Chapter 7

A Digital Game for Undergraduate Calculus: Immersion, Calculation, and Conceptual Understanding

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ABSTRACT

This study has two goals: first, to investigate the effectiveness of using a digital game to teach undergraduate-level calculus in improving task immersion, sense of control, calculation skills, and conceptual understanding, and second, to investigate how feedback and visual manipulation can facilitate conceptual understanding of calculus materials. One hundred thirty-two undergraduate students participated in a controlled lab experiment and were randomly assigned to either a game-playing condition, a practice quiz condition, or a no-treatment control condition.

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The authors collected survey data and behavioral-tracking data recorded by the server during gameplay. The results showed that students who played the digital game reported highest task immersion but not in sense of control. Students in the game condition also performed significantly better in conceptual understanding compared to students who solved a practice quiz and the control group. Gameplay behavioral-tracking data was used to examine the effects of visual manipulation and feedback on conceptual understanding.

INTRODUCTION

Calculus is the foundation for higher-level mathematics in disciplines such as physics, engineering, and economics. Calculus is not only important for understanding more advanced courses in school, it is also a significant predictor of one’s earnings at work beyond school (Rose & Betts, 2004). However, several studies have reported a disconnect between the calculus that students learned in classrooms and students’ ability to apply calculus concepts to other disciplines and to utilize calculus outside of schools (Lesh & Zawojewski, 2007). Students often fail to transfer their calculus knowledge because they lack hands-on experiences of applying their understanding to solving authentic problems; in fact, around 70% of problems in one calculus textbook are solved by mimicking the examples shown in the textbook (Lithner, 2004). This might cause students to be less motivated to learn because they do not understand the value of calculus in real-world applications. Studies have shown that students who experienced problem-solving scenarios in pre-calculus classes have better conceptual understanding of calculus applications, can identify and use appropriate resources, and are more motivated to take an active role in learning calculus (Stanley, 2002). Learning across multiple contexts (e.g., different media or different problem context) can also promote transfer because students can compare their experiences to abstract general concepts and construct a flexible understanding that can be applied to different contexts (Bransford, Brown, & Cocking, 1999).

Digital games have been proposed as an effective way to promote students’ conceptual understanding of abstract knowledge and problem-solving transfer (Boyle, Connolly, & Hainey, 2011; Garris, Ahlers, & Driskell, 2002; Gee, 2007). Modern digital games can facilitate meaningful problem-solving experiences for students, allowing them to visualize abstract concepts and situate the concepts in different contexts to gain a better understanding (Squire, 2003). They can provide immediate, or just-in-time feedback for students to assess and adjust their process (C.-Y. Lee & Chen, 2009). Games encourage players to form initial hypotheses, test them, observe the outcome, and revise their hypotheses. This process is similar to the process of experiential learning (Kolb & Kolb, 2005). In other words, digital
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