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Chapter 2

The Trends, Design, and Evaluation of Science Educational Game

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Preface

In the recently years, game-based learning has been gradually emphasized in the educational technology field, and novel technology and instructional methods which facilitated social interaction were also discussed and proposed by researchers in game-based learning. Nowadays, the cultivation of the citizens' scientific literacy has received more and more attention in all countries around the globe.

To improve the citizens' scientific literacy, technology-enhanced science learning has been highlighted by science educators. In particular, how educational games play roles in promoting student science learning outcomes and their scientific literacy should be a crucial research issue. Recently, research concerned with science educational games has been an emerging research field. The studies in this field can facilitate the integration of theories and practices in digital learning and science education, and provide insights into the use of educational games or toys to help science learners' knowledge construction, conceptual change, reasoning and argumentation, scientific inquiry, collaborative learning, and their learning engagement. To address this important issue, this workshop aims to explore the trends, design, and evaluation of science educational game.

Seven papers were finally selected for this workshop. Each selected paper went through a blinded peer review process. These papers explore various science educational game issues, including science teachers' experiences, attitudes and perspectives on digital games, web-based drill game and RPG game development, multi-user game system, 3D virtual worlds and evaluation of serious educational games. It is hoped that these papers will bring about in-depth discussions during the workshop.

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Elementary school science teachers' experiences, attitudes and perspectives on digital games and using digital educational games in science classrooms

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Abstract: This study aimed to investigate science teachers' experiences, attitudes and perspectives on digital games and using digital educational games in science classrooms. To this end, a total of 14 elementary science teachers were interviewed. The teachers' narratives obtained by tape-recorded interviews were analyzed qualitatively. Major findings and implications are discussed.

Keywords: digital game-based learning, digital game, science education, in-service teacher

Introduction

In the recent years, digital educational games have been considered as potentially effective and powerful instructional tools [1]. Consequently, digital game-based learning (DGBL) has been highlighted by researchers and educators [2].In science education, some empirical studies have been conducted to examine the effects of science educational games in school setting [3][4]. These studies have revealed that digital educational games are capable of improving science student content knowledge understanding, inquiry ability and motivation [5].

Many researchers have proposed that games are powerful educational tools if used appropriately [6]. However, digital game-based learning has not being widely adopted in schools by teachers [1]. Undoubtedly, teachers, teachers' experiences and perceptions on digital games and their perspectives on the use of digital educational games are crucial to their adoption of digital educational games in classrooms and the success of digital game-based learning. To address this important issue, this study investigate a group of elementary science teachers' experiences and perceptions on digital games and their perspectives on the use of digital educational games in science classrooms.

1. Methods

1.1 Subjects

The subjects of this study are 7 male and 7 female voluntary in-service elementary science teachers (a total of 14 teachers). Their teaching experiences ranged from three to twenty seven years, and all of them hold undergraduate degrees.

1.2 Data collection

This study was conducted to explore a group of elementary science teachers' experiences and perceptions on digital games and their perspectives on the use of digital educational games in science classrooms. To this end, tape-recorded interviews were conducted. The interview questions are listed below:

Question 1: Have you ever played a computer game? (Understanding science teachers' experiences in playing computer games)

Question 2: How do you think of playing computer games? (Assessing science teachers' perceptions in playing computer games)

Question 3: Do you agree that computer games could assist science education? Why? (Assessing science teachers' positions regarding the use of digital educational games in science classrooms)

Question 4: Have you ever employed any computer game in your science classes? If so, how did you apply it? (Assessing science teachers' experiences regarding the use of digital educational games in science classrooms)

Question 5: What are the possible advantages or disadvantages for students' learning if employing educational computer games in science classrooms? Why? (Assessing science teachers' perspectives regarding the use of digital educational games in science classrooms)

1.3 Data analyses

After the tape-recorded interviews, the narratives of the participants are transcribed and, then, were analyzed qualitatively.

2. Major findings and discussion

2.1 Science teachers' experiences in playing computer games and perceptions in playing computer games

This study explored the science teachers' experience of playing computer games. All the participants stated that they had played computer games. Four teachers only had little experience of playing computer games, while two teachers had very much experience.

Table 1. Teachers' attitudes toward playing computer games

	N (%)
Positive	8 (57.14%)
Negative	3 (21.43%)
Neutral	3 (21.43%)

As revealed in Table 1, more than a half of the interviewed teachers showed positive attitudes toward playing computer games. It should be noticed that three teachers had neutral attitudes toward playing computers. To sum, most of the teachers did not show negative attitudes toward playing computer games.

2.2 Science Teachers' positions regarding the use of digital educational games in science classrooms

Table 2 showed that most of the teachers in this study agreed with the use of digital games in science classrooms. Those agreed with the use of digital games in science classrooms proposed that use of digital games in science classrooms could encourage student motivation and improve their learning outcomes, while the only one teacher who disagreed with the use of digital games stated that if the digital games were just used as quizzes. Moreover, two teachers holding neutral position mentioned that proper digital games were still not available.

Table 2. Teachers' positions regarding the use of digital educational games in science classrooms

	N (%)	Reason
Agree	11 (78.57%)	Encouraging motivation (n=8), Improving learning outcomes (n=5)
Disagree	1 (7.14%)	Poor usage of digital games
Neutral	2 (14.29%)	Unavailability of suitable digital games

2.3 Science teachers' experiences regarding the use of digital educational games in science classrooms

In this study, science teachers' experiences regarding the use of digital educational games in science classrooms were also explored. It was found that a half of the participants (n=7) had ever employed computer games for science teaching, while a half of the participants (n=7) had not yet.

Most of the teachers having the experiences regarding the use of digital educational games in science classrooms mentioned that they used the digital educational games as instructional tools, such as teaching materials demonstrated by teachers or supplementary learning materials (n=4), while the other teachers employed computer games in their science classrooms as assessment tools (n=3).

Those who had not employed computer games for science teaching mentioned that because instructional time was insufficient they were not able to make use of digital educational games in their science classrooms. They also mentioned that the use of digital educational games may encourage learners' motivation.

2.4 Science teachers' perspectives regarding the use of digital educational games in science classrooms

The science teachers in this study also mentioned the possible advantages or disadvantages for students' learning if employing educational computer games in science classrooms. Their responses were summarized in Table 3. According to Table 3, three major advantages were mentioned by the teachers. The advantage most frequently mentioned by the teachers is that the use of educational computer games in science classrooms will encourage students' learning motivation. The second advantage most frequently mentioned by the teachers is that the use of educational computer games in science classrooms can be used as supplementary materials to support students' abstract thinking and promoting their conceptual understanding. Also, some teacher mentioned that educational computer games can be used for students' adaptive learning after school.

Table 3. Teachers' perspectives regarding the use of digital educational games in science classrooms

		N (%)
Advantages	Encouraging motivation	12 (85.71%)
	Enriching learning materials	6 (42.86%)
	Students' adaptive learning after school	2 (14.29%)
Disadvantages	Addiction in playing digital games	2 (14.29%)
	Uninterested in other learning materials or teachers' instruction	3 (21.43%)
	Healthy considerations	1 (7.14%)

The science teachers in this study also pointed out some disadvantages of the use of educational computer games in science classrooms. For example, they were afraid that students may have addition in playing digital games. Also they were afraid that students might only interested in the educational computer games used in science classrooms, and uninterested in their teaching or other learning materials. In sum, according to the possible advantages or disadvantages proposed by the teachers, it seems that the teachers might have poor understanding of educational computer games. As a result, they stated surface advantages or disadvantages of digital game-based learning.

3. Conclusions

This study explored elementary science teachers' experiences, attitudes and perspectives on digital games and using digital educational games in science classrooms. The findings of this study may provide some insights for teacher educators or educational game developer. This study revealed more than a half of the science teachers had positive attitudes towards digital games, and most of them agreed with the use of digital educational games in science classrooms. However, only a half of the science teachers had ever made use of digital educational games in their science classrooms. According to the possible advantages or disadvantages proposed by the teachers, it seemed that teachers in this study had poor understanding regarding digital game-based learning. To promote the implementation of digital game-based learning in science classroom, more digital educational games designed for science learning will be needed. Besides, to get deeper understanding regarding digital game-based learning, science teachers should be provided more opportunity to experience digital educational games. Also, teacher professional development regarding DGBL in science education will be crucial.

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Designing a web-based drill game to improve learners' resources classification abilities: A case study

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Abstract: There is still limited research investigated the effectiveness of and mental aspects toward web-based drill games on learning resources classification. The purpose of this study was to design a web-based drill game "Happy Black-faced Spoonbill", to improve learners' resources classification abilities. Content analysis was used to investigate each aspect of motivation, attention, perceived ease of use, and perceived usefulness toward the game owned by students from the interview data. Twelve students of grade 4 to 6 who were randomly selected from a cram school were volunteered in this study to play the game. The findings showed that the drill game could be useful in helping learners to acquire and practice the targeted content knowledge. In addition, providing features of fun, points, and rewards were deemed as important and attractive in game design for obtaining learners' attention and targeted learning outcomes. The game with ease of use and usefulness features could also facilitate students to improve their learning performance, increase their knowledge acquisition, and experience more effective learning.

Key words: Web-based drill games, motivation, attention, ease of use, usefulness.

Introduction

Recently, with prosperous technology, researchers have been interested in the possibilities that game brought to the learning environment [1, 2]. For instance, researchers have found that during game playing, learners were more active and engaged in learning [1, 2], possessed positive attitude toward learning, and displayed better learning performance [3]. It is found that game can be designed to supplement traditional classroom education through satisfying learners' varied preferences and providing opportunities for learners to think and learn in innovative ways and yet at the same time enhancing learners' performance.

According to Alessi and Trollip [3], the feature of drill game is providing useful learning information for repeated practices rather than oral guidance to enable fluency. The practice itself is very important, and as Alessi and Trollip [3] pointed out, "most educational games at elementary level are in fact drills in game clothing." Content knowledge and procedural skills can be learnt through reiteration with support of instructional strategies and principles designed in games. In this study, we have designed and developed a web-based drill game, which aims at facilitating students' learning through repeated playing experience online. Although several studies were conducted to investigate the effectiveness of drill game on learning mathematics [4], limited research

investigated the effectiveness of and mental aspects toward a web-based drill game on learning resources classification. Therefore the objectives of this study were to:

1. Design and develop a web-based drill game, "Happy Black-faced Spoonbill", for elementary-level students in a cram school to play and record the content of interviews.
2. Use content analysis to investigate each aspect of motivation, attention, perceived ease of use, and perceived usefulness toward the web-based drill game owned by students from the interview data.

Methodology

1. Participants

A total of 12 students consisted of 5 female students and 7 male students of 4th grade to 6th grade volunteered to participate in this study. These students came from a cram school in Taoyuan County in Taiwan. All of these students attended the cram school for additional instruction in English, Chinese, and mathematics.

