Computers in Human Behavior 30 (2014) 29–38

Contents lists available at ScienceDirect

Computers in Human Behavior

journal homepage: www.elsevier.com/locate/comphumbeh

Evaluating multiple aspects of a digital educational problem-solving-based adventure game

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ARTICLE INFO

Article history:
Available online 22 August 2013

Keywords:
Game-based learning
Adventure game
Problem-solving
Technology acceptance
Flow
Cluster analysis

ABSTRACT

This study aims to evaluate multiple aspects of a problem-solving-based educational adventure game, *Boom Room*©. The learning effectiveness, game acceptance, and flow experience of the game were empirically investigated. The game was designed and developed for teaching knowledge of computer assembly. Sixty-seven university students in Taiwan were asked to complete a pre-test before playing the game and a post-test after playing the game. These students also provided evaluations of not only the usefulness, ease of use, and design elements of the game but also their experience with various flow dimensions of the game. A 2-stage cluster analysis was also conducted to explore the potentially different groups of students by categorizing them in accordance with their performance, degree of game acceptance and flow states. The results suggest that this game is beneficial for students with insufficient background knowledge of computer assembly, allowing these students to obtain vital knowledge of this topic if they achieved a sufficient acceptance of the game and an adequate flow experience from their game-playing experiences. The various dimensions of flow that were experienced by these students were significantly correlated with game acceptance. Suggestions for future study, game design, and instructional practice are discussed.

1. Introduction

With the prevalence of personal computers and the availability of various computer hardware choices, computer assembly has become a practical skill for daily life. Individuals who possess the requisite knowledge and skills can assemble a computer in accordance with their budgets and their requirements for computer performance and functionality. These individuals can also accurately diagnose computer problems and replace broken components by themselves to avoid wasting the time that would be required to return the computer to the company for maintenance. Sufficient time must be devoted to repeatedly reviewing and practicing computer knowledge and skills to ensure that this learning is appropriately acquired and used. However, during the course of teaching computer knowledge and skills in school, the opportunities to engage in hands-on exercises are typically limited because of both the restricted availability of time and equipment and concerns regarding safety issues. The adoption of information and computer technology (e.g., simulation software) may provide a solution to overcome the aforementioned limitations and assist students' learning of the knowledge and skills that would be required for computer assembly. However, little research has been conducted to address the use of information and computer technology for contributing to the learning of this subject. Although a previous research has used ubiquitous learning technologies to support peer interactions during computer-assembling tasks (e.g., Hwang, Wu, Tseng, & Huang, 2011), the approach has been utilized as help-seeking assistants instead of as instructional tools that provide the direct tutoring of computer assembly.

Simulation learning tools are designed to provide an authentic and secure environment in which students can repeatedly manipulate learning content and observe the results of these manipulations (Alessi & Trollip, 2001). Simulations that model various concepts, such as computer architecture and operating systems, have been designed to support the instruction of computer science courses (e.g., Mustafa, 2010; Yehezkel, Yurcik, Pearson, & Armstrong, 2001). Students who used simulations experienced better learning outcomes than students who used traditional paper exercises (Mustafa, 2010). In a meta-analysis conducted by Vogel et al. (2006), researchers found that better cognitive gains and learning attitudes of students could be promoted by interactive simulations and games than by traditional instructions. However, as noted by Prensky (2001), simple and repeated manipulations in simulations might become boring for students. Thus, it has been suggested that the addition of game elements (e.g., goals, rules, challenges, and stories) to simulation instructional software could

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0747-5632/$ - see front matter
http://dx.doi.org/10.1016/j.chb.2013.07.052

help to create a diverting learning experience (Prensky, 2001). By providing students with an enjoyable learning experience and a specific and challenging goal, games are thought to be superior to simulations with respect to stimulating students' motivations to learn and engaging students in active learning.

To take advantage of both games and simulations, increasing numbers of researchers have integrated simulations into their game designs to create simulation games. This type of games allows students to learn from manipulating simulated content in contexts that include game elements to make these manipulations challenging and interesting. Simulation games have been employed to enhance learning through not only helping students understand the basic principles of either a domain (e.g., physics laws) or design models (e.g., computational models) but also immersing students in a game-based context that allows them to experience problem-solving processes as they attempt to complete the goals of the game (e.g., Anderson & Barnett, 2011; Liu, Cheng, & Huang, 2011; Squire & Klopfer, 2007).

Game-based learning has become a research trend in the field of educational technology (Hwang & Wu, 2012). Many researchers have suggested that digital educational games could facilitate learning (e.g., Gee, 2007; Oblinger, 2004; Prensky, 2001; Squire & Jenkins, 2003). Digital educational games have increasingly been applied to different learning domains (e.g., mathematics learning, health education, language learning, and social science learning), and their learning effectiveness has been reviewed and discussed by many researchers (e.g., Blakely, Skirton, Cooper, Allum, & Nelmes, 2009; Divjak & Tomić, 2011; Egenfeldt-Nielsen, 2006; O'Neil, Wainess, & Baker, 2005). From these reviews, it is obvious that most of the game-based learning studies have focused on evaluations of learning effectiveness, learning motivation, or game satisfaction. The multi-aspect investigations of game design elements, game acceptance, and gaming experience (e.g., flow experience) have been less emphasized by empirical studies in this field. However, these overlooked considerations are important aspects of designing a game that could better meet the needs of learners; therefore, these considerations merit the same level of attention that has been devoted to more extensively studied topics. Among the empirical studies in the literature, there is also a lack of multi-aspect empirical research that analyzes and evaluates specific digital educational games.

