Hayashi, Y., et al. (Eds.) (2017). Workshop Proceedings of the 25th International Conference on Computers in Education. New Zealand: Asia-Pacific Society for Computers in Education

The Impact of Prior Knowledge on the Usability Evaluation of a Competitive Game-Based Learning System Including Item Bank

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Abstract: By using a competitive game-based learning system including item bank, this study aims to explore the impact of prior knowledge on Nielsen, J's usability evaluation. The results show that it still needs improvement for "Aesthetic and minimalist design" and "Help and documentation". Regarding to prior knowledge, the average scores for high prior knowledge learners are significantly higher than those for low prior knowledge learners on "Visibility of system status", "Match between system and the real world", "User control and freedom", "Consistency", "Error prevention", "Recognition rather than recall", "Flexibility and efficiency of use" and "Help users recognize, diagnose, and recover from errors". It means that high prior knowledge learners are more satisfied than low prior knowledge ones.

Keywords: Prior knowledge, usability evaluation, competitive game, learning system, item bank

1. Introduction

Nowadays, information technologies has changed rapidly. Digital learning becomes a learning trend, because it can record students' learning situation on the learning system and help teachers to understand and manage students' learning portfolio (Hwang, Su & Chen, 2015). Prensky (2001) pointed out that game-based learning can improve learners' learning motivation, because games contains some elements those can attract learners, such as target, mechanism, interactivity and challenge, etc. (Dempsey, Lucassen, Haynes & Casey, 1996; Shi & Shih, 2015). Thus, many scholars found that game-based learning can effectively improve learning motivation to achieve good learning effectiveness (Chang, Hou & Chang, 2015; Chen, Wong & Wang, 2014; Hwang, Hsu, Lai & Hsueh, 2017). If games do not appropriately combine with teaching materials, learners may only focus on the games but ignore the teaching materials (Hsiao, Huang, Hong, Lin, & Tsai, 2010). On the other hand, competition is also a learning strategy that can effectively improve learning motivation and learning effectiveness (Yu & Liu, 2009; Atanasijevic-Kunc, Logar, Karba, Papic, & Kos, 2011). Learners will practice in order to win on the ranking, so appropriate competition is helpful for learning motivation and effectiveness (Davis & Rimm, 1985). However, competition may also have a negative impact on some learners' self-confidence. It may reduce learning motivation and affect learning effectiveness. Besides, human factors (gender, prior knowledge, cognitive style or learning style) are also the factors that affect learners' preference. Some scholars pointed out that different human factors have significant differences in the usability evaluation of learning systems (Hwang, Lee & Kuo, 2016; Hwang, Lee, Lai, Su & Cao, 2017). In these human factors, prior knowledge is the key factor to affect game-based learning (Chen & Huang, 2013). Therefore, this study will explore the impact of prior knowledge on the usability evaluation of a competitive game-based learning system including item bank.

2. Literature Review

2.1. Usability Evaluation

The maturity of system may affect the performance of learners (Virvou & Katsionis, 2008). Therefore, we used usability evaluation 10 user interface design guidelines proposed by Nielsen (1993; 1994) to understand the maturity of our system, because it is low cost and is the most popular method (Shieh & Liu, 2009) (See Table 1).

Table 1: Ten user interface design guidelines proposed by Nielsen (1995).

Usability Evaluation	Description
H1：Visibility of system status	The system should always keep user informed about what is going on by providing appropriate feedback within reasonable time.
H2：Match between system and the real world	The system should speak the user's language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.
H3：User control and freedom	Users should be free to develop their own strategies, select and sequence tasks, and undo and redo activities that they have done, rather than having the system do these for them.
H4：Consistency	Users should not have to wonder whether different words, situations, or actions mean the same thing and the system should follow platform conventions.
H5：Error prevention	Even better than good error messages is a careful design, which prevents a problem from occurring in the first place.
H6：Recognition rather than recall	Make objects, actions, and options visible. The users should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.
H7：Flexibility and efficiency of use	Allow users to tailor frequent actions. Provide alternative means of access and operation for users who differ from the ‘‘average’’ user (e.g., physical or cognitive ability, culture, language, etc.).
H8：Aesthetic and minimalist design	Dialogues should not contain information that is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.
H9：Help users recognize, diagnose, and recover from errors	Error messages should precisely indicate the problem and constructively suggest a solution. They should be expressed in plain language.
H10：Help and documentation	Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

