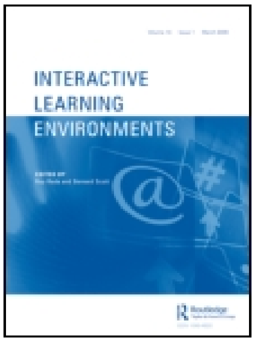

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The importance and use of targeted content knowledge with scaffolding aid in educational simulation games

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While most current educational simulation games provide learners with gameplay experience to motivate learning, there is often a lack of focus on ensuring that the desired content knowledge is actually learned. Students may focus on completing game activities without learning the targeted content knowledge, thus negating the desired learning outcomes. We argue that to help students achieve improved learning performance, providing targeted content knowledge should be a specific focus in designing educational games; in addition, scaffolding strategies to promote the use of in-game contents should also be provided. Thus, the present study explores the effects and usage of providing three types of scaffolding aids in two versions of educational simulations with in-game contents. The results suggest that providing targeted content with scaffolding aid in educational simulation games helps students to achieve better learning performance.

Keywords: targeted content knowledge; scaffolding aid; educational simulation games

Introduction

During the past decade, there has been a rapid proliferation of studies on educational simulation/games in the e-Learning community. The most common reason to support researchers in studying educational simulation/games is that games have many attributes of meaningful learning. For examples, many studies (Kulik, 1994; Terrell & Rendulic, 1996) have indicated that educational computer games can enhance students' learning motivation, interest, and concentration because the games can generate fantasy, excitement, and competition. Besides, the characteristics of rules, challenge, complexity, and goal of games could foster players' problem solving skills and self-regulation (Tsai, Yu, & Hsiao, 2007). Gee (2003) also posited that there are 36 implicit learning principles embedded in good digital games. Notably, simulation games can offer players the opportunities to tackle situations they might not be prepared to risk in reality (Leemkuil, Jong, Hoog, & Christoph, 2003), and to experiment with a concept or new ideas by manipulating

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different variables and observing the effects they cause. Therefore, many proponents (Aldrich, 2004; Prensky, 2001) of educational game have pointed out that digital game-based learning (DGBL) is emerging as a new model of e-Learning.

Although abundant studies (McFarlane, Sparrowhawk, & Heald, 2002) have indicated that educational simulation/games have a positive effect in math, science, and military education, recently more and more researchers (Papastergious, 2009; Ke, 2008) have argued that the empirical effectiveness of educational simulation/games is still a mystery. In fact, previous studies (Mitchell & Savill-Smith, 2004) have indicated that the common problem of educational games is students' distraction by gameplay. For example, students could spend a large amount of time completing the game activities such as shooting, bartering, and fishing without ever learning the targeted knowledge, such as geography, history, or mathematics, thus negating the desired learning outcomes (Caftori, 1994; Magnussen & Misfeldt, 2004). In addition, the complexity of games could affect students' knowledge acquisition. For example, when Squire (2005) used Civilization III, a popular commercial simulation game, as activities for exploring world history, some students complained that the game was too difficult and elected to withdraw from the game.

In other words, it is questionable whether students can acquire accurate targeted knowledge solely through playing educational simulation/games. Hence, even though there is no doubt that educational simulation/games have the power to create immersive experience, finding ways to help students learn accurate targeted knowledge in playing games is a critical issue. To solve the addressed concern, some researchers have pointed out a number of solutions. For example, Peters and Vissers (2004) indicated that participants should be invited to a debriefing session to examine how closely their performance had approached the target and what needs to be done to bridge the gap between performance and target after playing the simulation game. However, very few researchers thought that providing in-game content materials is important because, according to Bos (2001) and Gee (2003), successful video games know how to facilitate players learning complex sets of relationships only through games' feedback, interaction, challenges, or competition without having resources. In addition, reading in-game contents during gameplay could diminish players' state of extreme happiness, called 'flow' (Csikszentmihalyi, 1990), and make the gaming experience boring.

