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Learning through playing *Virtual Age*: Exploring the interactions among student concept learning, gaming performance, in-game behaviors, and the use of in-game characters

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ABSTRACT

Video games possess many unique features that facilitate learning. Meanwhile, teaching about evolution is never an easy task due to the existence of some barriers to its learning. *Virtual Age*, therefore, has been developed in an attempt to harness the power of gaming to increase student understanding of biological evolution. The aim of this study was to examine whether *Virtual Age* is effective for learning about evolution and to further explore the interplay of student concept learning, gaming performance, and in-game behaviors. A total of 62 7th graders took part in the study, and significant findings were revealed. The students did learn by playing *Virtual Age*, and their long-term knowledge retention was promising. The in-game behaviors, such as times and duration of viewing the relevant information embedded in *Virtual Age*, were significantly related to gaming performance (game score), which subsequently influenced learning outcomes. Moreover, the results of cluster analysis indicated that three clusters of low learning outcomes/low gaming performance, high learning outcomes, and high gaming performance emerged. Overall, *Virtual Age* is an effective game for learning about evolution based on its sound and sophisticated design. Implications derived from the study and suggestions for future work are proposed.

1. Introduction

In the past decade, a wide range of researchers and educators have investigated the potential of using video games in education due to the rapid growth of the gaming population among today's students (Annetta, 2008; Barab, Thomas, Dodge, Carteaux, & Tuzun, 2005; Connolly, Boyle, MacArthur, Hainey, & Boyle, 2012). Doubts about the influence of playing video games are now decreasing because more research supports the conclusion that playing video games can lead to positive consequences (Ferguson, 2007). The Serious Games Initiative, an association that promotes the use of video games for dealing with serious matters, has brought the term "serious games" (SGs) into wide use since 2002 (Djaouti, Alvarez, Jessel, & Rampnoux, 2011). Annetta (2008) further defined "serious educational games" (SEGs) as video games which are used for teaching and learning purposes in K-20 educational settings. Since then, a growing interest in investigating the effectiveness of SEGs has emerged.

Studies have now provided substantial evidence that the use of video games in education can be an effective way of increasing student knowledge acquisition, learning motivation, and classroom involvement (Annetta, Minogue, Holmes, & Cheng, 2009; Cheng & Annetta, 2012; Cheng, Su, Huang, & Chen, 2014; Papastergiou, 2009; Sung & Hwang, 2013; Tüzün, Yılmaz-Soylu, Karakuş, İnal, & Kızılkaya, 2009). However, in spite of growing support for the serious consideration of video games, researchers have suggested that more quality studies are needed to examine issues relating to the interactions between players and virtual environments because most of the currently available evidence focuses primarily on the consequences of learning by gaming (Young et al., 2012).

Evolutionary theory is considered to be an important cornerstone in modern biology (Mayr, 2001). The concepts of biological evolution include two different scales, micro and macro. Microevolution focuses on variations within a given population over generations, and

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macroevolution refers to major changes above the level of species over time. Natural selection is the most important mechanism by which species adapt and evolve (Reece et al., 2011). As it is an important idea within a biological model for explaining both the unity and the diversity of life on Earth, educators and scientists usually consider the theory of evolution to be a significant part of the biology curriculum. However, perhaps because the understanding of the theory is abstract and unintuitive (Bloom & Weisberg, 2007), evolution is never an easy topic for students to learn, and people often have many misconceptions (Kampourakis & Zogza, 2009).

With this in mind, our research team has developed an SEG called *Virtual Age* to assist students in their comprehension of biological evolution. The scientific concepts of evolution are realized, concretized, and gamified in *Virtual Age* in an attempt to harness the power of gaming to increase student understanding of biological evolution (Cheng, She, & Annetta, 2014). In addition, to investigate the effectiveness of using *Virtual Age* to teach students the concepts of evolution, this study sought to further explore student learning by gaming over time and the interplay of student concept learning outcomes, gaming performance, in-game behaviors, and the use of in-game characters in the virtual context of *Virtual Age* by using cluster analysis. Four research questions were addressed:

(1) Are there any differences in concept learning outcomes and gaming performance between high and low science achievers when such students play *Virtual Age* over an extended period of time?
(2) What are the correlations between student concept learning, gaming performance, and in-game behaviors?
(3) How do students use the in-game characters in *Virtual Age*?
(4) What is the interplay of student concept learning, gaming performance, and use of in-game characters?