Data source: Nielsen, J. (1995, January). *10 Usability Heuristics for User Interface Design.* Retrieve from https://www.nngroup.com/articles/ten-usability-heuristics/

In the past, some scholars pointed out those different human factors may have significant differences on the usability evaluation of systems. For an example, visual learners and verbal learners have significant differences on "H1: Visibility of system status" (Hwang, Lee, Lai, Su & Cao, 2017). In this study, we designed the questionnaire in the above manner in order to understand learners' satisfaction and opinions for different prior knowledge learners.

2.2. The Impact of Prior Knowledge on Learning Systems

Chen and Macredie (2004; 2010) pointed out that learners with different human factors using the same technology to learn may cause different learning performance. For examples, comparing to boys, girls cannot find the direction of problems usually. High prior knowledge learners like flexible ways to learning, but low prior knowledge learners love structured learning. Learners of different cognitive style like to find answers in different ways. However, prior knowledge is the key factor that affects game-based learning (Chen & Huang, 2013). Hwang, Lee and Tseng (2012) pointed out game-based learning can help low prior knowledge learners to improve their learning effectiveness, but not for high prior knowledge learners. Chen, Wong and Wang (2014) pointed out that in game-based learning, no matter high prior knowledge learners or low prior knowledge learners have good learning motivation.

3. Competitive Game-Based Learning System Including Item Bank

In this study, we used "HTML5 Certification Tutoring System Based on Competitive Games" developed by the Hwang, Chen, Cao and Su (2016). The system joins the "cultivating dinosaurs" as a game element. When learners first log in the system, they can choose a dinosaur which one they like. There are six dinosaurs in the game. Each dinosaur has seven stages. Learners can get experience by "Competitive Games" or "Personal Practice" to cultivating dinosaur. The design is for improving learners learning motivation (See Figure 1).

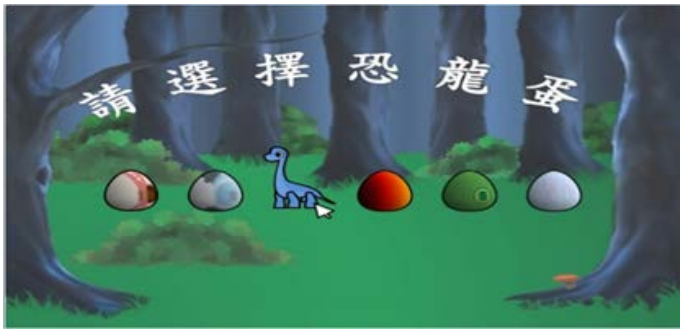

Figure 1. Choose a dinosaur.

Moreover, the system contains three modules, i.e. Competition Game, Personal Practice and Learning History. In the Competition Game Module, learners will compete with classmates in class. The rank will be shown on the left when the competition game is going. Learners will rank with their classmates to excite learners learning motivation and effectiveness (See Figure 2). When the competition game is finished, the system will show the rank and score of the learner in this round (See Figure 3).

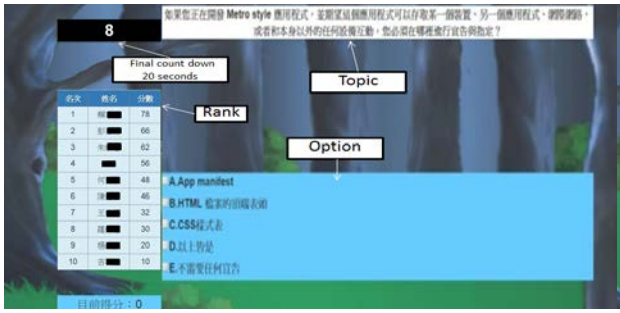

Figure 2. Competition game.