On the other hand, Graner-Ray (2003) stated that every puzzle in a computer game should have its solution found within the game. This may prevent players from becoming too frustrated and also prevent the players from leaving the game to find answers. It also could allow students to confirm their knowledge acquisition during gameplay, and do not need to bridge the gap between their learning and accurate target knowledge after gameplay. Moreover, it can be an alternative teaching material so that those who are not used to learning by playing games can still benefit from the game (Caftori, 1994). Hence, it seems that providing in-game content materials also has its values besides drawbacks.

From a constructivist perspective, the concept of scaffolding (Bruner, 1975) has been widely used in providing an explicit strategy to direct teaching for self-directed learners. Scaffolded instruction is the systematic sequencing of prompted content, materials, tasks as well as teacher and peer support to optimize learning (Dickson, Chard, & Simmons, 1993). Hence, one way to deal with the drawbacks related to providing in-game content materials may be to provide scaffolding strategies for players to promote the use of in-game contents during gameplay. According to

Hogan and Pressley (1997), providing assistance, which could take the form of cueing or prompting, questioning, modeling, telling, or discussing, could be one of the scaffolding strategies. Therefore, providing game questions related to the targeted knowledge in games could be a useful scaffolding strategy prompting players to use the in-game contents during gameplay.

However, even though providing good scaffolding strategies to promote players use of the in-game contents could facilitate players learning targeted knowledge during gameplay, it might have a downside as well, since it could disrupt the flow of thought and leave players dissatisfied with their experience. Thus, providing scaffolding strategies to promote reading targeted content knowledge prior to gameplay, while allowing additional access during gameplay may be best, since acquiring knowledge beforehand could decrease the need to frequently search for information during gameplay. Moreover, prior reading could help students form a macrostructure in which information learned in the later process can be stored (Kintsch, 1988).

Based on the above rationale, it is necessary to investigate the importance of in-game contents and to find an optimal way to appropriately utilize scaffolding strategies for enhancing students' use of in-game contents and learn targeted contents. Therefore, this article proposes an educational simulation game, TANK-Q (it will be described in detail later), which is a common tank's shooting game, and targeting knowledge about the principles of projectile motion. To enable students to confirm their observations during gameplay, in-game content materials related to the target knowledge of projectile motion were provided in TANK-Q. To promote students use of in-game contents and to find an optimal way of presenting this content, three different scaffolding conditions were used (they will be described in detail later): 'no scaffolding', 'scaffolding during gameplay', and 'scaffolding before and during gameplay' were proposed. Moreover, to understand the effectiveness of these three different scaffolding conditions, the following questions were investigated:

- Do different scaffolding conditions in an educational simulation game have different effects on students' knowledge acquisition?
- Do students have different behaviors or perceptions with different scaffolding conditions in an educational simulation game?

Method

Participants and procedures

Seventy-nine eighth-grade students selected from three classes of a junior high school in Kaohsiung city, Taiwan, participated in this experiment; each class included 27, 25, or 27 students. Before participating in this experiment, the participants had not learned any concepts about projectile motion in their science and technology course, and did not have knowledge regarding projectile motion. In the experiment, all of the participants were randomly assigned by class to three groups: 'scaffolding before and during gameplay', 'scaffolding during gameplay', and 'no scaffolding'. After a brief introduction about what the nature of the game and how to play, participants were asked to play TANK-Q based on their grouping conditions for two sessions (50 min each). In the 'scaffolding before and during gameplay' group, the teacher first suggested that students read in-game materials for 5 min, and then the students played a version of TANK-Q which provided scaffolding tasks (to be described in detail later) for prompting students to use in-game contents during gameplay. In the 'scaffolding during gameplay' group, students played the same version of TANK-Q as the 'scaffolding before and during gameplay' group, but they could freely determine whether to read the reference materials before gameplay. In the 'no scaffolding' group, students freely determined whether to use the in-game contents before and during playing, and played the version of TANK-Q without any scaffolding tasks. After the entire playing session, all of the participants took a 30 min performance test to evaluate their knowledge about projectile motion. Finally, students completed a 10 min questionnaire investigating their perceptions toward the TANK-Q after the assessment.