2. Game Introduction and Design Mechanics

2.1 Game introduction

The web-based drill game, "Happy Black-faced Spoonbill" was designed and developed by NTUST MEG Mini Educational Game Group in 2011 for elementary school students. The web-based drill game in this study was designed to be completed within three minutes for a single drill session, where players can choose to repeat the game for several times. Before each player starts to play, they are free to choose whether they want to view or skip the cover story on the main menu, which will take them one minute to complete. The game consists of the following features. First, learning goals are addressed in a specific way that learners know what should be learnt. In the current study, the game contains both content knowledge of resources classification and the features of drill-based learning, which is about repeated practices to maintain learnt content knowledge. Learning goal of the game is that players will be able to learn content knowledge of classifying resources based upon different classifying features, for instance, most medal objects can transmit heat, reflect light in a certain degree, and so on. Besides, the mission of this game expected learners to classify at least three resources for each of six recycle bins (medal, wooden, paper, plastic, glass, and poisonous bins) correctly. The cover story motivates learners to play within a context where Black-faced Spoonbill lives and to participate in tasks described in the mission. The role set as a curious elementary-level boy who attends to the Double Tenth Day to celebrate with friends and in some reasons becomes a Black-faced Spoonbill to help save the environment.

To connect the game goal/mission and learning goal, the player in the game has to search three resources to complete the game missions. The game interface was designed to be simple and intuitive for players to navigate without instructions and technical help. When students login the game, they can see the cover story, rules and mission, main screen for playing, and the ending story, in order. Players are only given ten health points and 180 seconds to complete the mission. When players are in final countdown, the speed of music will be faster until the time runs out. If the time or health points run out, the game is over. On the main screen for playing, players use the mouse to control the bird (cursor) to move around and clip, drag, and classify the scattered resources to the corresponding recycle bin.

The points are shown under each recycle bin so that players can evaluate how well or how poor they are doing at ease. The feedback is prompted at the bottom right corner of the screen with a Black-faced spoonbill's mad face each time when the player classifies resource wrong to a recycle bin. Also, if players classify resources wrong continuously, the health points will decrease to zero. Besides, players are given a badge on the upper right side of the screen every time when they collect more than three objects of garbage for each classification or recycle bin (e.g. medal) as reward mechanics. When the game is over, the score statistics will give performance of an entire play of the player.

Figure 1. The interface of "Happy Black-faced Spoonbill"

2.2 Design Mechanics

The domain knowledge of the game was fall into environmental sustainability, which encapsulates content knowledge about resources classification and conceptual knowledge of the environmental protection related to environmental sustainability issues. 3R, reuse, recycle, and reduce of used materials has been called on as major policies for environmental sustainability [5]. In addition, knowing how to classify resources (garbage and rubbishes) was deemed as the first step for 3R and for reducing the extremely huge cost managed by public sectors. Moreover, providing a vivid environment for young players to engage and notice the importance of protecting our environment was another focus of this game. Following, game factors will be discussed.

In the web-based drill game, graphic representation was used primarily to mimic authentic objects and living environment to arouse students' attention and concern for environmental issues. Using the mouse was designed as the only method for bird's moving and for selecting objects (resources) in this game because it's easy for novice users and nonreaders or non-typists [5]. In addition, the funny storyline was set up with fantasy atmosphere to further stimulate students to envision themselves in a situation of a black-faced spoonbill that faced an environment with varied kinds of garbage and resources around and to engage in the game task. Mainly, the avatar in the game was a bird, which provides an imaginary experience for players to feel fun. The design of the task was set as intermediate level of difficulty following an expert's suggestion so that students can involve in beneficial challenge and obtain content knowledge of resources classification.

Another factor, discovery, was also designed for players to move around with their cursor on the screen, which encourages them to discover new scene and resources within the main screen.

3. Procedure and Data analysis

At the beginning of the study, participants had received an informal instruction individually for less than 5 minutes about basic features of different kinds of resources, such as medal, wood, paper, plastic, glass, and poison, so that their prior knowledge about resources classification could be controlled as comparably similar to each other. Basic features such as glass as fragile, medal as malleable, and so on were introduced. Then, the students were invited to play the game individually. Following the first trial of the game was an interview conducted to probe players' feedback and understanding toward the game. The reason that interview was adopted in this study was because participants are not able to recognize the 'right' classification and the survey results can not reflect their true behavior, cognitive process, and error patterns [5].

Interview questions were designed to probe different aspects of motivation and attention. For motivation, major questions prompted, 1) Do you like this game and why? 2) Which part of this game you think is interesting and why? 3) Through this game, would you like to learn resources classification better? For attention, major questions included, 1) Were you diffused or concentrated while playing the game and why? 2) What was the most appealing part of the game to you and why? 3) Did you notice the cover story/main playing screen/score statistics and why?

Then each student was asked whether they want to play again the game. The treatment stopped whenever they required quitting the game. Following the game was a second interview session conducted to probe the players' perceived ease of use and usefulness toward the game. Major questions for perceived ease of use and perceived usefulness were, 1) Do you think this game was easy or hard to handle with and why? 2) Do you think this game was helpful in learning resources classification and why? The interview sessions lasted within 30 minutes.

Content analysis was utilized to analyze students' responses to the interview questions. After reading every single response from the 12 participating students and organizing the responses into systemic categories, two coders (researchers) coded each response to each question accordingly. The coders read all of the responses first, coded important keywords until categories emerged from similar codes, and discussed and reached consensus in categories and criteria. Their inter-coder agreements for these analyses were assessed and reported as greater than 0.80. In addition, the two researchers discussed the discrepancies and achieved the final level of agreement.

Results and Discussion

All participants were free to decide how many times to play the game during fifteen minutes so that students had enough time to explore on the game. Students' responses to the interview questions after they finished the game were categorized and summarized in Table 1 to Table 4 based upon main four perspectives, students' motivation, attention, perceived ease of use and perceived usefulness toward the game, consecutively. All numbers in four tables were only represented as the frequency and percentage of agreement to the corresponding question/dimension. For instance, if one boy agrees that he was alert by the main screen, then his response will be counted as one. Besides, The mark of * in Table 2 and Table 3 indicates each sub-category underneath the main category

consists of one question. That is, it consisted of 3 different questions for the main category, *Intensiveness* in Table 2, while there were 2 questions for the main category, *Clear and Understandable* in Table 3.

1. Motivation

The study categorized four main aspects of motivation toward the game, such as fun, fantasy, challenge, and learning based on interview data as well as literature review [3]. As students were asked to describe the reasons why they wanted to replay the game, it is found that all students experienced fun in the web-based drill game, except for one girl as shown in Table 1. For example, student #s04 mentioned, *"The game is fun. I like the game because it's more interesting during class.*" Besides, student #s05 described, *"I think the cover story is fun because it can make the whole class laugh*" Also, student #s07 indicated, *"The cover story teaches me about garbage classification and makes me feel the game following (the story) will be fun and hilarious.*" The game offers interesting and novel contexts that stimulate students' motivation to explore unknown environment. Players with fun experience may be more immersed in the learning environment provided by the game. The characteristic of fun proved to be major motivation for students to play and learn.

In this study, all the students played the game at least twice and were motivated to take up challenge. 67 percent of students mentioned that they wanted to play again because they were not satisfied with their performance in the previous trial. For example, student #s09 indicated, *"Since I didn't figure out how to play it well, I did not play it well at the first time. But I really desire to try again once I have the previous experience*." Also, student #s06 pointed out, "*I want to try again, because I want to break the record!*" It is worth of notice that comparably more boys than girls mentioned challenge as a main factor, which motivated them to play the game. During the first trial of the game playing, students may have some unclear concepts in resources classification. However, students may benefit from the following trials to notice and correct their mistakes. The triggered element of the game, challenge, can also be found in students' intention to compete against oneself. For instance, both student #s08 and student #s12 mentioned, "*I want to try again to see if I can make great progress next time*."

58 percent of students described their game playing experience as a novel one which is different from the real world. For example, students mentioned that the feeling of fantasy from the cover story and role-playing experience aroused their interest in playing the game. Student #s08 pointed out, *"It is incredible that a bird can pick up the trash!*" In addition, Student #s09 mentioned, *"I think it is a lot of fun when I saw the bird in the cover story. I wonder what I am going to play later on.*"

The experience of learning was shown to be another dimension of motivation while playing the game. Students did enjoy playing the game and learning when they sense their progression. As show in Table 1, all students mentioned that they were motivated to learn better on resources classification after playing this game. However, the experience of confronting ill-equipped problems will decrease students' motivation. Student #s01 pointed out, *"I do not have confidence in operating that (mouse) better because that (mouse) is hard to control for me*." Student #s05 also mentioned, *"I think this game is alright but the mouse is hard to control."*

Table 1. Frequency and percentage of the motivation toward the game

	Fun	Challenge	Fantasy	Learning
Girls	4 (80%)	2 (40%)	3 (60%)	5 (100%)
Boys	7 (100%)	6 (86%)	4 (57%)	7 (100%)
total	11 (92%)	8 (67%)	7 (58%)	12 (100%)

Note: n=12 (Girls: 5; Boys: 7)

2. Attention

To investigate players' attention toward the web-based drill game, the interview data were closely examined and compared with findings in the literature [6] and finally coded into three dimensions, which are, 1) distribution (diffused versus concentrated); 2) selectivity (the "what" of attention); 3) intensiveness (alert versus inattentive). As shown in Table 2, there was only one female reported that she was in a medium level of concentration, while most of other children reported that they were concentrated during the play. Among them, one girl #s02 and one boy #s07 mentioned that they were concentrated because the game was fun. Besides, one girl #s04 and two boys, #s09 and #s11, were concentrated because of focusing on classification itself. For instance, student #s04 said, *"I was concentrated since I would like to classify more and reduce the frequencies of my classifying wrong."* Also, student #s09 indicated, *"I was not diffused because this is a classification game and I need to focus on the classification."* Student #s012 revealed, "The reason I was concentrated was because of the homework I have not yet finished."

As for the "what" of attention students had, there were 42 percent of students mentioned that the main screen was appealing to them while there were also 42 percent of children said that it was the classification and statistics areas attracted their attention. For example, student #s02 indicated that the game provided a sense of adventure especially when the bird was flying. A male student even asked, *"It was most appealing to me why the bird can catch the garbage."* The same importantly, students who mentioned that the classification and statistics areas attracted them were those who care about goal and performance achievement. For instance, student #s11 said, *"The most appealing thing to me was that if I can get the score I will be happy."* Even though the number of mentioning the cover story as their selectivity was comparably low, 20 percent of girls and 14 percent of boys still mentioned that the cover story was fun, interesting, and creative. A possible reason that most students did not select the story as their major choice for attention could be their disfavor of birds' droppings in the cover story. As for gender difference, it was found that comparably more male students were appealed to the classification and statistics areas. The findings of intensiveness were parallel to the selectivity of attention as mentioned above. All students were alert by the main screen area and 92 percent of students were alert by the classification and statistics area.

Table 2. Frequency and percentage of attention toward the game

	Distribution	Selectivity			Intensiveness		
	Concentrated	Story	Main screen	Statistics	Story*	Main screen*	Statistics*
Girls	4 (80%)	1 (20%)	3 (60%)	1 (20%)	4 (80%)	5 (100%)	4 (80%)
Boys	7 (100%)	1 (14%)	2 (29%)	4 (57%)	5 (71%)	7 (100%)	7 (100%)
Total	11 (92%)	2 (17%)	5 (42%)	5 (42%)	9 (75%)	12 (100%)	11 (92%)

Note: n=12 (Girls: 5; Boys: 7), * indicates each sub-category consists of a question.