Figure 3. The rank of competitive games.

In the Personal Practice Module, by personal practice, learners can preview before class and review after class (See Figure 4). Instead of providing the right answer, the system provides the explanation that designed by a professional teacher. This purpose is to let learners have deeper understanding about the topics (See Figure 5). Moreover, the system can provide a chance to change the answer when learners get wrong answers (See Figure 6).

Figure 4. Personal practice.

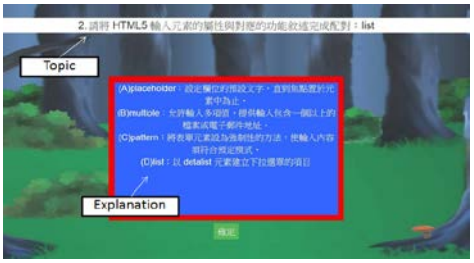

Figure 5. Explanation of topic.

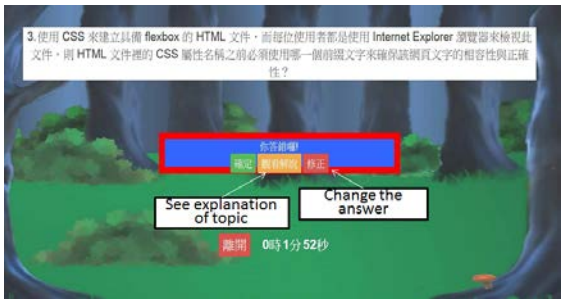

Figure 6. Change the answer.

In the Learning History Module, learners can see the chapters, practice time, and the number of right and wrong answers of learners selected in the Personal Practice Module. If the number of wrong answers is more than that of other chapters, learners can practice strongly (See Figure 7).

Figure 7. Learning history.

4. Research Method

4.1. Research Framework and Hypothesis

This study mainly explored the impact of prior knowledge on the usability evaluation of this system. Therefore, we proposed 10 hypotheses that prior knowledge has significant impact on the 10 aspects usability evaluation of this system (See Figure 8).

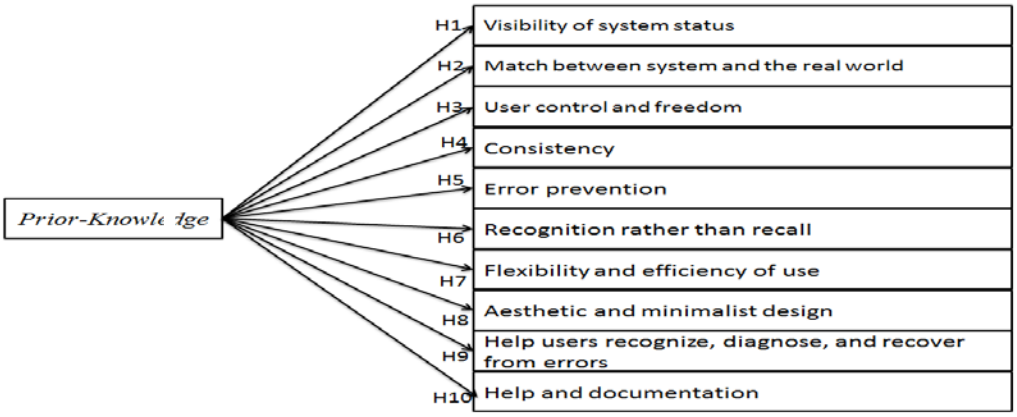

Figure 8. Research Framework.