Materials and instruments

Educational simulation game

In this study, TANK-Q, an award-wining educational simulation game originally developed by Kuo-Hsun Hung, Cheng-Ling Alice Chen and Selen Turkay, was used and modified as the educational simulation game. The main goal in devising this small computer game was to facilitate learning the principles of projectile motion through playing. TANK-Q players need to navigate a tank in virtual planets using a keyboard. There are nine levels with different planets in the game. In each level, players must control their tank to collect a key (see Figure 1) while destroying different enemies such as autonomous-moving bombs (see Figure 1). The enemies can destroy the three 'lives' of the players' tank. If players are able to collect a key and move their tanks to unlock a lock (see Figure 1), they can progress to the next game level. To destroy the enemies, players must adjust the tank's shooting angle and strength (velocity) according to the distance and height of the enemies, as well as the gravity of the planet. In addition, to prompt players to observe the motion of a projectile while playing, the game shows the tank's shooting angle and velocity, and indicates the gravity of the environment, as shown in Figure 1. Therefore, as some researchers (Garris, Ahlers, & Diskell, 2002) explained how game-based learning

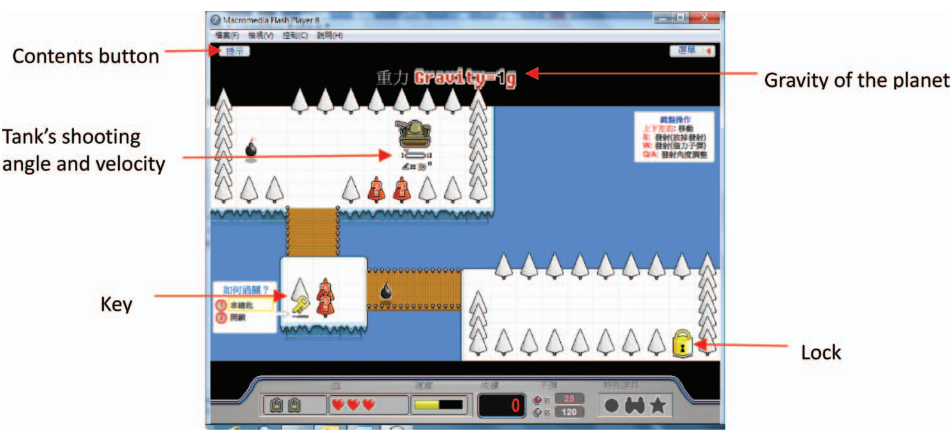

Figure 1. The first game version of TANK-Q for 'no scaffolding' condition.

works, the game incorporates the concepts of projectile motion with certain characteristics of games to provide players with opportunities for observing the motion of a projectile, and how the projectile moves at different angles, velocity, or gravitational environments during gameplay.

In order to enhance students to obtain a thorough understanding of the targeted knowledge behind the simulation game, i.e. in-game contents, the reference materials are available for providing the knowledge of projectile motion related to the game. Before starting to play the game, the game menu provides a link to the targeted contents wherein players can first read the knowledge of projectile motion. When starting to play the game from the first game level, the game provides a brief introduction before students enter every game level. This introduction reminds players that the tank shell will be affected by the shooting angle, velocity, and gravitational environment; it also suggests that players can read the reference materials while playing the game. When players enter every game level, the interface provides a link button, as shown in Figure 1. If players click the button, the game will pause and the reference materials will appear, as shown in Figure 2.