Several researchers have suggested important game characteristics to consider during the process of game design. In particular, Prensky (2001) listed a number of game design elements that make a game engaging and fun, including goals, rules, interactivities, feedbacks, and challenges. Alessi and Trollip (2001) also suggested that goals, rules, competition, challenge, fantasy, safety, and entertainment are general features of a game. Moreover, Aleven, Myers, Easterday, and Ogan (2010) proposed a design framework for educational games. Within this framework, in addition to learning objectives and instructional strategies, the game design elements of mechanics, dynamics and aesthetics are essential components of a game. The aesthetic design of a game would influence a player's emotional reactions or feelings of pleasure. Eight general aesthetic elements were suggested for games, including sensation, fantasy, narrative, challenge, fellowship, discovery, expression, and submission. For the design of a problem-solving game, Kiili (2007) proposed a problem-based gaming model that emphasized the importance of context, task, and feedback. According to Kiili, a problem-solving game should provide a well-designed game context that would allow learners to utilize different strategies to accomplish game goals (i.e., to solve the problems that they encounter in the game), and the process of reflection plays a very important role in this problem-solving process. It is necessary to design a game that could provide learners with appropriate and adequate feedback and enable them to reflect on their gaming strategies and adjust these strategies as necessary. Therefore, a problem-solving-based adventure game that incorporates both the challenging elements of game design and simulated manipulation scenarios may promote students' learning motivations, allow students to continuously reflect on their manipulations, and assist their process of effectively acquiring computer assembly knowledge.

Before an innovative technology can impact students' learning, students must be willing to use the technology. In his technology acceptance model, Davis (1989) suggested that "perceived usefulness" and "perceived ease of use" were two critical factors that would predict user intentions to use technology. Many scholars have used Davis' model to investigate the acceptance of various technologies (e.g., wireless technology, Facebook, e-libraries, mobile games, and online games) and the factors that would affect this acceptance (e.g., Fang, Chan, Brzezinski, & Xu, 2005; Hsu & Lu, 2004; Jeong, 2011; Kim, Kim, & Kim, 2008; Lee & Tsai, 2010; Suki, Ramayah, & Ly, 2012; Tao, Cheng, & Sun, 2009). In a study of game acceptance, Chang, Peng, and Chao (2010) found that the degree to which students accepted educational games could predict the learning interests of these students. Another study that investigated student acceptance with respect to the use of educational games in the classroom concluded that students' perceptions of the ease of use, usefulness, and learning opportunities of games and their prior game experiences would influence their degree of game acceptance (Bourgonjon, Valcke, Soetaert, & Schellens, 2010). Moreover, Liu and Li (2011) found that perceived usefulness, perceived enjoyment, and cognitive concentration positively affected university students' attitudes towards mobile gaming and that this attitude would then affect their intention to use mobile games. These studies suggested that the investigation of game acceptance would provide important information for game evaluation. Given the dearth of research that investigates the acceptance of simulated, problem-solving-based type of educational games, it is necessary to evaluate different aspects of the user acceptance of educational simulation games to understand the characteristics and limitations of this type of games.

In addition to the degree of game acceptance, the game-playing experiences of players have also been stressed by researchers that have studied game-based learning. The flow experience has commonly been used to describe a player's psychological state during the course of playing a game. According to the flow theory that was introduced by Csikszentmihalyi (1990), flow is "the state in which people are so involved in an activity that nothing else seems to matter; the experience itself is so enjoyable that people will do it even at great cost, for the sheer sake of doing it." (p. 4). When people enjoy doing a particular activity, they can obtain control over the quality of their experience and can thereby achieve the optimal experience. To promote students' quality of learning, the question of how to achieve certain flow states of students during their learning processes has recently drawn attention from many researchers. The flow experience has been found to either directly or indirectly influence learning outcomes (e.g., Choi, Kim, & Kim, 2007; Ho & Kuo, 2010; Schuler, 2007; Skadberg & Kimmel, 2004). In a study that used a simulation game to facilitate students' learning of computational problem-solving, it was found that students who played the game in question could experience higher levels of flow states than students who used traditional learning methods (Liu et al., 2011). Moreover, this previously published study also revealed that when students experienced flow in the game, they would perform multiple problem-solving strategies, including both deep and surface-level approaches, whereas students who felt bored or anxious during the performance of a game primarily utilized surface-level problem-solving strategies. Another study that explored students' flow experiences during gameplay concluded that a flow state was more readily achieved by boys than by girls (Inal & Cagiltay, 2007). The challenge of a game was stated by