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The Effect of Challenging Game on Students' Motivation and Flow Experience in Multi-touch Game-based Learning

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Abstract: Advancements in technology have led to the continuous innovation of learning methods for students. Specifically, the use of multi-touch interfaces applied to game-based learning has been shown to be effective in attracting students' interest and increasing their desire for participation. In this paper, we used a multi-touch game, an iPad app called Motion Math, to help students learn and put into practice the mathematical concepts of addition and subtraction. Based on findings from a pilot study, we categorized the game's 18 levels of difficulty into challenging (experimental group) and matching (control group) games. We aimed to investigate whether the challenging games were better able to improve the students' motivation andflow experiencein the experimental group as compared to that of the control group. The findings showed that the students in the experimental group achieved greater improvements in terms of flow learning experience.

Keywords: Digital game-based learning, flow experience, multi-touch interface, learner motivation

1. Introduction

Research has shown that integrating multi-touch interfaces with computer games facilitates positive intuitive interactions between humans and computers and in turn helps students become actively engaged in game-based learning activities (Ardito et al. 2013). A multi-touch interface allows students to move virtual objects in the scene by tapping on and dragging them (Rösler, 2009; Furió et al. 2013), which makes the game more engaging (Ardito et al. 2013). In their study, Furió et al. (2013) found that students prefer the multi-touch interface experience of an iPhone game to traditional learning games such as labyrinth games and worksheets. However, little research has investigated the benefits of integrating a multi-touch interface into computer games, or examined how multi-touch interfaces promote student learning. This study aims to address that gap, investigating the effect of challenging games on student motivation and flow experience through multi-touch game-based learning.

In recent years, an increasing number of teachers have endeavored to integrate educational computer games into training and teaching (Furió et al. 2013) because they perceive computer games to be an effective means to help students construct knowledge (Wang and Chen, 2010). In addition, educational computer games have been suggested as a tool to increase students' intrinsic motivation and levels of interest in learning (Huizenga et al., 2009; Dickey, 2007; Papastergiou, 2009). Previous studies have indicated that computer games can entertain, instruct, change attitudes, and enable the skill development of students (Alessi and Trollip 2001; C.-T. Sun et al. 2011). In addition, Liu and Lin (2009) found that student learning could be improved by providing learners with appropriately targeted educational computer games. Therefore, one of the purposes in this study was to assess students' levels of knowledge and skills with computer games in order to identify the proper difficulty levels that would enable students to improve their learning outcomes.

Digital game-based learning provides students with a problem-solving environment (Wang and Chen 2010) that may facilitate discovery learning (Kiili 2005). The characteristics of the gaming environment—such as offering interactional opportunities for users to explore and move the objectives—help learners use discovery learning to discover new rules and ideas instead of memorizing them. In turn, students shift their motivation from extrinsic to intrinsic perspectives (Kiili 2005). Researchers have emphasized the importance of providing learning supports for game-based problem-solving learning activities. Such supports improve the learning performance of students while engaging them in an enjoyable learning process (Hwang, Wu and Chen, 2012; Wang and Chen 2010). Wang and Chen's (2010) research suggested a "matching" game strategy, which clarifies concepts by prompting learners to match correct answers and select correct items or calculations from a list of possible answers. This study further explores the strategies of integrating such activities with game-based learning and examines their effect on student learning. In addition, it offers a comparison of matching games with those requiring strategies that are more conceptually complex, which we call "challenging" games.

To facilitate students' motivation and flow experience, this study proposed two types of games, challenging games and matching games, for conducting multi-touch game-based learning. It was hypothesized that students would experience full involvement, concentration, and enjoyment in the multi-touch game-based learning environment by participating in the iPad app *Motion Math*. The following research questions are investigated in this study. A brief conceptual model of the research is shown in Figure 1.

1) Are there differences in student motivation and flow experience depending on whether students played challenging or matching games?