As described above, this is the basic version of TANK-Q for the 'no scaffolding' experimental conditions. The other game version was designed to determine whether using scaffolding game tasks can promote students' active utilization of the in-game contents during gameplay. The significant difference between the basic version and second version is that the second version provides the scaffolding questions bar and answer towers during gameplay. The interface of the second version is shown in Figure 3. A game key is not displayed when players enter a game level. Players need to correctly answer a multiple-choice question about projectile motion displayed on the scaffolding questions bar by shooting the correct answer tower that has a number representing an answer selection (see Figure 3). For example, one of the multiple-choice questions is 'which shooting angle can make the tank shell shoot for longest distance if the tank shell keeps the same velocity?' These questions also are presented

Figure 2. Targeted contents in TANK-Q.

Figure 3. The second game version for ‘scaffolding before and during gameplay’ and ‘scaffolding during gameplay’ conditions.

in the brief introduction before entering every game level, and are aimed at promoting players to observe the motion of a projectile and actively to use the reference materials during gameplay.

Accordingly, the second game version was served as the ‘scaffolding before and during gameplay’ and ‘scaffolding during gameplay’ experimental conditions because the version provides a concrete scaffolding task to promote the use of the in-game contents during gameplay. The only difference between ‘scaffolding before and during gameplay’ and ‘scaffolding during gameplay’ condition was that the teacher suggested that students click the link button in the game menu for reading reference materials for 5 min as a scaffolding aid before starting to play the game. Moreover, to explore the learning behaviors between different conditions in playing different versions of TANK-Q, all game versions can record players’ behaviors.

Performance test

To understand whether TANK-Q promoted learning, a performance test for evaluating the study participants’ effectiveness of knowledge acquisition was developed. The test was constructed to measure the subjects’ knowledge about the principles of projectile motion based on the in-game contents. The test was composed of 10 true-false items and five multiple-choice items. To evaluate the validity and reliability of the performance test, two high school teachers, one who teaches technology and the other who teaches physics, vetted all items’ content validity, and the reliability was assessed by internal consistency (Kuder-Richardson 20, KR-20) through a pilot study with 61 eighth-grade students before the experiment. A KR-20 reliability coefficient of 0.79 was obtained.

Questionnaire of learning perceptions

This study developed a questionnaire to measure students’ perceptions regarding the two versions of the game. A five-point Likert-type scale (scoring explained below) consisting of five items (example of an item: ‘I feel the game is fun’) was used.

The Cronbach's α of the inventory was 0.83. An open-ended item was also included for this questionnaire.

Results

Evaluation of learning effects

The learning performance test was conducted to evaluate students' learning performances. The three groups' post-test scores are shown in Table 1. To compare the learning effects among three scaffolding conditions in an educational simulation game with in-game contents, a one way analysis of covariance (ANCOVA) was employed to examine the differences among post-test scores of the three groups with subjects' last semester's science and technology scores as covariate. The test of homogeneity of regression showed that the homogeneity of regression of the three groups was not different ($F = 1.052$, $p = 0.353$). The results of ANCOVA shown in Table 1 indicate that after the influence of covariate was controlled, the post-test scores of the three groups were significantly different ($F = 17.613$, $p < 0.05$).

Table 2 shows that after post hoc comparison using the LSD (least significant difference) method, the post-test scores of the 'scaffolding before and during gameplay' group was significantly better than those of the 'scaffolding during gameplay' group and 'no scaffolding' group ($p < 0.05$). The results indicated that providing scaffolding aids before and during gameplay had a better learning impact on students' learning outcome than only providing scaffolding aid during gameplay or no scaffolding. In addition, the post-test score of the 'scaffolding during gameplay' group was significantly better than the 'no scaffolding' groups ($p < 0.05$). This finding revealed that providing scaffolding aid during gameplay had a better learning impact on students than providing no scaffolding aid before and during gameplay.

Table 1. ANCOVA for post-test of different scaffolding groups.

Groups	*N*	Post-test Mean	Post-test SD	*F*	*P*
Scaffolding before and during gameplay	27	75.65	13.77	17.613	0.000
Scaffolding during gameplay	25	62.14	16.82		
No scaffolding	27	55.79	12.20		

Table 2. Post hoc comparisons of post-test scores (*p*-value of LSD comparison).

