of the words (L→R), card exchange cards (L→Q) and Helper (L↔H) while the LPK learners combined to use the Chinese hint with other hints, including the sentence hint (D→L) and card exchange (D↔Q). Such behavior suggested that the former favored to use the sentence hint while the latter were keen to use the Chinese translation. Unlike the Chinese translation, which showed small-scaled information, the sentence hint could provide large-scaled information. The HPK learners are good at incorporating new information into old knowledge (Moreno & Mayer,1999) so they could make the best use of the large-scaled information provided by the sentence hint. Conversely, the LPK lacked sufficient knowledge so they tended to use small-scaled information obtained from the Chinese translation. Furthermore, the HPK learners sought help from the sentence hint after getting the wrong answer (W→L). Conversely, the LPK learners attempted to obtain support from the form of the words after getting the wrong answer (W→R). Additionally, the LPK learners did not use the Helper at the right timing. This was due to the fact that they used the Helper after getting the correct answer (Y→H). In other words, the LPK learners did not effectively use the hints.

4.3.2 Task 2

The results from the LSA indicated that HPK learners and LPK learners demonstrated similar behavior sequences when performing Task 2. i.e., B→L↔L, S↔Y→E, and S↔W→H→S. Such results were as same as those found in Task 1. These findings suggested that such behavior was necessary to learners. However, the following behavioral sequence was found for Task 2 only, i.e., Q↔Q→D↔D. The details are explained below.

- Q↔Q→D↔D: Learners repeatedly used the Exchange cards before repeatedly using the Chinese translation hint.

The aforementioned finding was slightly related to Task 1. When undertaking Task 1, learners would repeatedly use the Chinese hint after using the Helper hint (H→D↔D). On the other hand, they would repeatedly use the Chinese hint after repeatedly using the card exchange in Task 2 (Q↔Q→D↔D). In other words, learners moved to rely on the card exchange, instead of the Helper, when performing Task 2. Information provided by the Helper included five options, but using the card exchange could obtain a new word only. In other words, the Helper provided a broad range of information while the card exchange offered a specific range of information. This might be the reason why learners were keen to use the card exchange. However, learners might not know the new words from the card exchange so they had to use the Chinese hint to know the meanings of such a word. Therefore, learners tended to use the card exchange and Chinese translation hint together in Task 2.

Further to similarities, HPK learners and LPK learners demonstrated some different behavior sequences when performing Task 2. These different behavioral sequences are presented below.

- L→Q, L→D (HPK) vs. None (LPK): HPK learners used the sentence hints before using the card exchange or Chinese hint. Conversely, the LPK learners did not have such behavior.
- L→S (HPK) vs. D→S (LPK): HPK learners used the sentence hints before sending the answer. However, the LPK learners used the Chinese hint before sending the answer.
- W→L, W→Q (HPK) vs. Y→H, Y→R (LPK): HPK learners got the wrong answer before using the sentence hints or card exchange. However, LPK learners got the correct answer before using the Helper or the form of the words.

Like Task 1, HPK learners combined to use the sentence hints with various tools or hints, including the card exchange (L→Q) and Chinese hint (L→D). Furthermore, they used the sentence hints before sending the answer (L→S). Such behavior suggested that HPK learners were still keen to use the sentence hints which provided large-scaled information. On the other hand, LPK learners used the Chinese hint before sending the answer (D→S). In other words, LPK learners sill favored to use the Chinese hint when undertaking Task 2. The other interesting finding was that HPK learners and LPK learners used at different timing. More specifically, HPK learners used various tools or hints after

getting the wrong answer (W→L) (W→Q). In other words, they used various tools or hints at the right timing. However, LPK learners used such hints or tools after getting the correct answer (Y→H) (Y→R) so they did not use the various tools or hints at the right timing. In other words, HPK learners effectively used the hints and tools while LPK learners ineffectively used the hints and tools.

5. Conclusions

In this study, we aimed to examine how HPK learners and LPK learners reacted to the AECSG. The results showed that HPK learners had higher task scores and got fewer answer card errors than LPK learners in Task 1. Additionally, HPK learners favored to collect large-scaled information with the sentence hint while the latter were keen to collect small-scaled information with the Chinese hint. Furthermore, HPK learners could effectively use the hints at right timing while LPK learners could not effectively use hints at right timing. Therefore, the former had higher learning performance than the latter. However, no significant differences between HPK learners and LPK learners were found for the scores of Task 2. These finding suggested that LPK learners accumulated some experience so that the gap between HPK learners and LPK learners could be removed.

The finding from this study can contribute for the development of personalized AECS. However, there were several limitations in this study. First, the sample is small, so we need to extend the sample to provide more evidence in the future. Second, this study only investigated prior knowledge so future research can consider other individual differences, such as cognitive style and gender difference. The results from such future works will be helpful to develop personalized GBL systems.

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