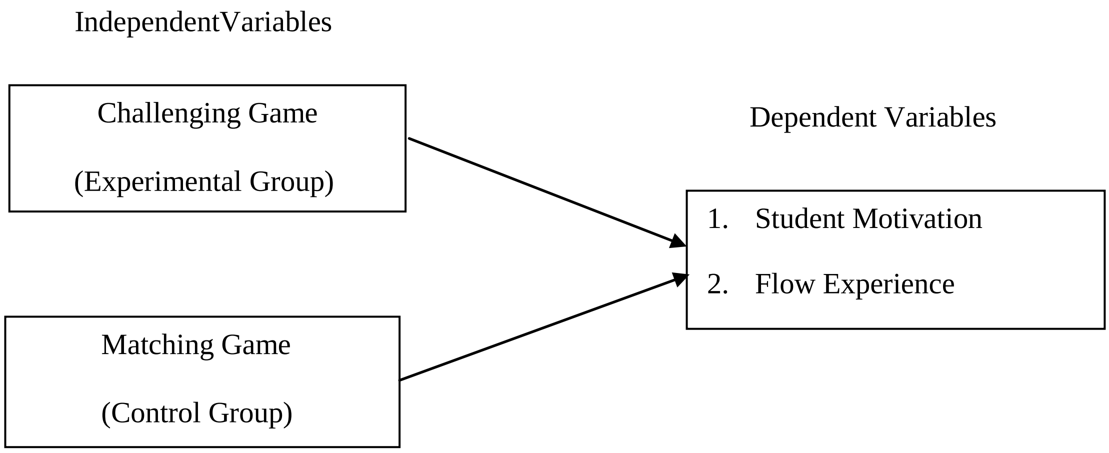

Figure. 1 Model of research questions

2. Literature Review

2.1 Flow Experience and Students' Motivation

"Flow" refers to the optimal experience of individuals who are deeply involved in an activity with full involvement, concentration and enjoyment (Hwang,Wu and Chen, 2012). During such an optimal experience, students are in a psychological state in which they are so highly involved with the task-driven activity that nothing else seems to matter (Csikszentmihalyi 1975). Previous research has shown that the flow state has a positive impact on learning (Webster,Trevino and Ryan, 1993), enhancing students' motivation to play the game; and these impacts should be taken into account when designing educational computer games (Kiili 2005). Moreover, several studies have investigated design features that enhance learning engagement and motivation by measuring students' flow experiences in game-based learning contexts (Inal and Cagiltay 2007). Games can incorporate strategies to increase players' flow experience, increase their engagement, and improve their learning outcomes (Kiili 2005).

Hwang, Wu and Chen (2012) proposed that the flow experience includes four dimensions: flow antecedent, flow experience, intrinsic motivation, and extrinsic motivation. Flow antecedent includes focused attention (Hoffman and Novak 1996), clear goals, unambiguous feedback (Chen et al. 1999), potential control (Finneran and Zhang 2003), a perception of challenges that are matched to the person's skills (Chen et al. 1999), playfulness (Webster,Trevino and Ryan, 1993), and speed and ease of use (Skadberg and Kimmel 2004). Flow experience includes a merging of action and awareness, concentration, a sense of control over the activity (Chen et al. 1999), time distortion, and telepresence (Finneran and Zhang 2003). The flow experience leads to improved learning outcomes (Skadberg and Kimmel 2004), increased exploratory behavior (Webster,Trevino and Ryan, 1993), an acceptance of information technology (Hwang, Wu and Chen, 2012), and perceived behavioral control (Kiili 2005).

The present study measures the aforementioned flow experience in each of the four dimensions proposed by Hwang, Wu and Chen (2012): flow antecedent, flow experience, intrinsic motivation, and extrinsic motivation.

2.2 Game-Based Learning

Kinzie and Joseph (2008) claimed that "a game is an immersive, voluntary and enjoyable activity in which a challenging goal is pursued according to agreed-upon rules." Previous studies (Brom, Preuss, and Klement, 2011; Huang, Huang, and Tschopp, 2010; Hwang, Sung, et al., 2012; Hwang, Wu, et al., 2012) have emphasized the potential for employing digital educational games in improving the students' learning performance. For instance, studies have shown that digital games play important roles in the development of children's cognition and social processes (Yien, Hung, Hwang, and Lin, 2011). Researcher (Ebnerand Holzinger, 2007) have reported that educational computer games can improve students' interest in learning, and in turn increase their learning motivation (Burguillo 2010; Dickey 2011).