	Adjusted means	Scaffolding before and during gameplay	Scaffolding during gameplay	No scaffolding
Scaffolding before and during gameplay	75.50	–	0.000*	0.000*
Scaffolding during gameplay	62.66		–	0.32*
No scaffolding	55.49			–

Note: *$p < 0.05$.

Evaluation of learning perceptions

Students were asked to rate their perceptions toward different scaffolding kinds of game after the performance test. A five-point Likert-type scale ranging from 1 (strongly disagree) to 5 (strongly agree) was employed for this purpose. Students' responses to the questionnaires are shown in Table 3. Mean score was used to represent students' average attitudes toward their gameplay, and ANOVA was used to examine the difference among the three conditions in every item.

Generally speaking, the mean scores of most items were above 3.5, as shown in Table 3. It shows that most students had positive attitudes toward the game, no matter what game version they played. There were no significant differences in every item among the three conditions. The result suggests that providing scaffolding aid during gameplay may not affect students' playing motivation when comparing it to the condition of 'no scaffolding' group, although the scaffolding game questions seem to enhance the difficulty of the game.

According to the responses to the open-ended item in this questionnaire, many students indicated that 'it is fun', 'it is interesting', 'not bad', 'it is fun and enhances my knowledge', or 'this game helps me to learn some concepts of projectile motion'. It supports that most students loved to play the game and felt the game promoted learning, no matter whether or scaffolding aids were provided in the game. Besides, in the responses to the open-ended items, some students, especially male students, wrote: 'I suggest that more game levels can be provided', 'the game can be more difficult', or 'it is easy to feel bored when playing the game repeatedly'. This could be the reason that the mean scores of the first item were not as high as had been expected. On the contrary, some students, especially female, wrote that 'it is difficult to control the tank's shooting velocity' or 'it is fun but a little difficult'. This could be the reason that the mean scores of the second item were not as high as had been expected. These conflicting results suggest that there appears to be a gender bias toward the degree of difficulty of the game.

Table 3. Comparison of three groups on learning attitude.

Items	Scaffolding before and during gameplay	Scaffolding during gameplay	No scaffolding	ANOVA
1. I feel this game is fun	3.81	3.76	3.89	$F = 0.192$ $p = 0.826$
2. I feel this game is easy	3.48	3.44	3.63	$F = 0.280$ $p = 0.757$
3. I observe how the tank's shell moves while playing	3.52	3.60	3.70	$F = 0.231$ $p = 0.794$
4. I pay attention to what factors affect the shell's motion while playing	3.63	3.68	3.59	$F = 0.054$ $p = 0.948$
5. I feel I acquired knowledge about the projectile through this game	3.78	3.72	3.63	$F = 0.163$ $p = 0.850$

Evaluation of learning behaviors

A survey on game usage derived from system logs was undertaken to analyze if the different kinds of scaffolding strategies affected students' learning behaviors. Figure 4 shows the average time of using reference materials among different kinds of scaffolding conditions. It reveals that students with scaffolding before and during gameplay spent more time in using the reference materials than did those with scaffolding during gameplay or without scaffolding. Hence, the result implies that most students in the no scaffolding game seldom used the in-game contents. On the contrary, the finding also suggests that the scaffolding strategies promoted students' behaviors to use the in-game contents, and that scaffolding strategies provided before and during gameplay had better impact than those which were only provided during gameplay.

Although students with scaffolding before and during gameplay spent more time on using the reference materials than other groups did, there were different patterns of time spent on using the in-game contents between the period of before and during gameplay among three groups. Figure 5 shows the average time of using reference materials before or during gameplay among different kinds of scaffolding conditions. It reveals that the average time spent using reference materials in 'scaffolding before and during gameplay' group showed an obvious decreasing trend. The students in

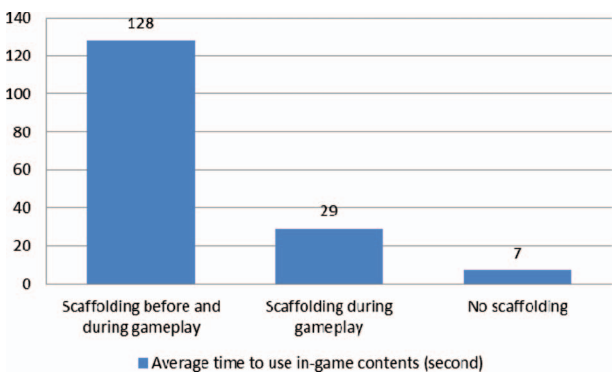

Figure 4. Average time to use in-game contents among different groups.