4.2. Experimental Participants

In this study, the subjects are the learners of information related departments in a university of central Taiwan. There are 44 learners. Learners must fill in the questionnaire of usability evaluation. After check reverse question, we found that four learners are invalid samples. Therefore, only 40 samples are valid, including 10 high prior knowledge learners (master and senior students) and 30 low prior knowledge learners (junior students).

4.3. Experimental Tools

The experimental tools contain an HTML5 game-base certification tutoring system, the usability evaluation scale and SPSS 19. We used 10 user interface design guidelines proposed by Nielsen (1994). The questionnaire is designed by Likert's five-point scale (Likert, 1932) and contains 60 questions that each aspect including five questions and one reverse question. In order to achieve the expert validity, we invited two senior scholars who had designed questionnaires more than 10 years.

4.4. Experimental Flow

In the study, we used "HTML5 Certification Tutoring System Based on Competitive Games" developed by the Hwang et al (2016) and conducted a five-day experiment from November 25, 2016 to November 29, 2016. First, we explained how to use this system by 10 mins, and then students used this system by 20 mins. At the end, learners filled in the questionnaire of usability evaluation (See Figure 9).

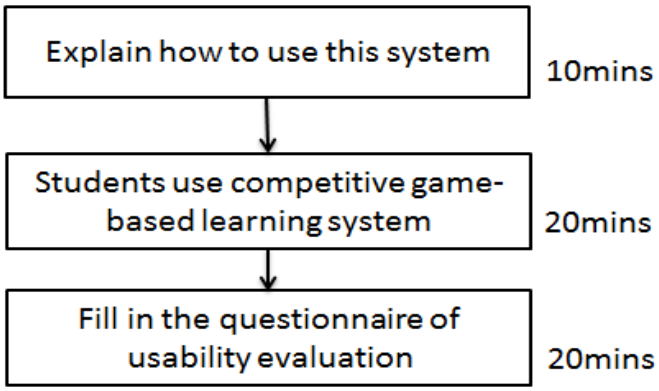

Figure 9. Experimental Flow.

5. Results and Discussions

In this study, the valid samples are 40 learners. We used SPSS to analyze data. First, we analyzed the reliability of the questionnaire. The results show the Cronbach's α of the questionnaire are between 0.808 and 0.974. It means the reliability of the questionnaire is high (Nunnally & Bernstein, 1994).

Form the overall satisfaction of usability evaluation, the average score of "H8: Aesthetic and minimalist design" and "H10: Help and documentation" are less than 4.0 and lower than others. It means the system is still needed to be improved at artwork and explanation. However, "H9: Help users recognize, diagnose, and recover from errors", "H5: Error prevention" and "H1: Visibility of system status" are greater than 4.2 and higher than others. It means the system can prevent errors and help learners recover from errors (See Table 2)

Table 2: The overall satisfaction of the usability evaluation.

Usability Evaluation	Number	Average	SD
H1：Visibility of system status	40	4.23	0.54
H2：Match between system and the real world	40	4.16	0.57
H3：User control and freedom	40	4.10	0.80
H4：Consistency	40	4.00	0.63
H5：Error prevention	40	4.25	0.58
H6：Recognition rather than recall	40	4.12	0.64
H7：Flexibility and efficiency of use	40	4.11	0.61
H8：Aesthetic and minimalist design	40	3.80	0.79
H9：Help users recognize, diagnose, and recover from errors	40	4.28	0.61
H10：Help and documentation	40	3.97	0.73

In this study, we used *t* test to explore the impact of prior knowledge on the usability evaluation of a competitive game-based learning system including item bank. However, prior knowledge has significant differences on "H1: Visibility of system status", "H2: Match between system and the real world", "H3: User control and freedom", "H4: Consistency", "H5: Error prevention", "H6: Recognition rather than recall", "H7: Flexibility and efficiency of use" and "H9: Help users recognize, diagnose, and recover from errors". It means that high prior knowledge learners are more satisfied than low prior knowledge ones when using this system (See Table 3 and Figure 10).

