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

Meng-Tzu Cheng* **& Chang-Hung Chung**
National Changhua University of Education, Taiwan (ROC)
*mtcheng@cc.ncue.edu.tw

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.

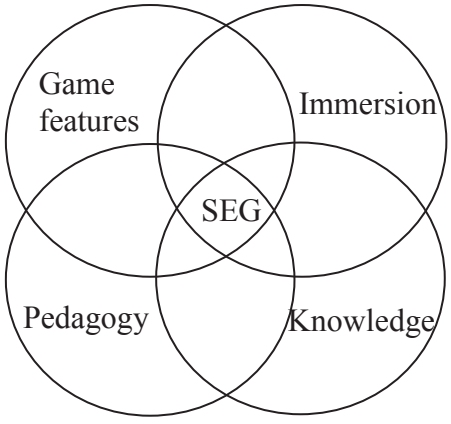

Figure 1. A theoretical framework for evaluating the effectiveness of SEG.

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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