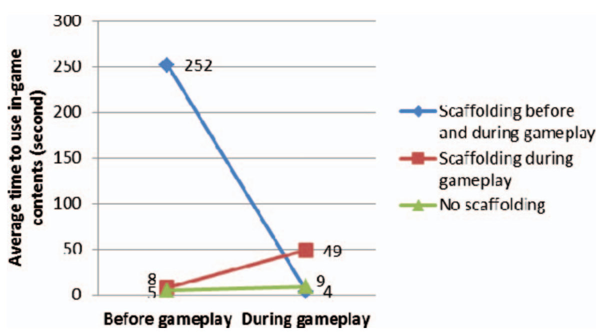

Figure 5. Average time to use in-game contents in two periods among different groups.

'scaffolding before and during gameplay' condition seldom used the in-game contents during gameplay. On the contrary, the average time using reference materials in 'scaffolding during gameplay' group showed an obvious increasing trend, while there was no difference of using reference materials in the 'no scaffolding' group between the period of before and during gameplay. This finding implies that the scaffolding aid before gameplay was useful for motivating students to spend more time using in-game contents; it seems that students did not need to use the in-game contents anymore during gameplay. Comparing the pattern between the 'scaffolding during gameplay' and 'no scaffolding' group seems to indicate that the scaffolding aid during gameplay was useful for promoting students' use of in-game contents.

Finally, this study also analyzed the accuracy in correctly answering scaffolding questions during gameplay between the 'scaffolding before and during gameplay' group and 'scaffolding during gameplay' group, because only these two groups of students were provided scaffolding game tasks during gameplay. The result showed that the 'scaffolding before and during gameplay' group (accuracy = 0.73) had significantly ($t = 3.258$, $p = 0.002$) higher accuracy than did the 'scaffolding during gameplay' group (accuracy = 0.57). The low accuracy implies that most students in 'scaffolding during gameplay' group could answer the questions by guessing, even though they spent more time using the reference materials than did the 'scaffolding before and during gameplay' group during gameplay. This result suggests that spending time on using in-game contents before playing, such as the 'scaffolding before and during gameplay' group did, could be more useful to correctly answer the questions about principles of projectile motion during gameplay.

Discussion and conclusions

Providing and using in-game contents are important

In fact, whether or not in-game contents are provided, the TANK-Q's developed in this study possesses the ability to promote learning the principles of projectile motion through simulation and observation during gameplay. However, after the experiment, the students in the 'no scaffolding' group, which seldom used in-game contents (the average time of using reference materials was only 7 s as shown in Figure 4), obtained the worst scores on the performance test among the three experiment conditions. This finding implies that the students in the 'no scaffolding' group may have treated TANK-Q's as a shooting game without observing the motion of projectiles, even though the game repeatedly prompted students observing the motion of a projectile before entering every game level. If so, it means that the game could distract students from learning, which is consistent with previous researchers' findings (Caftori, 1994; Magnussen & Misfeldt, 2004; Mitchell & Savill-Smith, 2004). Meanwhile, it also proves why very few researchers feel that providing in-game content materials is needed, because the 'no scaffolding' group actually seldom used in-game contents if no scaffolding game tasks were provided for them before or during gameplay.