Table 3: Analysis of prior knowledge on the usability evaluation.

Usability Evaluation	Prior Knowledge	Number	Average	SD	*t*	Cohen's d
H1：Visibility of system status	high	10	4.70	0.39	3.62**	1.41
	low	30	4.07	0.50		
H2：Match between system and the	high	10	4.58	0.48	3.00**	1.13

Usability Evaluation	Prior Knowledge	Number	Average	SD	*t*	Cohen's d
real world	low	30	4.01	0.53		
H3：User control and freedom	high	10	4.62	0.49	2.55*	1.05
	low	30	3.92	0.81		
H4：Consistency	high	10	4.38	0.64	2.34*	0.83
	low	30	3.87	0.59		
H5：Error prevention	high	10	4.58	0.50	2.15*	0.82
	low	30	4.14	0.57		
H6：Recognition rather than recall	high	10	4.56	0.46	2.71*	1.07
	low	30	3.97	0.63		
H7：Flexibility and efficiency of use	high	10	4.50	0.49	2.50*	0.97
	low	30	3.97	0.60		
H8：Aesthetic and minimalist design	high	10	4.06	0.83	1.24	0.44
	low	30	3.71	0.77		
H9：Help users recognize, diagnose, and recover from errors	high	10	4.70	0.48	2.73*	1.04
	low	30	4.14	0.59		
H10：Help and documentation	high	10	4.24	0.75	1.36	0.49
	low	30	3.88	0.71		

**p<.05 **p<.01*

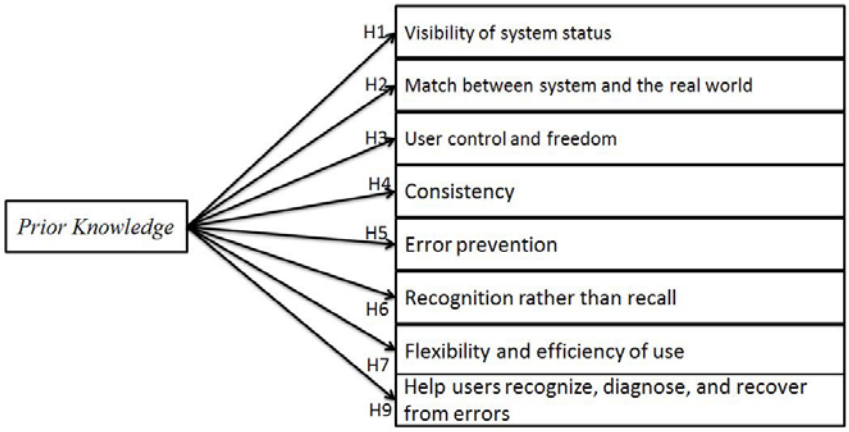

Figure 10. Prior knowledge has significantly different aspects in usability evaluation.

6. Conclusions and Recommendations for Future Work

This study explores the impact of prior knowledge on the usability evaluation of a competitive game-based learning system including item bank. We used "HTML5 Certification Tutoring System Based on Competitive Games" developed by the Hwang et al (2016) to conduct the experimental teaching.

Then, we analyzed the questionnaire of usability evaluation. The results showed that the average of the overall satisfaction is high, but the average scores of artwork and explanation are lower than other aspects. It means that the system is still needed to improve in artwork and explanation. We also found that the high prior knowledge learners are more satisfied than the low prior knowledge ones while the high prior knowledge learners and the low prior knowledge learners are no significant differences in artwork and explanation.

In the future, we will improve the system based on the above research results. Moreover, we will carry out experimental teaching to explore the impact of human factors on competitive game-based learning.

Acknowledgements

This study is supported in part by the Ministry of Science and Technology of the Taiwan under Contract NO. MOST 105-2511-S-275-003, MOST 105-2815-C-275- 008-U and MOST 106-2511-S-275-002.

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