Wang and Chen (2010) found that the challenging games enable learners more challenging and engaging in gaming activities, allowing them to better feel the game's flow experience, while no significant improvement was found in terms of flow antecedent. Moreover, they are often used in programming training instead of the training for mathematics. However, studies have indicated that the iPhone game was lead to at least equivalent learning outcome as the traditional game and children prefer the iPhone game (Furió, et al. 2013). Therefore, the use of multi-touch interface in educational settings may help students actively engaged in game-based learning activities. Inal and Cagiltay (2007) further examined the flow experiences of children in an interactive social game environment, and results revealed that the challenge and complexity elements of the games had a greater effect on the flow experiences of the children than clear feedback.

From these studies, it was found that educational computer games have become a widely-discussed research issue. Therefore, research on improving the effectiveness of educational computer games remains an important and challenging topic.

3 Methodology

3.1 Research Design

In this study, we used Motion Math, a pleasurable learning game that has fun for young student, to conduct finger-touch game-based learning activities. Figure2 shows the example of the game, we used this game to help students train their mental addition and subtraction. Motion Math was developed by a game design studio in San Francisco, emphasizing developing fun and engaging iPad and iPhone games to train children mental arithmetic skills. Past research (Riconscente 2011) reported that Motion Math improved test scores and also found that students' confidence towards math problems improved after playing the games. Motion Math inverts mathematical instruction to teach conceptual knowledge. The addition and subtraction in this game described as follows: If the fish is labeled as 18, there are several ways to get the addition equation such as 8+10, 7+11, and 9+9. Similarly, if the fish is labeled as 32, the ways to get the subtraction equation may be 34-2, 42-12, or 51-19. During the gaming process, tapping the screen gets the fish to chomp on bubbles with the different numbers, and the points are collected accordingly. Part of the fun comes from adding a visceral component to math instruction. As a result, students learn the process by which they can reach an answer, instead of just memorizing a bunch of number combinations.

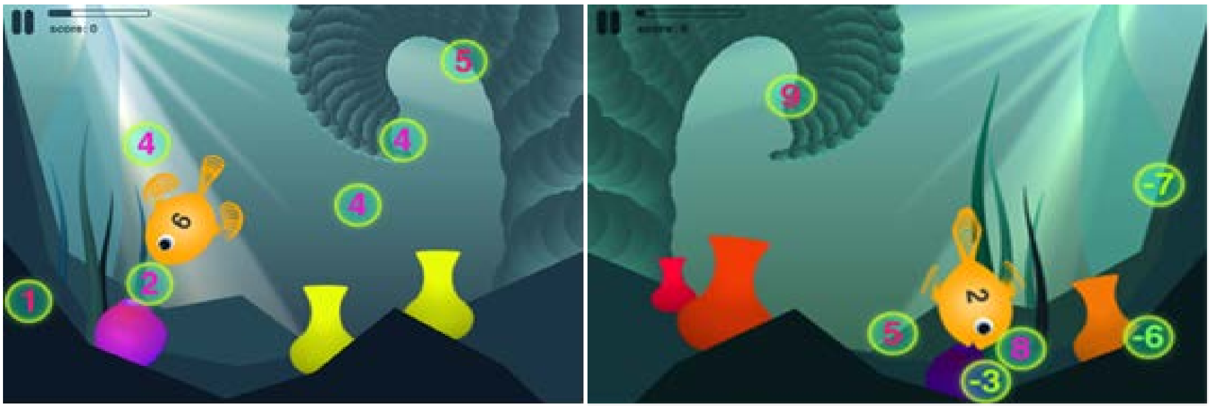

Figure2. Example of a motion math

As suggested by kiili (2005), this game provides a frame story: your fish is hungry, and hungry for numbers (see Figure 2). This fun addition and subtraction game for iPad, iPhone, and iPod touch has instant addition and subtraction, by finger touch two numbers together to instantly add or subtract. Most addition or subtraction games teach in the form of 3 + 4 = __ or 9 - 2=_, while this game challenges players to find different ways to make a 7 (e.g. 1+6, 2+5, 3+2+2, or 8-1, 10-3, 18-11). The purpose is to encourage players to look for different ways to make a solution and in turn facilitate the discovery learning process and construct their own knowledge and shows of hierarchically-ordered intellectual skills. There are 18 levels of challenges (for 4-year-olds to adults) and bonuses to customize your fish with new colors and fins. These levels can be adjusted to provide the learners with more challenging and engaging to enhance their perception of the game flow experience. Details of these levels are described as follows: 1) Difficulty 1: Number Matching, 2) Difficulties 2-6: Basic addition or subtraction (not including addition with carrying and subtraction with borrowing), 3) Difficulties 5-14: Bigger number, faster gameplay (including addition with carrying and subtraction with borrowing), and 4) Difficulties 11-18: Challenging, even for adults (including addition with carrying and subtraction with borrowing, and higher degree of computational complexity).