On the other hand, the 'no scaffolding' group may already have seriously observed the motion of the tank's shell, but they still could not acquire perfect targeted knowledge because they did not confirm their observation by frequently referencing in-game contents. If so, it signifies that using in-game contents in an educational simulation game is important because the students could not acquire accurate targeted knowledge only through gameplay. This inference is also supported by the finding (Table 1 and Figure 4) indicating that students in the 'scaffolding before and during gameplay' group, which took much time on using in-game contents besides playing, performed significantly better on acquiring knowledge than did the other two groups. Moreover, according to the analysis, a statistically significant ($p < 0.05$) correlation ($r = 0.438$) between each student's average time of using in-game contents and their post-test scores also supports that using in-game contents is important. Besides, the accuracy in correctly answering questions while playing for the 'scaffolding before and during gameplay' (accuracy = 0.73) and 'scaffolding during gameplay' groups (accuracy = 0.57), also supports that more reading in-game contents is useful to promote learning.

Therefore, even though this study proves that students did not like to read in-game contents during gameplay as well as the prediction of flow theory (Csikszentmihalyi, 1990), it proves that using in-game contents is important for students according to the findings of the experiment. Spending time on using in-game contents can help students to get better learning effectiveness in an educational simulation game.

Providing scaffolding is useful for promoting the use of in-game contents

In the beginning, this study argued that providing in-game contents could not be insufficient for students, and hypothesized that providing scaffolding aid could be useful for promoting the use of in-game contents. Accordingly, two scaffolding strategies were proposed, and three scaffolding conditions in an educational simulation game were examined. According to the findings of the experiment as discussed in the following, the argument and the hypothesis should be accepted.

In the findings of experiment, the students with no scaffolding aid spent the least amount of time to read in-game contents (see Figure 4). It is consistent with our argument and previous researchers' findings (Tsai, 2007) indicating that students do not like to read the learning contents during gameplay. The result also supports that providing scaffolding aid could promote the use of in-game contents. According to the results of comparing students' average time to use of in-game contents, students with two scaffolding strategies spent the most time in using the learning contents in the game. This result implies that providing scaffolding aid in an educational simulation game is useful for promoting the use of in-game contents.

Moreover, according to the questionnaire responses, providing scaffolding tasks in the game does not seem to leave students dissatisfied when comparing students' perceptions toward the game among the three groups. It also supports that providing scaffolding strategies could be workable and useful for promoting the use of in-game contents. In summary, providing scaffolding is useful in promoting the use of in-game contents; furthermore, it is also useful in enhancing learning effectiveness in an educational simulation game due to the importance of using in-game contents, as discussed above.

Future works

Because the 'scaffolding before and during gameplay' group spent less time on using reference materials during gameplay, and got the best post-test scores among three group, this study cannot be certain if providing scaffolding aid before and during gameplay is the best way to promote learning. It may imply that only providing scaffolding aid before gameplay is the optimal way to promote a better learning impact than providing scaffolding aid only during gameplay. Further research to clarify this issue can be conducted in the future. Besides, more games need to be evaluated in regard to whether the effectiveness of using in-game contents with scaffolding aids is similar to the finding of this study. Moreover, according to the results of students' perceptions regarding the TANK-Q, gender could be a factor that affects students' perceptions toward the degree of game's difficulty. It could mean that female students are not interested in playing a shooting game like TANK-Q or have less experience with similar types of games. Therefore, different kinds of games can be adopted and assessed in the future. Finally, a revision of TANK-Q can be created to limit the time for answering the scaffolding game questions or tracing the players' cursor moves; providing a debriefing session after gameplay can also be evaluated in the future.

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Kuo-Hsun Hung holds a doctoral degree in the Instructional Technology and Media program from Teachers College, Columbia University and an EdM degree in the Technology, Innovation, and Education program from Harvard University. He has led and worked with others on many award-winning educational game and MMORPG-related projects as a game designer, illustrator, programmer, interface designer, and researcher. He is currently working with Dr. Charles Kinzer and Cheng-Ling Alice Chen on developing his newest educational MMORPG called Ed-Wonderland, which aims to assist Taiwanese students' learning of English as a foreign language (EFL).

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