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Investigating the role of self-explanation and co-explanation in 4th graders' game-based science learning

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Abstract: This study extends our previous studies on investigating the effects of embedding self-explanation principle into game-based science learning. In order to enhance the students' generating their own explanations during the game, we replaced the multiple choice questions with the design of allowing dyads to co-explain their causes of failure in the game via utilizing the technique of online chat. The participants were 60 4th graders recruited from an elementary school in southern Taiwan. They were randomly assigned to dyads of either an experimental group (conducting co-explanation via online chat) or a control group (conducting self-explanation via multiple choice questions). The measurements included the pretest, posttest, and a three-week retention test. The results show that both games had a positive impact on facilitating the students' acquisition of scientific concepts. But, the players who performed co-explanation via online chat did not outperform those who used multiple choice questions as self-explanation prompts. Through analysis of dialogue of the players in the experiment group, we found that the quality of the dyads' dialogue was poor; they rarely discussed the causes of failure when the prompts appeared in the game.

Keywords: Game-based learning, self-explanation, science learning, multiplayer game

1. Introduction

Researchers (Chi, Bassok, Lewis, Reimann, & Glaser, 1989) found that students learned well when they were asked to generate explanation to themselves. This constructive learning process enables learners to generate inferences to fill in information gap, integrating information, and monitoring and repairing faulty knowledge (Roy & Chi, 2005). In the recent years, a growing number of researchers attempt to integrate self-explanation principle into educational games and investigate its impacts on players' learning outcomes (Adams & Clark, 2014; Hsu, Tsai, & Wang, 2012 & Hsu, Tsai, & Wang, in press; Johnson & Mayer, 2010). This study extends our previous studies (Hsu et al., 2012, in press) on investigating the effects of embedding self-explanation principle into game-based science learning. Although both studies as well as the previous research (Adams & Clark, 2014; Johnson & Mayer, 2010; O'Neil et al.,2014) have identified the positive impacts of using multiple choice questions as self-explanation prompts, it might still risk limiting learners' generating inferences and hinder robust learning outcomes. Thus, to enhance the students' generating their own explanations, Hsu et al. (in press) suggested replacing the multiple choice questions with the design of allowing dyads to co-explain their causes of failure in the game via utilizing the technique of online chat. Through interaction with peers in the game, we hypothesize that the experimental condition would outperform the control condition since the dyads in the experimental group could share diverse perspectives, co-construct knowledge, and benefit from explaining another person's reasoning. In sum, this study attempted to examine how different forms of self-explanation influence students' game-based science learning. The guiding questions are:

1. What are the effects of self-explanation and co-explanation in game-based science learning?
2. How is the quality of co-explanation during game playing?

2. Methodology

2.1 Participants

The participants were 60 4th graders recruited from an elementary school in southern Taiwan. Without receiving formal instruction regarding light and shadow concepts, they were randomly assigned to dyads of either an experimental group (conducting co-explanation via online chat) or a control group (conducting self-explanation via multiple choice questions). There were 13 females and 17 males in the experimental condition and 16 females and 14 males in the control condition. Both groups played a multiplayer game with self-explanation embedded.

2.2 The game

The game of this study was developed by the researchers to support forth graders' learning of shadow and light concepts. The game consisted of three stages and each one was designed to instruct a core concept, such as the relationship between the height of a light source and the length of the shadow produced, shadow change throughout the day, and shadow intensity, respectively for Stage 1 to 3. The participants were required to play the game with a peer randomly assigned by the researchers (see Figure 1). That is, neither of them knew who their partner was or where she or he was situated. During game playing, a self-explanation prompt appears whenever a mistake is made. Both players had to stop playing and respond to the prompt. The participants in the experimental group were encouraged to discuss the causes of failure via online chat. When the discussion was completed, they could click a button and continue the game. However, the students in the control group used multiple-choice questions as self-explanation prompts in the game context. The time limitation for all the three stages was 35 minutes. The players would be directed to the posttest when failing to meet the limitation.