After the student calculates the correct number, the fish eats the correct number and grows larger. Once the fish grows to a certain size, the student progresses to the next level. Conversely, if the student does not calculate the correct number or miscalculates, the fish cannot eat the correct number and it becomes increasingly small. Consequently, the student fails the level. The higher the difficulty level of the game, the faster the speed, and the shorter the time students have for calculating the results.

3.2 Polity Study

Based on pilot study results, we defined Levels 1 to 6 as matching games (control group) and Levels 7 to 14 as challenging games (experimental group). During the process of the matching games, students are able to clarify concepts through matching correct answers and selecting correct items or calculations, while in a challenging game, students are able to consolidate and elaborate concepts through progressive challenges were employed by means of limited time for task completion, levels of performance and cumulated scores for learners to challenge themselves in identifying correct concepts and examples, upgrade their levels of performance and gain higher scores (Wang and Chen, 2010).

3.3 Participants

Of the 52 second-grade students attending a school in northern Taiwan who participated in this study, 50% (n = 26) were in the experimental group, and 50% (n = 26) were in the control group. Female students (n = 28) represented 53.8% of the participants in this study. The mean age was eight years. All of the students were taught by the same instructor, who had more than two years of experience teaching science.

3.4 Experimental Procedure

Before the experiment, the two groups of students were given a 60-minute lesson on the basics of addition and subtraction as a part of their existing course in mathematics and science. Before beginning the game activity, the students were also taught how to operate the multi-touch app Motion Math and instructed on game rules, including how to operate the system with multi-touch gestures.

During the learning activity, the students in the experimental group participated in the challenging learning activities while those in the control group undertook the matching learning activities. Students were also videotaped during the exercise to enable later behavioral characterizations (see Discussion below).

After the learning activity, the students took the post-test and completed a second questionnaire exploring their learning motivation and flow experience.

3.5 Research Tools

The instruments in this study included a questionnaire for measuring students' motivation and flow experience. All of the survey instruments used a 6-point Likert-type scale, ranging from 1 (strongly disagree) to 6 (strongly agree).

The questionnaire on flow experience was adapted from the measurement developed by Hwang et al. (2012b). It consists of 14 items in four dimensions; that is, four items for "flow antecedent" (e.g., "The goals of the game were clearly defined"); four items for "flow experience" (e.g., "My attention was focused entirely on playing the game"); three items for "intrinsic motivation" (e.g., "In a class like this, I prefer course material that really challenges me so I can learn new things"); and three items for "extrinsic motivation" (e.g., "I want to do well in this class because it is important to show my ability to my family, friends, employer, or others"). The internal consistency coefficient (Cronbach's Alpha) values on each of the four dimensions were 0.75, 0.80, 0.82, and 0.72, respectively.

4. Research Results

4.1 Analysis of Flow Experience

Independent sample *t*-tests revealed significant differences in students' flow experience between the experimental and the control groups ($t(41) = 2.17$, $p < .05$). Specifically, students in the experimental group had significantly higher flow experience ($M = 5.58$, $SD = .36$) than that in the control group ($M = 5.27$, $SD = .57$), indicating possible benefits of using challenging games to increase students' flow experience. The results of the *t*-tests are presented in Table 2. Consistent with previous studies, challenge, control and enjoyment were found to be key factors related to flow experience during the gaming process (Kiili 2005; Wang and Chen 2010). Similar to the benefits of traditional games, the aforementioned factors can be activated by providing immediate and appropriate feedback, unambiguous goals and dynamic challenges (Csikszentmihalyi 1991; Kiili 2005). Therefore, the challenging game may situate students in the flow state when they are more engaged in the multi-touch game-based learning activity and more actively enjoying the process. In terms of the four dimensions of flow experience, there were statistically significant differences in flow antecedent ($t(41) = 2.47$, $p < .05$) and flow experience ($t(41) = 2.21$, $p < .05$), but no statistically significant differences were found in intrinsic motivation ($t(41) = .87$, $p > .05$) or extrinsic motivation ($t(41) = -0.32$, $p > .05$). The results of the *t*-tests are presented in Tables2 and 3.

