Math Learning Environment with Game-Like Elements: An Experimental Framework

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ABSTRACT

Educational games intend to make learning more enjoyable, but carry the potential cost of compromising learning efficiency by consuming both instructional time and student cognitive resources. Therefore, instead of creating an educational game, the authors create a learning environment with game-like elements, the aspects of games that are engaging but that do not negatively impact the learning effectiveness of the system. This paper presents an experimental framework for determining the effect of game-like elements in terms of their benefits such as enhancing engagement and learning, as well as their costs such as distraction and working memory overload. As a first experimental step, the authors develop four versions of a math tutor with different degrees of game-likeness, such as adding narrative and visual feedback. Based on a study with 297 students, it is found that students reported more satisfaction with the tutor with more game-like elements, but there was no conclusive difference in learning among the different versions.

Keywords: Cognitive Overload, Educational Games, Game-Like Elements, Gamification, Intelligent Tutoring System

INTRODUCTION

Intelligent Tutoring Systems (ITS) and educational games are two research areas in educational technologies. Intelligent tutors, which are primarily concerned with cognitive aspects of learning, provide students with adaptive, individualized tutoring and have been shown to improve learning significantly (Koedinger & Corbett, 2006). On the other hand, education researchers have also been interested in computer games due to their immense popularity and affordance of new types of interactions. Games can not only enhance the affective aspects of learning, but also hold the potential to improve cognitive outcomes of learning as well. But despite this intuitive appeal of educational games, there is not enough empirical evidence on the effectiveness of educational games (Hays, 2005; O’Neil et al., 2005; Sitzmann, 2011). Although there is a relative scarcity of evidence directly comparing the educational effectiveness of educational games vs. computer tutors, recent comparisons have found an advantage for traditional tutoring approaches over educational games (Easterday, 2011; Jackson & McNamara, 2011). However, computer tu-
tors, although able to produce learning gains, have had difficulties in maintaining students’ interest for long periods of time, which limit their utility for generating long-term learning (Jackson & McNamara, 2011).

Given these complementary benefits, there have been considerable efforts to combine these two fields. There is an active community of intelligent educational games (Conati, 2002; Spires et al., 2011; Habgood, 2005). Some researchers have incorporated elements from games into computer tutors to make them more engaging (Jackson & McNamara, 2011), and some have incorporated instructional features such as detailed content feedback into educational games (Easterday et al., 2011).

Creating highly engaging educational games that are as effective as tutoring systems in terms of learning, would have clear benefits. However, there are several difficulties in fulfilling this vision. First, research has demonstrated that due to our limited working memory, too many extraneous details can be detrimental to learning (Sweller, 1994; Mayer, 2009; Clark, 2011). Second, there are practical constraints such as time, as games tend to take more time to convey equivalent amount of educational content due to time consumed on gameplay aspects. Thus, the act of combining the best aspects of ITS and educational games is a challenging design goal, as it entails maximizing both engagement and learning. Fortunately, engagement and learning are not necessarily incongruent. In fact, they can reinforce each other as engaged students learn more and students get more engaged as they learn. But aligning these two goals is a very delicate design process and the abundance of failed educational games, which can generate neither fun nor learning, and thus resulting in a negative and unappealing impression of educational games, only confirms this difficulty (Clark, 2011). Realizing these constraints, the authors are taking a conservative stance and rather than maximizing both learning and engagement, are taking an incremental research path to optimize the tradeoff between these two elements. Instead of completely integrating educational content into a game framework, this approach is to analyze and inspect game-like elements (i.e., elements within the game that are engaging) in terms of their pedagogical impact, and then integrate the beneficial ones into the tutor, thus creating tutors that may be more engaging. Though there are increasing efforts to make tutors more game-like, there is still dearth of controlled studies to study individual game-elements (Wilson et al., 2008). In this paper, the authors are designing a theoretical and experimental framework for assessing these game-like elements and thus find a “sweet spot” for learning that provides both high levels of entertainment and learning outcomes. The authors have created Monkey’s Revenge, a coordinate geometry tutor with game-like elements such as narrative, immediate feedback, sensory stimuli, etc. The next step is to generate different versions of the same tutor with and without individual game-like element and then conducted a randomized controlled study to compare them in terms of learning and liking. This approach takes a measured and minimalist approach by incrementally making a complete tutor more game-like by weighing each additional game-like element in terms of retaining all the learning features of a tutor and minimizing the limitations, while exploiting the benefits of games.

**MONKEY’S REVENGE**

Monkey’s Revenge is a coordinate geometry math-learning environment with game-like elements. The environment consists of a series of 8th grade coordinate geometry problems wrapped in a visual narrative. Students have to help story characters solve the math problems in order to move the story forward. Similar to classic computer tutors such as ASSISTments (http://www.assistments.org/), students obtain hints and bug messages when they stumble upon problem and misconceptions. In the story, a boy, Mike is expelled from class for playing a game on his cell phone. He is happy to be outside in the sun but the day is going to be a strange one as his world is now mapped into
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