3. Perceived Ease of Use and Perceived Usefulness toward the game

3.1 perceived ease of use

To evaluate students' perceived ease of use toward the game, the interview data were finally coded to three dimensions: easy to handle, intuitive design, and clear and understandable. As shown in Table 3, it was found that 58 percent of students expressed that the game was uneasy to handle with. Especially, student #s09 mentioned, "when I

was moving the mouse, sometimes the cursor on the screen will leap out if my movement was too big." Only 42 percent of students thought that the game was easy to handle with. For instance, a male student #s08 said, "it's easy to operate and there is no reason…there is no problem for me to control the bird using the mouse."Girl #s02 said, "It's easy since I played it for three times and I get used to it, so there is no problem for me." It seems to be a problem that students encountered obstacles in controlling the mouse. Especially, a boy #s06 said, "Actually I understand how to handle (it) but the mouse is too big for me…it will fall down if I didn't control it well."

As for the intuitive design of the game, 67 percent of students agreed that the game design was intuitive. For example, male student #s12 indicated, "Because the beak clipart looks just like the tool for holding the resources." In addition, all students expressed that the rules and score statistic areas were clear and understandable. Boy #s12 said, "It's easy for me to understand because there are numbers shown over there and it's clear." When asked about level of difficulty of the game, 17 percent of students said it was very easy, 67 percent of students said easy, and 17 percent of students said the difficulty is moderate.

Table 3. Frequency and percentage of perceived ease of use toward the game

	Easy to handle	Intuitive design	Clear & understandable	
	Easy	Agree	Rules & missions*	Statistic*
Girls	1 (20%)	3 (60%)	5 (100%)	5 (100%)
Boys	4 (57%)	5 (71%)	7 (100%)	7 (100%)
Total	5 (42%)	8 (67%)	12 (100%)	12 (100%)

Note: n=12 (Girls: 5; Boys: 7), * indicates each sub-category consists of a question.

3.2 Perceived usefulness

To evaluate students' perceived usefulness toward the game, the interview data were coded into three dimensions. As shown in Table 4, three dimensions mentioned above are: performance improvement, knowledge acquisition, and comparison of learning effect. First of all, all students reported that the web-based drill game would improve their learning performance. For example, student #s04 mentioned, *"The game will help me learn. Once something I did wrong the first time, I understood that it was not belonged to the category that I thought previously. Therefore, I would try to think whether it belongs to another category and try it again to see if I classify it right this time."*

As for knowledge-acquisition, which can be referred to knowledge learnt and acquired from game playing experience, all students except for one girl mentioned that they understood the principles of classification more clearly and gained some new concepts of classification. For example, student #s06 mentioned, *"The game helps me understand what kind of resources would be harmful to the earth…for example, battery within the poisonous category."*

Finally, as we asked students to further compare the effectiveness between their previous learning experiences of resources classification with the experience of the current game, 33 percent of students mentioned that they experienced equally effective, and 58 percent of students regarded the game as more effective. Student #s12 mentioned, *"When comparing with my previous learning experience, this game was more effective. Because the game contains more resources and it seems to have more classifications, I think it's even harder and that's why it is more effective."* Also, student #s04 pointed out, *"Compared to in-class learning, this game was more effective because the textbook*

consists of more text than pictures usually. So I did not want to read. Therefore, I thought this game to be more fun and I will be more likely to learn through it."

Table 4. Frequency and percentage of perceived usefulness toward the game

	Performance improvement	Knowledge acquisition	Comparatively more effective
Girls	5 (100%)	4 (80%)	4 (80%)
Boys	7 (100%)	7 (100%)	3 (43%)
total	12 (100%)	11 (92%)	7 (58%)

Note: n=12 (Girls: 5; Boys: 7)

Conclusion

This paper was intended to examine the learning effectiveness of the web-based drill game through query students' motivation, attention, perceived ease of use, and perceived usefulness. From the interview data, we found that the web-based drill game could be useful in helping learners to acquire and practice the targeted content knowledge. Firstly, players with fun experience may be more immersed in the learning environment provided by the game. Also, the fantasy context provided by the game was found to be significantly attractive to students to learn content knowledge. As for players' attention toward the game, most children reported that they were concentrated during the play. The game therefore seemed to be able to catch players' attention. About the selectivity of attention, 42 percent of students said it is the main screen for playing, while there were also 42 percent of students mentioned that the scores statistic area was most appealing to them. It was also found that the classification and statistics areas attracted comparably more boys than girls. As a result, providing fun, points, and rewards thus seemed to be important and attractive in game design for obtaining learners' attention and targeted learning outcomes. Last but not least, the game with ease of use and usefulness features could facilitate students to improve their learning performance, increase knowledge acquisition, and experience more effective learning. The limitation of this exploratory study is the sample size and the restriction of the data to one cram school only, which limits the generalization of the results. However, the design of the web-based drill game in this study was a prototype useful for future modification.

Acknowledgments

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The Design of Multi-User BCI Game System

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Abstract: The purpose of the study is using the Brain Computer Interface (BCI) device as game equipment to develop a multi-user BCI game system (MBCIGS). The MBCIGS includes a multi-user management system and three playing modes of BCI games which are a single user exercise mode, a multi-user practice mode, and a multi-user gaming mode. The multi-user management system is to handle the connection and the message transmission between players, while the three modes of BCI games are to offer the players using BCI devices from the status of practicing to competition. The MBCIGS uses a MindSet as BCI device, an Electro Server as the multi-user platform, and Flash software as client game developing system. Several suggestions are presented in the study.

Keywords: Brainwaves, Brain Computer Interface, Multi-user, Game Design

Introduction

With the rapid development of technology, Brain Computer Interface (BCI) in recent years has been one of the key research agenda. Traditionally, record and analyze brain waves are to use a large measurement machine. As the BCI technology becomes more mature, the way to measure brain waves is not limited to space and size constraints, but emphasizes the use of convenience and comfort in the increasingly widespread. Early BCI uses mainly in people with disabilities so that they do not need to rely on peripheral nerve and muscle, and can send commands through the brain to communicate with the outside world (Pfurtscheller, Guger, Müller, Krausz, & Neuper, 2000). However, because of the new BCI development, applications of today's brain wave research are not only for specific disabilities, but extend to learning and entertainment purposes (Crowley, Sliney, Pitt & Murphy, 2010; O'Hara, Sellen & Harper, 2011). In particular, many studies（Ko, Bae, Oh, & Ryu, 2009; Yoh, Kwon & Kim , 2010; Ryu, 2010) have used mobile BCI devices to develop brain wave games, such as the MindSet headset. The current technology in the single user electroencephalogram (EEG) measurement is not the problem, but multi-user brain wave detection as well as multi-player games in using BCI devices is still needing to be overcome. Therefore, this study proposes a systematic framework to simultaneously detect multi-user brain waves, and to apply to multiplayer games in order to provide a new development direction.

Related work

The function of a BCI is primarily through the use of electronic devices to receive and analyze the brain waves, including δ、θ、α and β. It usually consists of three parts: signal acquisition、signal processing、and device commands (Wolpaw, Birbaumer, McFarland, Pfurtscheller & Vaughan, 2002) (Fig.1).

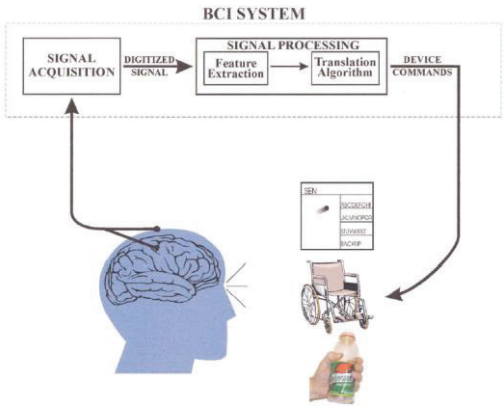

Figure 1 The basic structure of a BCI (Wolpaw et al., 2002)

Because of its special brain-computer features, the applications of using BCI technology have been widely used, such as electronic prosthesis, electronic driving, and emotional cat ears (Pfurtscheller et al., 2000; AutoNOMOS, 2011; Neurowear, 2011) With the same features and more convenient, the MindSet headset (NeuroSky, 2011) also plays a significant substantial advantage in BCI domain application.

The MindSet is non-invasive EEG equipment, and can detect the brain's state of focus and relaxation. With a dry electrode sensor placed on the human forehead, and the reference electrode and circuit ground systems placed in the left ear, the MindSet uses dry - electrode sensors to collect the biological brain signals (α, β, γ, δ, θ-wave), and sends the collected signal into ThinkGear chip, The ThinkGear then filters and amplifies the desired signal, and output to the computer through Bluetooth devices for future application. Crowley, Sliney, Pitt and Murphy (2010) found that the MindSet headset could be a measure of the level of the instrument for focus and relaxation in the Tower of Hanoi called the color test. Ko, Bae, Oh and Ryu (2009) used the MindSet to develop a brain wave game which includes practical and game mode in a single user environment and indicated the value of mobile BCI devices. Base on the needs of user interaction excitation, Alchemytech (2011) offers Zigbee synchronized brain wave evaluation system to asses multi users' brain situation. However, the Zigbee system is only to provide state of brain wave of the observing people, and cannot provide the interaction between users. Thus, in this paper we propose the design of a multi user BCI game system (MBCIGS) to enhance the effectiveness of users' interaction in MindSet gaming environment.

System design of MBCIGS

The MBCIGS system is a client-server multi-user game platform system. The Socket server uses Electro Server 5 (Electro Server, 2011), the client software is to use Flash CS5 with ActionScript 3 (Fig. 2). The function of the MBCIGS system allows users to observe their own as well as others real-time status of brain waves, and to process interactive brain game with each other. The structure of the MBCIGS system consists of two parts: zone and room. There are two kinds of zones: lobby and gaming zone in the system. The lobby is a tutorial system for novel users. The gaming zone divides into three rooms: single exercise mode, multi-users practice mode, and multi-users gaming mode. The single exercise mode is a room where the user can exercise and observe their status of brain waves through the MindSet headset (Fig. 3). The multi-users practice mode is a room where multi-users can practice each other MindSet headset and view their status of brain waves (Fig. 4). Finally,

the multi-users gaming mode (Fig. 5) is a room where multiple users can play game through each other MindSet headset and comparing the values of their brain waves.

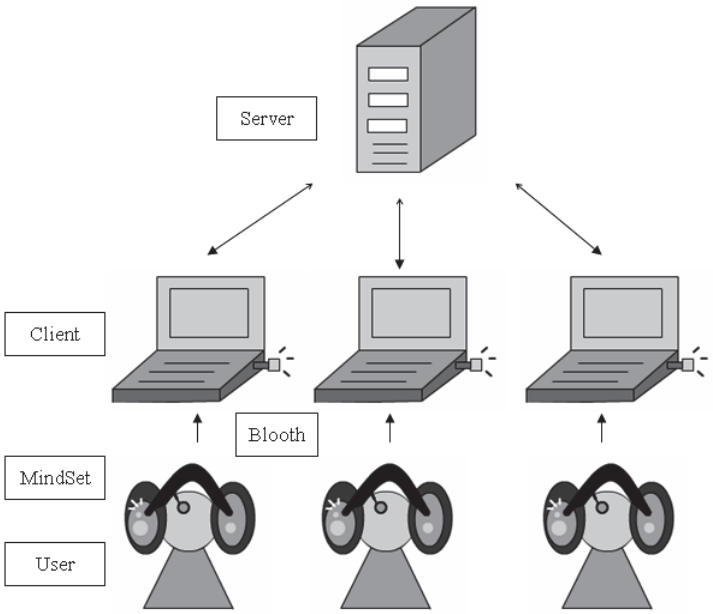

Figure 2 The system structure of MBCIGS

Figure 3 Single exercise mode

Figure 4 Multi-users practice mode

Figure 5 Multi-users gaming mode

The users could login into the MBCIGS system and choose any zone and room to practice their concentration and mediation using MindSet headset. This system, with individualized BCI functions and internet-based multi-user interactive features, will enhance the ability of the learning and gaming activities in the future application.