Table 2:*t*-Test result of flow experience of the two groups.

Group	*N*	Mean	S.D.	*t*
Experimental group	22	5.58	0.36	2.17*
Control group	21	5.27	0.57	

*$p < 0.05$.

Table 3: *t*-Test result of the four aspects of flow experience.

	Group	*N*	Mean	S.D.	*t*
Flow antecedent	Experimental	22	5.86	0.25	2.47*
	Control	21	5.39	0.86	
Flow experience	Experimental	22	5.70	0.39	2.21*
	Control	21	5.23	0.94	
Intrinsic motivation	Experimental	22	5.32	0.88	0.87
	Control	21	5.05	1.14	
Extrinsic motivation	Experimental	22	5.29	0.86	- 0.32
	Control	21	5.37	0.75	

*$p < 0.05$.

One way to measure flow experience is to observe the behaviors of people experiencing flow (Admiraal et al. 2011). In this study, we used videotaped data to observe and count students' behavioral indicators of distraction, such as chatting with other students or looking around the room, over a forty-minute period. The experimental results reveal that the students in the experimental group (M = 7.25) showed less evidence of distraction than those in the control group (M = 25.5), indicating that the challenging games help students focus on learning activities. Results of the in-class observations are shown in Figure 3.

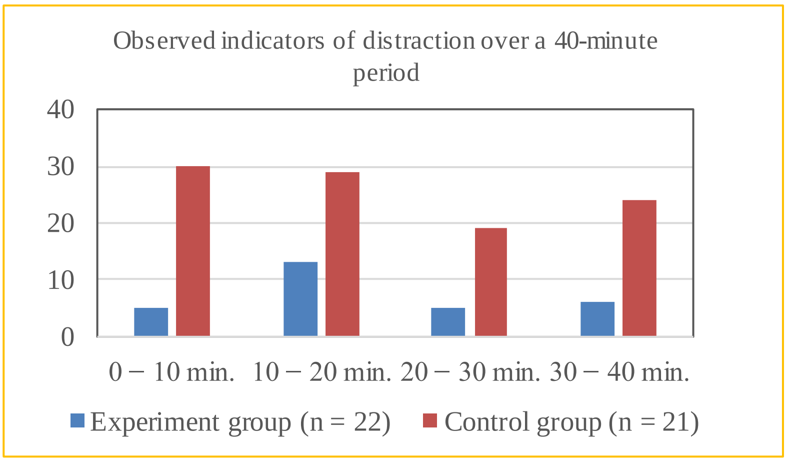

Figure 3. Distraction rates by group

5. Discussion andConclusion

The experimental results of this comparison reveal that the challenging game is better than the matching game for improving flow learning experience, suggesting that students tend to focus on learning activities featuring intense involvement, concentration, and enjoyment. In contrast, students playing the matching game reported less immersive and possibly less enjoyable experiences during the experiential gaming process. In educational contexts, deep absorption in the immersive flow of gaming activities has been found to promote optimal learning experiences (Admiraal et al. 2011).

This study represents an important development, investigating similar questions through the multi-touch interface of the iPad, which involves a quite different form of interactive learning activity—that is, multi-touch game-based learning. Furthermore, studies comparing challenging games and matching games (Wang and Chen 2010) have so far focused on programming training in traditional game-based learning environments without multi-touch interfaces. As technology advances, students and learning methods are changing (Furió et al. 2013), and one of the major contributions of this study is that it uses similar means for mathematical training, but combines it with a multi-touch interface to produce an innovative, effective and enjoyable learning activity.

This study examined students' use of a digital education game with a multi-touch interface. The general objective was to induce students to develop their learning motivation through a medium that could capture and hold their attention and engage them in the learning process. Recently, this method of developing students' performance has grown in popularity throughout the field of educational research (Ardito et al., 2013; Furió et al., 2013). In their evaluations of the gaming process, students reported that experiencing an interactive learning approach in a classroom environment made them feel engaged and satisfied. Therefore, this innovative approach appears to both create a flow learning experience.

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