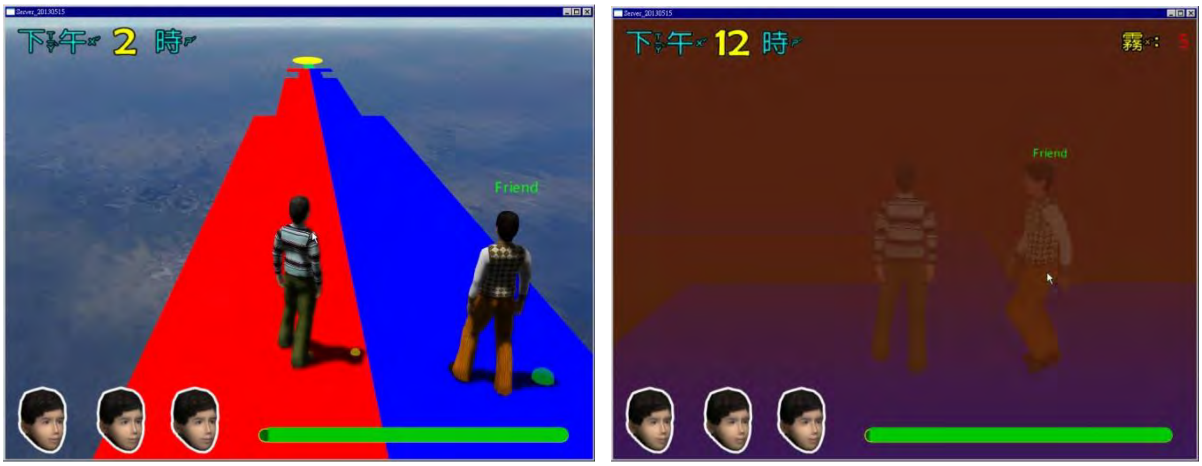

Figure 1. Screenshot of the game.

2.3 Measurement

A 10-item test was used to measure the participants' understanding regarding light and shadow covered around the main concepts in the game. Each student took the test before the game, right after the treatment, and three weeks after the treatment. Sharing the same questions, the test only varied in the order of displaying the questions and options. These items were also used in Hsu et al.'s (2011, in press) studies. The reliability coefficient was 0.60 in Hsu et al. (in press), suggesting acceptable reliability.

2.4 Procedure

Participants were randomly assigned to either the experimental or control group and individually seated at a computer when entering the computer classroom. A researcher introduced the study and the tasks to the class. Following the introduction, the students took a pretest without a time limit (averagely less than six minutes). Later, the researchers helped the students build up an online connection of the game with their partners, and log in Skype (a technology allows users to communicate with peers by using a microphone over the Internet) for those in the experimental condition. Their narration during the game playing would be recorded for further analysis. The students then played the game for 30 minutes. They received a posttest when passing the three stages or over the time limit. Each student also took a retention test after three weeks.

2.5 Data analysis

First of all, a series of paired t-test were conducted to compare students' improvement from the pretest. This study later investigated the score difference of both groups by using the pretest scores as a covariate. A content analysis was utilized to probe the dialogue of the players in the experimental group during game playing.

3. Results

Table 1 shows the results of paired t-tests. As indicated, the students' posttest and retention scores were significantly higher than their pretest scores in both experimental and control condition. This finding suggests that both games could positively facilitate the students' acquisition of scientific concepts.

Table 1: Paired t-tests for the scores of the control and experimental groups.

Group	Test Type	N	Mean	SD	*t*
Control	pretest	30	5.83	1.80	-4.87*
	posttest	30	7.63	1.50	
	pretest	30	5.83	1.80	-4.82*
	retention	30	7.53	1.85	
Experimental	pretest	30	5.37	2.16	-5.96*
	posttest	30	8.23	1.63	
	pretest	30	5.37	2.16	-5.46*
	retention	30	7.97	1.94	

*<.001

This study further examined the score difference between the two groups by using the pretest scores as a covariate and the posttest and retention score as dependent variables. The assumption of homogeneity of regression was tested and was not violated (F =1.16, $p > .05$; F = 1.44, $p < .05$). The ANCOVA results of the posttest and retention are shown in Table 2. As shown, no statistically significant difference was identified. That is, the players who performed co-explanation via online chat did not outperform those who used multiple choice questions as self-explanation prompts.

Table 2: Descriptive data and ANCOVA results for the posttest and retention scores.