Conclusion

In order to achieve multi-user BCI game system, the study proposes a feasible solution. In this scenario, the MBCIGS integrates the MindSet brainwave headset, Flash software and Electro server to allow users to practice their learning ability of concentration and to interact with each other through the internet. Because of the hardware detection limitation in the traditional BCI application, the MBCIGS system could expand BCI applications, especially for users in the interactive use of incentive and interest environment, to enhance future learning.

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Save the forests: A pilot study of a role-playing game for environmental education

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Abstract: The purpose of this study was to explore the potential of a PC-based role-playing game for teaching the subject of forest preservation. Four elementary students participated in this case study. The observation and interview were implemented to collect their gaming behaviors and feedbacks about the perceived ease of use, perceived usefulness, and the design elements of the game. The results showed that students viewed the game as an easy and useful learning tool that fulfilled major game characteristics. Suggestions were proposed for the design of the game and future research.

Keywords: Game-based learning, role-playing game, RPG, environmental education, forest preservation

1. Introduction

What makes role-playing game (RPG) attractive is that it provides a unique space where players play the game through the eyes of a game character to experience the virtual world following the storyline of the game. Role-playing has been viewed as an important strategy that allows students to learn a complex issue from different perspectives by playing different roles [2]. Combing with gaming environment, the RPG can be a fun and situational context that engages students to practice given roles embedded with diverse knowledge and values. Currently, the popularity of massively multiplayer online role-playing game (MMORPG) has drawn researchers' attentions to explore its potential for learning [4]. Unfortunately, it is difficult to develop an educational MMORPG with limited budgets, people, and time in educational context because of its complexity of design. On the contrary, a single-player PC-based RPG will be easier to develop by using game authoring tools. Also, it might be easier for teachers to integrate a PC-based RPG to their curriculum because of its limited scale and easy management of students' learning. Even without providing interactions among players, a PC-based RPG that featured with storytelling, premise of the fictitious reality, and narrative experiences can still engage players to the game context and the role they play [5, 7]. However, the potential of using PC-based RPG for learning seems to be overlooked. It is necessary to examine the feasibility and effectiveness of employing PC-based RPG as a learning environment.

With the increasing destroy and threats to the natural environment, how to protect it and achieve sustainability become a critical issue all over the world. The curriculum guidelines of environmental education (EE) for primary schools in Taiwan stress the need for students to understand the relationship between human and the environments, and to develop appropriate attitudes, values, and actions toward the environments. However, most of the content provided in the textbook is factual knowledge with limited scope and provided to students usually by lecturing. Students might be able to remember some factual knowledge but whether they can connect the knowledge to their daily life and develop

adequate values and attitudes are remained questionable. As stated by researchers, role-playing that combined with a simulation or a game could present students with an authentic and situated learning environment that promotes students' understanding of knowledge and values from multiple perspectives [6]. With the attractive feature of fantasy storyline, RPG might be a good way to motivate students' learning and make learning relevant to their life both in knowledge and attitude. In this study, a PC-based RPG was developed for environmental education, specifically on forest preservation which is closely related to our lives. The purpose of this study was to pilot test the game empirically and evaluate the degree of acceptance and design factors of the game.

2. Methodology

2.1 Participants

Four elementary students voluntarily participated in this pilot study. Because the game was originally designed for 3rd to 6th grade elementary students, participants across different grades were recruited to test the game. The background information of these participants is shown in Table 1.

Table 1. Background information of the participants

	Player			
	1	2	3	4
Gender	Female	Female	Male	Male
Grade	6	4	5	3
Age	12	9	11	8
Game experience [a]	Moderate	Moderate	Experienced	Inexperienced

[a] The students' game experience was identified based on their own descriptions of game playing history and frequency during the interview.

2.2 Research Design and Procedure

This study employed a case study design to test the feasibility of a self-developed educational game. Observation and interview were conducted to collect individual student's game playing process and feedbacks.

The parents of these students were informed the aim of the study first and the students were arranged to play the game individually. Before they started to play the game, each student was given a short instruction of game operations. The playing process of each student was observed and noted in details including time spent and reactions toward dialogues and attacks. Students were expected and encouraged to complete the assigned game tasks by themselves. Assistance was only provided when students had difficulties to continue the tasks. After each student achieved the game tasks, an interview was conducted to assess students' learning outcomes as well as collect their opinions about the game.

The main interview questions were divided into three parts to evaluate "perceived ease of use," "perceived usefulness," and "game design elements." The first two parts were based on the Technology Acceptance Model (TAM) [3] and the third part was drawn out from the essential factors of game design illustrated by Alessi & Trollip [1]. The interview structure and example questions are listed in Table 2.

Table 2. Interview structure and example questions

Structure	Description	Example Questions
Perceived ease of use	Students' perception about whether it is easy for them to play the game.	Do you think you went smoothly in the course of the game? Did you encounter any difficulty during the course?
Perceived usefulness	Students' perception about whether the game could help them to achieve learning goals.	Did you learn how to protect forest before? Does this game help you to learn (more about) how to protect forest? What are the ways to protect the forest that you learned from the game?
Game design elements	Students' feedbacks toward each element. The elements include goals, rules, competition, challenge, fantasy, and entertainment.	Do you think the game is challenging? What do you think about the degree of the challenge (too difficult, appropriate, or too simple)? Please describe briefly about the challenges you faced in the game and to what degrees the challenges were.

2.3 Game Description

In this study, an authoring tool – *RPG Maker™XP* – was used to develop a PC-based RPG named *Forest*. The game was designed for 3rd to 6th grade elementary students. The only pre-requirement of the players was basic level of Chinese reading ability.

Both gaming and learning aspects were taken into account when the game was designed. First, to immerse students in a situated learning context, a background story was provided at the beginning of the game:

"Forest" is a wizard kingdom of the trees that coexists with human world since ancient times and provides rich woods resource for human life. However, with the increasing demand of woods by human, the woods resource has been overused. While the forests are excessively destroyed in human world, the Glory Tree that supports the life of "Forest" is dying at the same time. The elder elf foresees that the "Forest" will cease to exist in one year. When that happens, human world will be vanished too. The only way to avoid this disaster is to bring back Green Leaves from human world to save the Glory Tree.

In this game, the participants played the role of Essen, who was born to save the "Forest" and human world. Essen was accompanied by Green Wizard to carry out the tasks (i.e., finding Green Leaves in human world). Green Wizard was set to follow Essen's movements automatically. When encountering attacks, a player could control Essen and Green Wizard separately to make a fight.

Second, the content and tasks were designed for students to gain knowledge about forest preservation by achieving the game tasks. Mechanisms of task guiding and task performing were employed to facilitate students' learning. In RPGs, text-based communication is the main channel for players to get information and task guidance. Two types of communication were adopted in this game: one-way knowledge delivery and interactive dialogue (see Figure 1). When the former one was used, the whole piece of learning content was displayed directly in the text box. For example, "*Some people call the forest 'lungs of the Earth' because the trees will absorb large amounts of carbon dioxide for photosynthesis to produce oxygen and to help regulate the temperature of the surface environment*." When the latter one was applied, the learning content was embedded in the dialogue that players would have to obtain the information by conversing with non-player characters (NPCs). The example is as following.

Essen: *Excuse me, sir! What can we do to protect trees from being overused?*
Expert: *Well ... I would advise you to reduce the demand for wood.*
Essen: *How to do that?*
Expert: *For example, we do not have to always buy new furniture or wooden items. I like to help my neighbors to fix their wooden furniture so that they can use it for a long period of time.*

(a) (b)

Figure 1. The screenshots of text-based communication: (a) one-way knowledge delivery; (b) interactive dialogue.

The first reading of each learning unit would be rewarded with experience points that could help increase the level of the game character. The mechanisms of task performing defined the actions needed to achieve the tasks. The matching learning goals, game goals, and mechanisms of *Forest* are listed in Table 3.

Table 3. The design of learning mechanisms

Learning Goals	Game Goals	Mechanisms	
		Task Guiding	Task Performing
Learn basic knowledge about forests			
-Functions	Find "Knowledge Palace" in "Forest". Hit and read all items that embedded with target knowledge so that Essen and Green Wizard can go to the human world to find Green Leaves. (Required task)	One-way knowledge delivery	Find places & Hit items
-Elements	Talk with NPCs in "Forest" to learn about anion and phytoncid. (Optional)	Interactive dialogue	Meet NPCs & Activate dialogue
Learn applied knowledge about protecting forest resource	Build a resource center in human world by inviting three experts to work in the center, and then talk to key NPCs to find a Green Leaf. (Required task)	Interactive dialogue	Find NPCs following directions & Activate dialogue
	Talk with NPCs to learn more about the ways to save forests. (Optional)	Interactive dialogue	Meet NPCs & Activate dialogue

Third, enemy attack was built in the game to provide challenging and exciting experience for students as well as connections with learning goals. Most of the attacks were invisible and triggered randomly by the system. The enemies were either tools or machines that would destroy the forests (e.g., axe, tree-cutting robot, fire-spraying robot, paper-eating machine) (See Figure 2). Fighting with the enemies meant saving the forests. In addition, anion and phytoncid were designed as items that players could collect by winning the fights or from treasure boxes. The mechanisms of anion and phytoncid in the game were similar to their functions in real world that players could use anion and phytoncid to supply blood (i.e., life) and power (i.e., energy) of Essen and Green Wizard respectively.

Figure 2. The screenshot of fighting with a tree-cutting robot in the forest

3. Results and Discussion

3.1 Overview of game playing process

An overview of each student's game playing process is illustrated in Table 4.

Table 4. Overviews of the students' game playing process

	Player			
	1	2	3	4
Total Playing Time (min.) [a]	91	105	94	96
Number of Failures [b]	1	0	2	0
Interaction with NPCs [c]	38 of 48	36 of 48	42 of 48	41 of 48
Battle Frequency [d]	51 of 58	38 of 68	55 of 65	20 of 59
Needed Assistance	Direction	Direction Task Operation	Direction Task	Direction Task Operation Attack

[a] The rest time during the game was not calculated.
[b] The number of "game over" occurred when the main characters failed to survive from the attacks.
[c] The number of NPCs activated by the players among all NPCs.
[d] The number of fights executed by the players among all triggered attacks.

The average time of game playing is 96.5 minutes. The observation showed that all students were attracted to "talk" to more than 75% NPCs in this gaming context. This indicated a great possibility to deliver learning content through NPCs. Generally speaking, students could complete the game tasks without replaying the game too many times. However, all of them need assistance to some degree in different aspects. All students faced

some problems of finding right directions to the target places. Task-related clues were also provided to most of the students when they did not know what to do in the next, forgot the task, or missed key NPCs or items. It was observed that the younger the students were, the more the frequency and types of guidance were needed when they played the game for the first time.

3.2 Perceived Ease of Use

All students agreed that the game was easy to operate and play. It was also easy for them to get familiar with the game except Player 4, who had the least game experience among the four students. It was obvious from the observation that Player 4 needed more help in finding target places and items, and took longer time to learn the fighting mechanisms.