2. Literature review

2.1. Teaching and learning of biological evolution

Scientists have been speculating about the origin and history of all living things on Earth for centuries. After more than a century of development, biological evolution, which is a unifying model that brings all the fields of biology together to explain both the unity and the diversity of life on Earth, is now regarded as a well-supported theory beyond dispute within the scientific community (Yates & Marek, 2013). Evolution includes two related phenomena, micro- and macroevolution, which together explain a broad range of processes, from the variations in a given population to the changes above the level of species over time.

Educators and scientists generally consider the theory of evolution to be a major concept which should be emphasized in the K-12 science curriculum because its explanatory and unifying powers allow for the investigation of a variety of biological questions in a scientifically meaningful way (National Science Teachers Association, 1997; Rutledge & Warden, 2000). A framework for K-12 science education proposed by the National Research Council (2012) claims that biological evolution is one of the four core ideas essential for a conceptual understanding of the life sciences enabling students to make sense of emerging research findings. The framework indicates that the science instruction for K-12 student learning of biological evolution should encompass the evidence of common ancestry and diversity (including both genetic information and fossil records), the mechanism of natural selection, the interactions between individuals and the environment (adaptation), and biodiversity and humans. Moreover, it has even been argued that not only students but also members of the public at large need to understand evolution because of its importance for understanding so many dimensions of the modern world (Smith, 2010).

The theory of evolution is central to our modern understanding of science; however, it is commonly agreed that teaching and learning about evolution is never an easy task due to the existence of various barriers to its learning for students and the general public alike. For example, biological evolution accounts for diversity over a long period of time, making it difficult to see the relevance of evolution in our daily lives. In order to understand evolution, one has to deal with concepts ranging from the micro scale (such as molecular biology) to the macro scale (such as population genetics). Moreover, a person's acceptance of evolution might be influenced by his or her worldview; for example, the idea of evolution conflicts with certain religious beliefs. The most challenging obstacle is that many misconceptions are held because an accurate understanding of evolution is anti-intuitive and clashes with individual naïve theories. These obstacles all make the learning of evolutionary concepts more difficult than learning about many other topics (Heddy & Sinatra, 2013; Rosengren, Evans, Brem, & Sinatra, 2012).

Given the aforementioned difficulties in learning about evolution, a number of instructional approaches have been proposed with solid theoretical foundations and various combinations of teaching techniques (for a review, see Smith, 2010). Researchers have indicated that it doesn't work to simply add evolutionary concepts to existing student knowledge, and that what is needed is to provide students with opportunities to approach the world and think about evolutionary processes in new and different ways than we generally do (Sinatra, Brem, & Evans, 2008). Despite the fact that many forms of instruction have been developed, however, research into using SEGs as tools for students to learn the theory of evolution remains lacking. Moreover, to our knowledge, there is still no study that has delved into the relationships between student in-game behaviors, the use of in-game characters, and the learning of evolutionary concepts through SEG play.

2.2. Serious educational games

Despite previous negative impressions, greater focus has now been placed on the positive impact of video games on learning (Gee, 2013). Video games provide players with various degrees of the subjective impression of immersion (Cheng, She, et al., 2014), and researchers argue that such immersion is the key leading to successful learning through multiple perspectives and situated experience in a digitally enhanced setting (Dede, 2009). Video games create a virtual world wherein players experience embedded activities in much the same way as when they think and act in the real world (Shaffer, Squire, Halverson, & Gee, 2005). They also continuously provide players with different challenges and tasks, and game features such as competitiveness and playfulness allow players to be engaged and immersed in the tasks so that they are willing to repeat the activities over and over (Garris, Ahlers, & Driskell, 2002). As a result, the cognitive skills of players are enhanced and learning subsequently occurs while video games are being played. The available empirical evidence has supported the fact