Type	Group	N	Adjusted mean	Std. error	*F*
Posttest	Control	30	7.61	.29	2.57
	Experimental	30	8.26	.29	
Retention	Control	30	7.47	.33	1.44
	Experimental	30	8.03	.33	

As aforementioned, the players' communication during the game would be recorded and transcribed for further analysis. In this preliminary analysis, we focus on the players' narration right after the failure in the game. The results show that the dyads rarely discussed the causes of failure when the self-explanation prompt appeared, such as:

Participant 12: I am dead.
Participant 10: I am dead, too.
Participant 12: No problem, let's play again.
Participant 10: Well, this time we should walk slowly.

In addition, they tended to blame their partner for the cause of mistakes. Take Participant 13 for instance, "I hate you. I only make one mistake but you make two. It is annoying that we keep failing." Although some dyads might come up with the tricks to pass the game, these tricks were not absolutely correct. An example is:

Participant 1: Oops, I am completely dead
Participant 6: I told you not to move but you never listen. Maybe you should walk on the red lane. Be careful! Do not fall in the sea.

Regarding the above example, the players should pay attention to shadow change throughout the day, rather than the difference in the lanes they walk.

4. Discussion

Self-explanation effects become effectively when learners can generate inferences to fill in missing information, integrate information and repair faulty knowledge (Roy & Chi, 2005). However, the previous research pointed out that utilizing multiple choice questions as self-explanation prompts in the game context was likely to limit the players' generating inferences (Hsu et al., 2014). To solve this problem, this study implemented a design by having dyads co-explain their causes of failure during game playing and investigate its impact on the participants' learning outcomes. However, no statistically significant difference was identified. Players who co-explained via online chat did not perform better than those who used multiple choice questions as self-explanation prompts. In addition, through analyzing the dyads' dialogue, we found that the quality of the dyads' narration was not satisfied and they rarely discussed the possible causes of failure when the prompt appeared. They chatted all the time and blamed their partner for failure. Although some of them could identify some tricks to pass the game, they might not be accurately linked to the targeted concept.

According to Chi's (2009) framework of passive-active-constructive-interactive learning strategies, interacting with a peer in a computer-based environment can be classified as interactive learning activities only when the dialogue includes substantive contributions from both partners, as well as learners respond to scaffoldings and modify errors based on feedback. It seems like that the participants of the experimental condition simply taking turns speaking, which could not be categorized as an interactive learning event. To sum up, having dyads collaboratively construct knowledge in game-based science learning is a one of ultimate level of learning strategies. But, future studies still need to think about ways to promote quality of players' interaction, such as designing events to confront or challenge the partner's statements, or encourage involvement into deeper discussion.

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References

Adams, D. M., & Clark, D. B. (2014). Integrating self-explanation functionality into a complex game environment: Keeping gaming in motion. *Computers & Education*, *73*, 149-159. doi: 10.1016/j.compedu.2014.01.002

Chi, M. T. H., Bassok, M., Lewis, M. W., Reimann, P., & Glaser, R. (1989). Self-explanations: How students study and use examples in learning to solve problems. *Cognitive science, 13*, 145-182.

Hsu, C.-Y., Tsai, C.-C., & Wang, H.-Y. (2012). Facilitating third graders' acquisition of scientific concepts through digital game-based learning: The effects of self-explanation principles. *The Asia-Pacific Education Researcher*, 21, 71-82.

Hsu, C.-Y., Tsai, C.-C., & Wang, H.-Y. (in press). Exploring the effects of integrating self-explanation into a multi-user game on acquisition of scientific concepts. *Interactive Learning Environments*. doi: 10.1080/10494820.2014.926276

Johnson, C. I., & Mayer, R. E. (2010). Applying the self-explanation principle to multimedia learning in a computer-based game-like environment. *Computers in Human Behavior, 26*, 1246-1252. doi: 10.1016/j.chb.2010.03.025

O'Neil, H. F., Chung, G. K. W. K., Kerr, D., Vendlinski, T. P., Buschang, R. E., & Mayer, R. E. (2014). Adding self-explanation prompts to an educational computer game. *Computers in Human Behavior, 30*, 23-28. doi: 10.1016/j.chb.2013.07.025

Roy, M., & Chi, M.T.H. (2005). The self-explanation principle in multimedia learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 271-286). New York: Cambridge University Press.