3.3 Perceived Usefulness

Students' perceptions about usefulness of the game are reported in Table 5. All the students were also asked to recall as much as they could about the knowledge they learned from the game. Player 4 was a special case that he did not perceive the game as useful in all knowledge learning. As stated by Player 4, he remembered seeing the information somewhere in the game but he did not learn the knowledge. The following analysis was based on the rest of the students.

The basic knowledge about forests was embedded in the "Forest" that students would learn from the first half of the game. Students perceived usefulness differently when learning basic knowledge. All three students had learnt functions of the forests previously and thought the game would help them to enhance formerly studied knowledge and learn new one as well. However, only Player 1 and Player 3 could recall two of the six functions roughly. As for learning the knowledge about elements (i.e., anion and phytoncid), only one student thought the game was useful. Yet, all three students could recall the gaming functions of the elements used in fighting.

Table 5. Students' perceived usefulness of the game to achieve learning goals

		Player			
Learning Goals		1	2	3	4
Basic Knowledge					
Functions	Prior Knowledge	Yes	Yes	Yes	No
	Usefulness	Yes	Yes	Yes	No
Elements	Prior Knowledge	No	No	Yes	No
	Usefulness	No	Yes	No	No
Applied Knowledge					
Forest protection	Prior Knowledge	Yes	Yes	Yes	No
	Usefulness	Yes	Yes	Yes	No

Students were set to learn the applied knowledge about forest protection after they entered the human world. These students talked to most of the NPCs whether those were required or optional ones. They all agreed that the game helped them to learn more about the ways to save the forests. All of them could recall the basic concepts of this applied knowledge such as reuse of the paper and wooden products. It was found that Player 1 could remember the most of the application methods while Player 3 could sometimes describe the learning dialogue in details in addition to recall of those methods.

The above findings suggested that students who were elder or had more game experience could benefit more from this role-playing game. This might be because they had

better reading comprehension, or they could pay most of their attention on learning content instead of making effort to get familiar with the game itself. Moreover, students could recall more learning content when they were reminded with specific context in the game. This indicated that this role-playing game could enhance students' learning by connecting learning to a situated gaming context.

In sum, three of the four students stated that they would be motivated to learn more about forest preservation in the future because of this game. Students who mentioned learning useful knowledge from the game also stated that they would apply the knowledge learnt in their daily life.

3.4 Game Design Elements

According to the feedbacks from the students, the game tested in this study had clear goals and rules, provided competition and challenge, and satisfied the expectation of fantasy and entertainment. However, among these elements, students' views about competition were different from what was expected for the design. In this game, the competition came from the attacks of enemies. Only one student (Player 2) thought the amount of attacks was appropriate while the rest of the students felt the attacks happened too frequently. However, the data in Table 4 showed that Player 2 decided to run away from about half of the attacks. She stated that the completion of the tasks was more important than winning the fights to get items. It was also interesting to notice that among students who thought being attacked too often, Player 1 and Player 3 still chose to fight with most of the attacks because they wanted to collect more items and checked whether their special fighting skills were increased. On the contrary, Player 4 escaped from more than half of the attacks because he thought it was a waste of time to fight and he did not want Essen to lose blood. The findings indicated that frequent attacks would disturb younger students' gaming and learning process that might cause negative impacts on their learning achievements.

When considering the challenge aspect of the game, it was too simple for experienced player (Player 3), too difficult for inexperienced player (Player 4), but appropriate for students who had moderate game experience (Player 1 & 2). A common challenge for all the students was finding target places or NPCs in a large scene which could not be overviewed in the game window. As observed in their playing process, students were often stuck in the scene before getting some guidance from the researcher. The challenge was even greater for Player 4 that he mentioned the text was too much to read and he had problems of understanding some of the words.

4. Conclusion

The purpose of this pilot study was to explore whether this educational PC-based RPG could help students achieve the learning goals by providing a situated and motivating learning environment for students. The findings indicated that in general, these students reported positive experience of playing and learning in this game. This game was showed to fulfill major game characteristics as stated by Alessi & Trollip [1]. In addition, the game was viewed by the students as an easy and useful learning tool. According to TAM [3], the potential of this game to be accepted for learning was granted. Moreover, the learning of the students seemed to be promoted by this situated gamine context.

Based on the results of this preliminary study, several suggestions in relation to learners' characteristics, game design, and research design were listed as follows:

- *Learners' characteristics:* Reading comprehension might affect learning effectiveness especially for younger students when the learning content was mainly delivered by text format. There is a need to make the reading easier or use other formats of knowledge

representation to enhance the learning of younger students. In addition, previous game experience might also be an important factor to influence students' learning in a RPG that needs to be explored in future studies.

- *Game design:* The results suggested a possibility that students would learn more from interactive dialogue than from one-way knowledge delivery. Future studies will be needed to control possible confounding variables to examine the learning effectiveness of different mechanisms of text-based knowledge delivery in RPGs. To overcome the problem of disorientation in a large scene, a thumbnail could be adopted to help students find target places. Moreover, the design of attacks will need to be adjusted in frequency and mechanism to provide exciting competition without impeding the learning process.
- *Research design:* In this pilot study, all students were only given one chance to play the game. Even though two students needed to re-enter the game after losing the fights, they started the game from the locations they were failed instead of starting from the very beginning. As it was observed, students took about more than one and half hours to complete the game and they all felt tired to some degree during the process. The lack of flexibility for students to decide their playing time and paths might cause the inefficient learning outcomes of a lengthy game, especially for younger students. There are two possible solutions to overcome the problems. First, shorten the length of the game by reducing the scale of the scenes and the frequency of attacks but save all the learning content in the game. How to keep the game challenging and competing will be the issue to consider. The second solution is to allow students to play the game in their own paths and patterns within a given time range. By doing this, methods to collect data sufficiently and efficiently from individual computers will need to be carefully designed.

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From Speaking to Acting - Enhancing Interactivities of Learning in the 3D Virtual Worlds

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Abstract: Some common educational activities being discussed for fitting 3D virtual worlds include the following types: interpersonal role-play, oral production, and traditional lecturing [1]. These examples are discussion-based or dialogue-oriented by heavily use of the text-typing or voice communication tools in the virtual scenarios. To take more advantages of the virtual space for enhancing the learning interactivity, this paper demonstrates an example which addresses the interactivities not only among learners by texting but also between learners and learning context. Through configuring the Activity Awareness (AA) model [2] with our designed learning context and activities for teamwork in computer-supported collaborations, we attempt to explore the possibility of enhancing interactivities in the virtual worlds, e.g., a learning task requiring learners to manipulate 3D virtual objects collaboratively. Rather than using commercial platforms like the Second Life, we develop a lightweight yet dedicated system to implement the experiment. Our study demonstrates that the AA model is more feasible for enhancing the interactivity among learners in the learning environment than discussion-based activity is in the 3D virtual learning worlds.

Keywords: Activity Awareness, 3D Virtual Worlds

Introduction

There has been an increasing research interest of the 3D multi-user environment in education since the MMORPG (Massively Multiplayer Online Role-Playing Game) has been introduced to the world, such as the World of Warcraft (WoW) and Ultima Online. However, educators confront challenges when they try to use this kind of 3D virtual worlds as a supplementary virtual learning material. Traditional 2D web pages with learning content, group video conference, asynchronous forum, email or instant messaging system may need to be reconfigured with a 3D rendering engine. Also, some different mechanism may require being reconsidered for 3D multi-user information sharing and distributing system. Resembling a classic type of lecturing class directly in such a virtual world is an easier and popular way. This method could enlarge the number of audience comparing to the restricted physical classrooms; however, it doesn't certainly increase the interactivity that are important for learning community and learning outcomes among learners in the learning context.

To testify and provide other feasible examples to fill the gap, we conducted the AA model to design a thematic learning activity for compromising with the taking of the 3D multi-user virtual worlds as learning environment. By reviewing guidelines and principles of pedagogies, we combined with educational theories and practical system designs to

establish a collaborative type of learning activity to enhance the interactivity mentioned in the previous paragraph. We implemented a web-based 3D multi-user system, along with a small projectile motion learning activity called virtual parabola festival. The AA model was introduced to design various collaborative learning tasks and system functions in this activity for triggering the interactivity among learners, between learners and the learning context as well as the learning contents. The practice which the AA model could be used to enhance the interaction in the virtual shared activities will be discussed in section 3. Since the platform is created by researchers, the database and the designated learning data could be easily accessed.

Comparing to other similar studies which use existing Second Life or other commercial platforms as experiment environment, our study initiated from the very beginning by asking a fundamental question: What mechanism and principles should be considered for designing a 3D virtual learning system in order to support learning collaborative activities? Not only engaged in theorizing, we also developed a lightweight system for empirical test to confirm the feasibility. We have the experiment executed by the system programmers, educators and testers to verify that the AA models can enhance the virtual learning interactivities in the 3D virtual worlds.

1. Learning examples in the Second Life

Jaeger [1] proposed an evaluation framework for educational activities in virtual worlds based on Media Richness and Task Closure Theories from Management Information Systems. He used three types of educational activities in the Kamimo virtual campus project in the Second Life to find out which type was more appropriate for such kind of learning environment.

1.1 Interpersonal role-play

In this scenario, students were divided into four teams, a buyer team and three vendor teams. Their avatars were gathered in a 3D meeting room for role playing the "Response to Request-For-Proposal" activity. The activity is usually developed in a classroom, and is obviously easy to be represented in the 3D virtual world. Fig. 1 shows that the activity is discussion-based via texting or voice communication. Learners interact with each other rather than between a learner and the 3D learning context.

Fig. 1. Discussion-based activity

1.2 Breaking into conversations

This activity demonstrated how to people interaction in a polite way. The main technique was to have a buddy group discuss a topic and sit around a campfire when another buddy group broke into their conversation in a polite way. Moreover, the interactivity still focused on the learners, leaving out the 3D stage settings, objects, and insignificant elements. The scenario could be implemented by replacing the conference table with a campfire shown on the figure 1.

1.3 Traditional lecturing

Some teachers use the Second Life system to display their slides or teaching materials for students as they do in the physical classroom. It is a way of passive learning since there is bare interaction among learners or between teachers and learners.

The results of Jaeger's study shows that "Interpersonal role play" and "Breaking into conversations" have greater potential to be successfully implemented than "Traditional lecturing" in the Second Life. Although the Second Life provides a universal platform for any possible virtual educational activities, there is still time and space to modify various educational activities each time. That is why we must respond to interactions between the system and activity designs.

2. The Activity Awareness Model to Enhance Interactivity in Learning

Carroll et al. proposed a framework of four aspects for understanding the joint endeavor of activity awareness [2][3], which are all important in computer-supported collaborations: common ground [4], community of practice [5], social capital [6], and human development [7]. Based on the general concept of shared knowledge [8] plus a more elaborate view that includes common beliefs, complementary knowledge, social, cultural, and physical concepts [9], the framework shifts the focus from shared concepts to shared activity, and is helpful for designing technology and enhancing team effectiveness derived from interactivity.

Table 1 summarizes the four facets of activity awareness and gives clearer guidance for designing and developing a virtual learning environment which could effectively enhance the interactivity in learning process.

Table 1: Four facets of activity awareness (Carroll, et al., 2006)

Facet	Description
Common ground	A communication protocol for testing and signaling shared knowledge and beliefs
Communities of practice	The tacit understanding of community-specific behaviors shared through enactment
Social capital	The creation of persistent social goods through networks of mutually beneficial or satisfying interaction
Human development	Innovative behavior or decisions entrained by open-ended, complex problem solving, and evolving skills of both members and teams

Collaborative learning contains social knowledge construction, peer interaction, communication and collaboration; in this research, the framework is adopted as a blueprint for developing and implementing a realistic system.

The common ground may be considered as a communication protocol for establishing the co-existing and situated learning atmosphere for learners to share knowledge and beliefs within, like the players in WoW. The learning context and relevant activities provide an opportunity for a community of practice to develop; through the deployment of sticky learning tasks in various scenarios, learners could communicate and interact with others to achieve social capital, eventually enhancing human development for both learners and their teams.

All above considerations could be easily developed in a physical classroom; however, educators seldom elaborate these facets into the 3D virtual worlds. The reason may due to the lack of system programming skills, burden of learning commercial tools, as well as the control of the platform or cooperation with the commercials; therefore, those leave a question for us to verify that if the AA model is really feasible in such new environment.

3. Design of the System and Learning Activity

A space can only become a place when an understood activity is scheduled or ongoing [10], so does the 3D virtual learning space. We designed a thematic learning activity including series of tasks - the virtual parabola festival, to bring the AA model into practice in our small yet dedicated 3D virtual space named the Best Digital Village (BDV). The main activity is deployed in the virtual buildings as series of tasks in the learning scenarios, and two kinds of tasks are designed: those for individuals and those for team collaboration.

3.1 The learning tasks for individuals to interact with learning context

The scenarios and tasks for individuals are as follows: The Town Hall is the reception and administration center wherein the learners can look up other learners' and team profiles. Team management along with information on the "Honor Roll" and "Score Board" can also be obtained from kiosks in this building. Learners who frequently visit and use the kiosks will receive experience points (EP).

The Community Center is the building where learners gather for a summit or discussion, as well as to counsel each other. Chatting or discussing topics with others will earn charisma points (CP). All dialogues will be recorded in a database and can be output in the form of a reporting document sorted by team, date, week, month, and year for further review and analysis. In addition, joining a discussion in the BDV forum on the web portal for asynchronous communication will also earn extra CP.

The Library in the BDV is used to encourage learners to contribute their knowledge. Learners can recommend or upload the related web links or digital multimedia resources to earn EP, so do those who frequently visit and use the resources in the library. Learners can examine every book shelf or digital facility in the library to gain parabola-related information to better understand the important parameters like velocity and angle in a parabolic flight motion.

In the School, there is a classroom within which a parabola knowledge test for scholarship is held, and learners can take the exam and earn extra EP. They can also discuss the answers in online forums to get more CP. Fig. 2 shows the actual screenshots of each scenario described above.

Fig. 2. Actual screenshots of the scenarios: From left to right, top to bottom: Town Hall, Community Center, Library and the Classroom in the School

The Exhibition Center has various zones using interactive 3D parabola-related objects and artifacts that demonstrate how the parabola formula works and is applied in daily life. Learners who visit these zones and interact with the 3D artifacts to learn more about the topic will get EP, and details of these zones are as follows. Concept Zone: This zone is decorated with posters of parabola mathematics, physics, and formula drafts from historic to scientific factors, and is helpful for understanding the evolution and recalling the calculations related to parabola. Entertainment Zone: This zone shows Frisbee, quoits, fishing rod swinging, and many other entertaining parabolic activities. Learners can click on the objects to see how these games are played. Daily-Life Zone: This zone introduces parabolic applications and phenomena in our daily life. Military Zone: This zone gives details of the ancient and modern weapons using the parabolic flight formula. Learners can click on the vivid 3D models to see how they work. Sports Zone: This zone illustrates basketball shooting, pitching, and many other parabolic games. Learners can click on the sports items to see how the parabola formula is applied. The thematic zones are illustrated in Fig. 3:

Fig. 3. Actual screenshots of the different zones: From left to right, top to bottom: Lobby of Exhibition Center, Zone of Concepts, Life with Parabola, Entertainment, Military and Sports

3.2 The learning tasks for team collaboration to enhance interactivity among learners

In the Exhibition Center, the Innovative Artifacts Gallery allows team leaders hold a brainstorming session to create new ideas by applying what they have learned. They put a blueprint or draft on a web page, including a brief description of the ideas, and then upload the information to the gallery.

All teams are required to score and comment on the other teams' ideas and innovations and initialize "peer reviewing" by clicking on the work of each team on the gallery wall, and earn CP during the process. Domain experts are also invited to examine and evaluate the practicality and creativity of each idea, then give each team extra EP. Fig. 4 shows the interior of the gallery along with the scoring and commenting interface, used in the library scenario for learner-contributed materials.

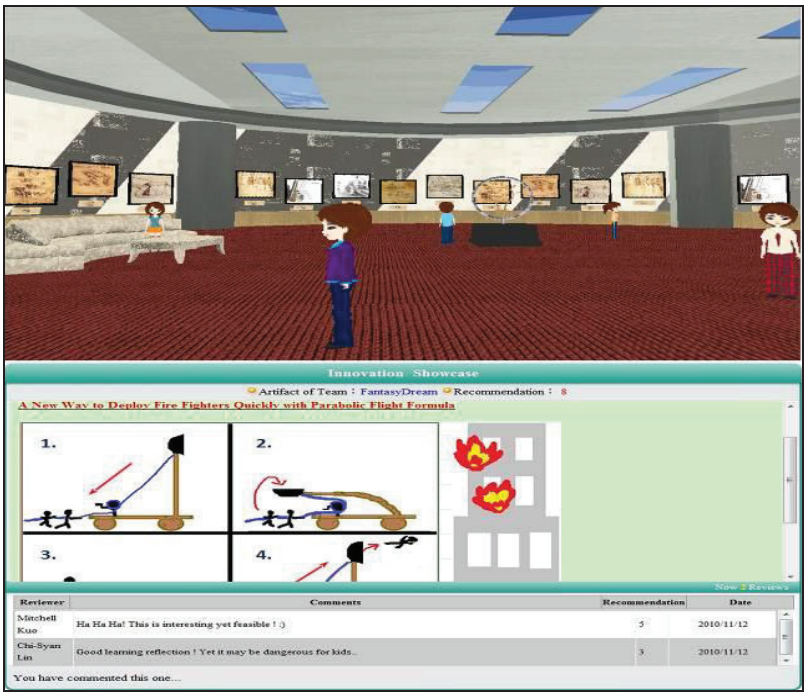

Fig. 4. From top: The Innovative Artifacts Gallery and the interface for peer reviews

The other collaboration task is a catapult simulation game in the Park scenario, which utilizes the virtual game currency as gold converted from EP and CP by rubrics. After all team members earn enough gold, they can get together in the park to play the catapult simulation. Each team involved in the simulation game needs to fulfill the following five roles to coordinate the parameters of the parabola formula. The Commander, played only by a team leader, is responsible for coordinating and negotiating about solutions among teammates; he or she is the only one who can press the "fire" button to launch the virtual catapult. The Observer has binoculars to observe surroundings and is responsible for reporting back the results; the Navigator is responsible for calculating the fire angle parameter. The Controller is responsible for resolving the initial velocity parameter. The Counselor is generally a teacher who can give minor adjustments to the final solution. Thus, a game-based role-playing learning prototype emerges from this arrangement of interactivities, while the learners form a team and achieve a consensus on the solution.

Fig. 5 shows a collaborative firing condition, along with the simulation game flow. The Commander asks for a new target and coordinates teammates to input and confirm the firing parameters. Every time after the commander pushes the button to fire, the observer reports back the position between the target and the point of impact, as well as the firing results, which may be: "perfect," "excellent," "not bad," and so on, each with an appropriate amount of rewarded EP and CP given back to each team member. The team then discusses and decides whether keep playing with the same target until they achieve a bull's eye, or to give up and ask for another new target. The colored blocks in the flow chart represent the processes where interactivity and social capital should occur.

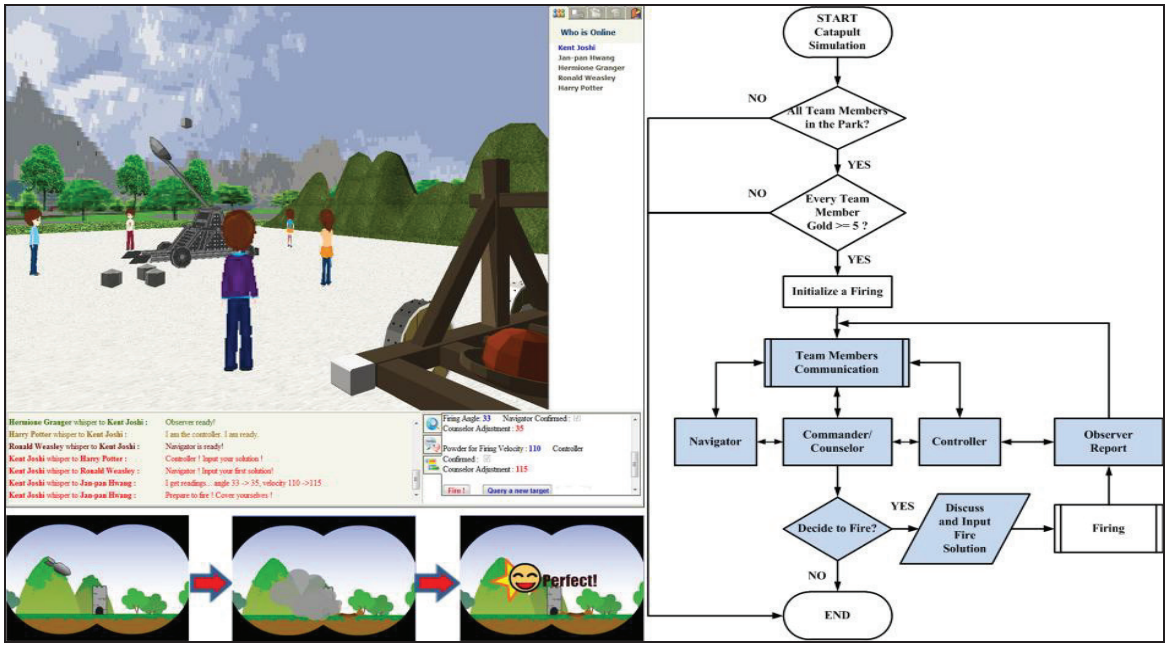

Fig. 5. The catapult game play and the activity flowchart

Discussion and Conclusion

Comparing to the discussion-based activities, the AA model could enhance interactivities among learners and between learners and the learning context in the 3D virtual worlds. Although the AA model is easy to implement and to be testified in a real classroom, it is seldom discussed in the 3D virtual worlds. One reason may be that educators lack the experiences to either develop a complex activity in a commercial platform or learn how to bring the script alive in the Second Life, thus leave the learning context for only background decorated curtains on the stage. We tried to design more interactive activities with our own applied system supports and empirically confirmed that the AA model could be improved and configured for learning in the 3D virtual worlds, not only for science education but also for any other virtual collaborative activities to enhance interactivities in many aspects, increase the bonding of learners, learning context and learning activity, and thus promote the learning performance accordingly.

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Integrating educational computer games in science teaching: In-service science teachers' perspectives

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Abstract: This study explored a group of science teachers' perspectives on integrating educational computer games in science teaching. Through tape-recorded interviews, the participant teachers' perspectives regarding the integration of educational computer games in science teaching were collected and analyzed qualitatively. To ensure the teachers had basic experiences regarding playing science educational computer games, the participant teachers were asked to play a science educational computer game designed for third graders before being interviewed. Some important findings are reveled and educational implications are discussed.

Keywords: educational computer game, science teaching, science teacher

Introduction

Rapid development in information technologies has dramatically influenced the ways of teaching and learning [1]. In recent years, more and more researchers and educators have reorganized the powerful potential of using computers games or online games for educational purposes [2]. As a result, digital game-based learning (DGBL) has been highlighted.

Computer games are powerful educational tools if used appropriately [3]. When using an educational computer game in classrooms, the instructional strategies used by teacher should be crucial for the success of the integration a digital computer game into his/her class [4]. Undoubtedly, teachers' understanding of educational computer games will influence how they make use of this powerful instructional tool. In other words, teachers' perspectives on the integration of educational computer games into science teaching should be one of the important research issues.

In the last decade, more and more researchers paid their attention to DGBL-related issues. However, most of them addressed the effectiveness of the use of educational computer games in students' learning outcomes [4] and their motivation [5]. Not many studies have focused on teachers' understanding or adoption of educational computer games [6][7]. In particular, research aiming to explore science teachers' perspectives on the integration of educational computer games into science teaching. To address this important issue, this study explored a group of elementary science teachers' perspectives on the integration of educational computer games into science teaching.

1. Methods

1.1 Subjects

The subjects of this study are 21 voluntary in-service elementary science teachers (including 9 male and 12 female teachers). Only one of them had a master degree, and the others had undergraduate degrees. Their teaching experiences ranged from three to twenty seven years. The interview has shown that 20 participants have experiences in computer game, only one participant has non-experience.

1.2 Data collection

This study was conducted to explore a group of elementary science teachers' perspectives on the use of digital educational games in science classrooms. To this end, tape-recorded interviews were conducted. To ensure the teachers had basic experiences regarding playing science educational computer games, the participant teachers were asked to play a science educational computer game designed for third graders before being interviewed. This computer game was designed in Hsu, Tsai and Liang (2011) to teach the concepts of light and shadow [8].

After playing the computer game, the teachers were interviewed with the following questions:

(1) What are the differences between educational computer games and computer games?
(2) Are you willing to employed educational computer games in your science instruction?
(3) How will you applying educational computer games in your science classes?
(4) What are the advantages and disadvantages of integrating educational computer games in science teaching?
(5) When employing educational computer games in science instruction, what relevant professional abilities teachers will needed?

1.3 Data analyses

The teachers' narratives obtained from tape-recorded interviews are transcribed. And the data regarding the teachers' perspectives were analyzed qualitatively.

2. Major finding and discussion

2.1 Science teachers' perspectives on the differences between an educational computer game and a computer game

In this study, 12 participants (60%) considered that educational computer games had included science content, principle, learning progress and purpose. For example, a teacher mentioned that "the game of light and shadow is easily to be identified by science educators or experts, but it also invokes young students to think how they pass the game missions by the game's contents."

Besides, the teachers in this study also mentioned some common characters. Six participants (30%) believed educational computer games had included entertaining effect in order to attract young students interested, and provided additional explains and cues to assist players passing the game. Also, 3 participants (15%) mentioned the educational computer game and

a game without education have the same user interface and equipment, such as keyboard and mouse; furthermore, vivid sound and video effects attract young students' learning willing.

2.2 Science Teachers' willing to employed educational computer games in science education

After experiencing the educational computer game, 19 participants (95%) expressed that they were willing to employ educational computers games for young students if the games' contents synchronize class progresses. No participant (0%) disagree that the educational game is a positive medium. Besides, only one participant (5%) did not response in this issue.

2.3 Science teachers' ideal application of educational computer games in science teaching

The teachers in this study mentioned the ideal ways for them to apply educational computer games in their science classes. Their responses are summarized as follows:

(1) *Partly employed the game after teacher explained*: 6 participants (30%) considered to use educational games as a review after teachers' instruction.
(2) *Partly employed the game in a class beginning*: 4 participants (20%) consider that the game has an inducement for young students study firstly.
(3) *Partly employed the game as the assessment after a class progress has completed*: 6 participants (30%) mentioned that educational computer games could be used for assessments.
(4) *Fully employed the game in a class*: Only one participant (5%) mentioned that an educational computer game could be used as a learning activity in science classes.
(5) *Supplementary learning materials*: 1 participant (5%) mentioned that educational computer game could be used as supplementary learning materials.

It seems that the teachers in this study showed diverse perspective on how to use educational computer games in science classes.

2.4 Science teachers' perspectives regarding the advantages and disadvantages of integrating educational computer games in science teaching

Regarding the advantages of integrating educational computer games in science teaching, most participants (50%) mentioned that an educational computer game could be used as a replacement of real world, and it could improve young students' confidence and attention in order to encourage themselves. Some participants (20%) also stated that the educational computer game has improved real condition and preparation. Additionally, it assists teachers to understand young students' characteristic.

The teachers also majorly mentioned three disadvantages of integrating educational computer games in science teaching. The first disadvantage mentioned by the teachers is that integrating educational computer games in science teaching may increase their teaching load. For example, although a class has 40 minutes for students learning, the teachers have to add their extra personal time to prepare and training themselves in order to teach students how to learn by playing the educational computer game. The second one is that students may over-rely on playing educational computer game; and, as a result, they may not be interested in other learning materials or teachers' instruction in the classes. Also, they may

have addiction in playing computer games. It seems that the teachers may think that compare with educational computer games, their instruction is less attractive to their students. The third is that if an educational computer game is not designed properly, students may have alternative conception after playing an educational computer game.

2.5 Science teachers' perspectives regarding relevant professional abilities for integrating educational computer games in science teaching

The relevant professional abilities for integrating educational computer games in science teaching mentioned by the teachers in this study were:

(1) *Specialized pedagogical content knowledge*: All the teachers mentioned about that. It seems that all the teachers in this study viewed the integration of educational computer games in science teaching as a new pedagogy. Teacher professional development on digital game-based learning may be needed.
(2) *Basic computer skills*: All the teachers mentioned about that. It may due to that the teachers in this study may be not confident of their computer literacy.
(3) *Advanced computer skills*: Five out of twenty-one teachers in this study mentioned that if teachers have advanced computer skills they can develop educational computer games by themselves. Such as one participant described that he would probably design a particular educational game for his students by *Adobe Flash*, if he has the advanced technique in developing an educational computer game.

3. Conclusions

This study investigated elementary science teachers' perspectives on integrating educational computer games in science teaching. This study revealed most of the science teachers in this study recognized the educational entity of educational games, and almost all the teachers in this study were willing to integrate educational computer games in their science classes. Besides, teachers proposed diverse ways for using educational computer games in science classes. They also mentioned the essentiality of specialized pedagogical content knowledge and basic computer skills when conducting computer game-based instruction. In addition, a half of participants believe that the occasion of applying educational computer games are partly employed in a class after teacher explained, or as an assessment after a class progress has completed. The finding of this study may provide some insights for teacher educators and educational designers. For example, teacher professional development regarding integrating computer game in science instruction will be needed. Besides, how to prevent students' alternative conception derived from educational games may be another important issue for educational game designers. Therefore, collaborative work from science teachers and educational computer game developers may be crucial of much importance.

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Preliminary Investigation on a Theoretical Framework for Evaluation of Serious Educational Games

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Abstract: We propose a theoretical framework for evaluation of Serious Educational Games based on systematically reviewing available literatures. The framework we introduce consists of four aspects, game features, immersion, pedagogy, and knowledge. Hopefully, the framework could provide a new perspective that helps researchers and educators to better investigate and understand the effectiveness of Serious Educational Games.

Keywords: Serious Educational Games, Game features, Immersion, Knowledge, Pedagogy

Introduction

Play facilitates cognitive growth by providing children with experiences and opportunities to interact with the world. It is a really serious matter, which has been supported by many theories since the beginning of 1870's (Mitchell & Mason, 1935). Play includes many varieties and settings, and video game play might well be the newest and most popular form that has burgeoned recently. Although people usually perceive video game as merely an entertainment media, its potential in education has nowadays attracted much attention as today's learning generation is extremely video game literate and spend much more time playing video games than participating in other learning activities (Prensky, 2001). The idea of Serious Games that advocates the particular use of simulations and video games for training and/or educational purposes has therefore emerged since 2002 (Gudmundsen, 2006), attempting to bridge reality to virtual reality in numerous dimensions and to combine learning with playing to facilitate the occurrence of learning. Thus far, it is believed that the use of Serious Games will become a new wave for technology-mediated learning (TML) in the near future (Tay, 2010).

Serious Games have a broad definition in that both formal and informal settings are included and the subjects consist of all the masses. Annetta (2008, 2010) further defined Serious Games as Serious Educational Games (SEG) to distinguish non-entertainment games specific to K-20 educational settings. In this paper, we propose a theoretical framework for evaluation to preliminarily investigate how we can harness the power of SEG to engage students and improve their learning achievement.

1. A theoretical framework for evaluation

The goal of commercial video games is merely for entertainment, and people generally don't care about what users learn from playing the video games, except those games involving violence or gender issues. However, the main purpose of SEG is for teaching and learning, so how to evaluate their effectiveness becomes a major consideration for educators and researchers. Unfortunately, research that focuses on the evaluation of SEG are quite few so far. Garris, Ahlers, & Driskell (2002) proposed an input-process-outcome model of instructional games and learning which indicates that game features combined with instructional content are a powerful driving force in triggering the game cycles that are repeated cycles of *user judgment, behavior, and feedback,* which engage players in the game play activities. They concluded that game characteristics can be classified into six categories: *fantasy, rules/goals, sensory, stimuli, challenge, mystery,* and *control*. Their model is an elaborate idea that clearly explains how SEG works. However, they did not emphasize on the evaluation of SEG and how to integrate the instructional content with the game features. Fu, Su, and Yu (2009) developed a scale to assess user enjoyment (flow experience) through using SEG as an indicator for understanding the strength and flaw of the game. A total of eight dimensions are included in their scale: *immersion, social interaction, challenge, goal clarity, feedback, concentration, control,* and *knowledge improvement.* It is a rigorous assessment for evaluating the level of enjoyment provided by SEG; however, they overlooked the instructional aspect. We do believe that user enjoyment plays a crucial role in users' ability to learn through SEG play; however, we think there are still other major components that need to be taken into consideration in order to make the evaluation more sound and complete.

In order to better evaluate the effectiveness of SEG, we introduce a theoretical framework that includes four aspects, *game (game features)*, *individual (immersion)*, *pedagogy*, and *knowledge* (Figure 1). We argue that only a game which takes all the four dimensions into account can be considered a good and effective SEG. The four aspects are discussed in detail as below.

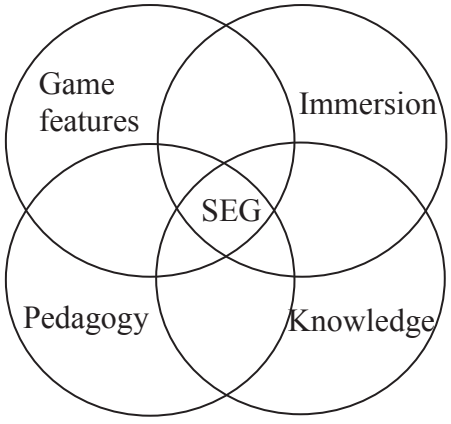

Figure 1. A theoretical framework for evaluating the effectiveness of SEG.

2. Game features

Video games have many unique features that motivate players, and different researchers have different ideas regarding those game characteristics. For example, Malone & Lepper (1987) posited that challenge, curiosity, fantasy, and control are the four important features that intrinsically motivate individuals, whilst Thornton, Cleveland (1990) argued that interactivity should be the essential aspect of a game, and Baranauskas, Neto, and Borges (1999) suggested that the essential game features are challenge and risk (1990). Garris et al.

(2002) argued that although different studies use different terms, these different approaches actually describe similar game characteristics. Therefore, they concluded that any type of games could be described by six key dimensions, fantasy, rules/goals, sensory stimuli, challenge, mystery, and control. Based on these previous studies, we further employ rules/goals, sensory stimuli, imagination, challenge, control, and interactivity as crucial game features for evaluating SEG.

2.1 Rules/Goals

Clear goals and rules should be provided in SEG settings so that the players can know what the ultimate goals of the SEG are and achieve the goals through guidance embedded in SEG. Rules provide SEG with some limitations and players rely on the rules to complete the game. In other words, the rules provide players with scaffoldings to achieve the ultimate goals in SEG. Rules are sometimes set in order to create a specific context in the game, or sometimes they are established as the concepts embedded for learning have particular limitations. Rules also affect the format of competition and as well as the degree of challenge in the games.

2.2 Sensory stimuli

Another reason for explaining why games are so attractive is that games provide players with the distortion of perception. Sound effects, dynamic graphics, dazzling colors, and other sensory stimuli provided by games grab the attention of players, evoke their arousal, and cause great excitement. Hence only the SEG that offers some kind of sensory stimuli would have greater potential in motivating players.

2.3 Imagination

The narratives, scenes, and/or contexts of games are not necessarily real, which provides games with a certain degree of imagination. Because of the feature of imagination, games can simulate specific situations and conditions that are unreal or generally hard to encounter. Imagination allows games to create a virtual world that is separate from real life wherein players are insulated from real consequences. Therefore, players could elaborate their skills and enhance learning outcomes through trial and error without any fear of failure.

2.4 challenge

Challenge of games is related to the degree of difficulty that games provide. If a game is too hard or too easy, players are likely to feel anxious or perceive the game as being boring. Therefore, an effective SEG needs to be designed with different and progressive levels of complexity. Factors affecting the level of challenge of a game include the player's abilities, how much time is allowed to play the games, whether the rules are clearly specified and the competitors formidable, so on and so forth.

2.5 Control

"Control refers to the exercise of authority or the ability to regulate, direct, or command something" (Garris, et al., 2002, p. 451). Hence, games need to provide players with some extent of authority and control over certain elements of the game and be able to perform decision making in the game world. Moreover, an effective SEG should be developed with

an intuitive and friendly user interface so that players can manipulate the objects in the game with minimal frustration. Certain gaming peripheral products can also improve the feature of control as well. For example, using a pedal and a steering wheel makes players feel like they are really driving a car compared to using keyboard and mouse (Cheng, 2009; Cheng, Annetta, Folta, & Holmes, 2011).

2.6 Interactivity

Interactivity plays a crucial role in distinguishing games from other technology-mediated learning forms. Games can provide two kinds of interactivity, human-to-computer and human-to-human. Human-to-computer interactivity relies on immediate feedback provided by the game. The feedback allows players to track their progress and know what to do for the next step. Players can then modify their strategies and review their decisions based on the feedback they receive in-game, so that they can achieve the desired goals successfully. On the other hand, human-to-human interactivity refers to social interactions. Games with functions that allow players to communicate with others provide many opportunities for improving social interactions. Therefore, interactivity allows individuals to actively participate in the learning activity embedded in the game world rather than passively receive the information offered.

3. Immersion

The aforementioned game characteristics have much potential in motivating individuals intrinsically; however, they do not ensure the individual's enjoyment. In other words, players might agree that the games do have certain game features, but they do not necessarily enjoy playing it. Enjoyment is a subjective feeling and hence can vary from people to people. Therefore, we argue that a complete evaluation should also take players' experiences into considerations.

Generally, people would like to use the term 'flow' to describe the state in which individuals are intensely absorbed in an activity. The idea of flow is proposed by Csikszentmihalyi (1990) to describe a positive experience in which individuals perceive a congruence of skills and challenges with a high level of enjoyment and fulfillment. Because this gratifying state is so enjoyable, people are willing to put forth effort to reach and maintain that state, with little concern for their surroundings or what they will be getting out of it, even when it is difficult or becomes dangerous. Csikszentmihalyi concluded a total of nine characteristics of flow: challenge-skill balance, action-awareness merging, clear goal, unambiguous feedback, concentration on task at hand, sense of control, loss of self-consciousness, transformation of time, and autotelic experience. The experience of flow is a major incentive of intrinsically motivated behavior (Schiefele, 2001), which is fundamental to all learning. So far, much research has evidenced that people could experience flow state while engaging in sports, creation, art activities, and even web surfing.

Obviously, video game play provides people with a flow experience in which individuals enjoy and engage themselves as well. Flow is an optimal and extreme state; however, researchers are used to employing immersion instead of flow when it comes to video game play most of the time. Researchers describe immersion as a sub-optimal and non-extreme state as it is the precondition of flow and flow is the extreme state of it. While playing video games, individuals might be very immersed in the gamealthough they might not experience flow (Jennett et al., 2008). Brown & Cairns (2004) employed grounded theory to investigate game immersion, pointing out that immersion actually comprises of three stages,

engagement, engrossment, and total immersion, respectively. They further contended that barriers exist among these three stages, and players will not get into the stage until barriers are overcome. Cheng (2011) conducted a research that has evidenced the three stages of immersion as well; therefore, we employ their definitions of immersion to construct our framework for evaluation.

3.1 Engagement

Engagement is the first stage of immersion. Two barriers, access and investment, should be overcome in order to enter this level. Access refers to the gamers' preference and game controls. In other words, players must like the type and/or style of the game they are playing and feel a congruence of their skills and challenges encountered. Once the game satisfies gamers' preference and game controls, they are going to invest time and efforts into the game. As individuals invest much time and efforts into the game, they gradually become more focused and engaged.

3.2 Engrossment

As gamers become further involved and engrossed with the game, they enter into the second stage, engrossment. There are also two barriers that affect if individuals get into this level or not. First, their perceptions of surroundings and physical needs become lower and their emotions directly attach to the game. While experiencing engrossment, the game becomes the most important part of the gamers' attention, so that they become less aware of their surroundings and less self aware. They might not be able to hear people calling or the conversations around them, and they even don't feel hungry or tired. During that time, players' emotions are affected directly by the game and they feel emotionally drained and empty when they stop playing.

3.3 Total immersion

The final stage is total immersion. Gamers have feelings of presence and empathy while experiencing this stage, and will by now totally lose their self-awareness as if their consciousness has transferred from reality to the game world. They will feel entirely attached to the game characters and empathize with their situations. They will be detached from reality to the extent that they feel like they are actually in the game and the game is all that matters. Total immersion is an optimal, extreme state as flow and it is only a fleeting experience.

4. Pedagogy

Evaluating a SEG from a pedagogical perspective considers the instructional methods embedded in the game for supporting learning processes. We believe that the development of SEG without applying well-established teaching and learning theories may cause failure to meet its desired educational goals, and individuals will then merely be entertained by using the games without obtaining any specific skill and knowledge (Gunter, Kenny, & Vick, 2008). We contend that individuals' learning outcomes through using SEG depend heavily on the teaching and learning theories selected. We discuss the pedagogical perspective in terms of context, representation, prior knowledge, reflection, and transfer.

4.1 Context

For SEG, context affects how the given knowledge represented and the learning resources contained in the game world. Moreover, learning through SEG play may occur in both physical surroundings and virtual world at the same time. Therefore, the interaction between players and their context becomes particularly important when it comes to evaluating SEG (Freitas, Rebolledo-Mendez, Liarokapis, Magoulas, & Poulovassilis, 2010). The context created in the SEG not only has to be in accordance with the concepts embedded, but should also provide proper and sufficient experiences for learning.

4.2 Representation

When learners select the presented relevant information, organize partial information to mental representation, and coordinate new verbal and visual representation with prior knowledge, they actively engage in cognitive processing, and meaningful learning occurs (Mayer, 1997). Hence the representation of information deeply affects the occurrence of meaningful learning. Especially for SEG, since misrepresentations of information could lead gamers to perform wrong behaviors in the game consistently (Devetag & Warglien, 2008), proper representations become critical for determining the effectiveness of SEG.

4.3 Prior experience

From the constructivist viewpoint, learning involves the construction of new knowledge upon part of existing knowledge by connecting new experiences and information to prior experiences. However, the design of SEG perhaps presuppose too much prior knowledge on partial learners, causing other learners to feel too difficult to engage with the virtual world (Freitas, et al., 2010). Hence, it is also very important that the development of SEG should consider students' prior experiences and provide them with opportunities to connect their previous experience to the game world.

4.4 Reflection

Another essential instructional element that helps to ensure students in achieving the learning tasks rather than merely play, is to provide students with opportunities to reflectively review their learning processes and analyze their current state of knowledge at all times. As long as student reflections could be promoted in SEG, effective learning occurs and students learn better.

4.5 Transfer

Gunter et al. (2008) developed a RETAIN model to aid with the evaluation of educational games. They argued that knowledge acquired during gameplay can be transferred to other contexts is an important instructional component. Therefore, learning with SEG should not only enable students to learn beyond rote, but also facilitate knowledge transfer to occur. Transfer thus is necessary for evaluation of SEG as well.

5. Knowledge

Finally, a game which has game features and provides players with the experience of immersion might be a good commercial game as players are entertained and fulfilled; however, it will not be an educational game if individual understanding of specific content is not improved, even if it uses profound instructional theories to support learning. One of the major goals of SEG is to integrate certain key principles of given topics into the game to

facilitate student knowledge construction. Currently, research has indicated that SEG does improve students' performance in science, mathematics, and computer science (Chuang & Chen, 2009; Echeverría et al., 2011; Gillispie, Martin, & Parker, 2010; Papastergiou, 2009). Therefore, the aspect of knowledge acquisition should be a key dimension to be evaluated as well.

We employ Bloom's revised taxonomy (Anderson, Krathwohl, Airasian, Cruickshank, Mayer & Pintrich, 2001) to define learning objectives of the SEG and to classify student learning behaviors in the game to better understand knowledge and skill acquisition through using SEG. This taxonomy categorizes learning objectives into two dimensions: knowledge and cognitive process. The knowledge dimension consists of four levels: factual, conceptual, procedural and meta-cognitive, and the cognitive process dimension comprises of six levels: remember, understand, apply, analyze, evaluate and create. When a game facilitates students to acquire higher levels of knowledge and to perform higher levels of cognitive processes, it is then considered a well-developed SEG.

6. Conclusions

Although research focusing on the use of games in education has grown rapidly over the past two decades, the effectiveness of the developed SEG is still hard to be evaluated since it is a relatively new technology for learning and theories that support its implications have not yet been fully developed. By systematically reviewing available literatures, the purpose of this paper aims at preliminarily investigating and developing a theoretical framework for evaluating SEG using four critical aspects, game features, immersion, pedagogy, and knowledge. We further attempt to develop an instrument for evaluation based on the framework we introduce in the near future. Hopefully, this framework that focuses on evaluating SEG from four different and crucial dimensions will provide researchers and educators a new perspective to consider in the development of SEG and have a more complete picture regarding the effectiveness of SEG.

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