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A Computer-Based Game that Promotes Mathematics Learning More than a Conventional Approach

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ABSTRACT

Excitement about learning from computer-based games has been palpable in recent years and has led to the development of many educational games. However, there are relatively few sound empirical studies in the scientific literature that have shown the benefits of learning mathematics from games as opposed to more traditional approaches. The empirical study reported in this paper provides evidence that a mathematics educational game can provide superior learning opportunities, as well as be more engaging. In a study involving 153 students from two middle schools, 70 students learned about decimals from playing an educational game—Decimal Point—whereas 83 students learned the same content by a more conventional, computer-based approach. The game led to significantly better gain scores in solving decimal problems, on both an immediate (d = .43) and delayed (d = .37) posttest and was rated as significantly more enjoyable (d = .95). Low prior knowledge students especially benefitted from the game. This paper also summarizes the game's design characteristics.

KEYWORDS

Computer Games, Digital Games, Educational Games, Mathematics Learning, Mathematics Problem Solving

INTRODUCTION

The enthusiasm about computer-based educational games is by now well documented and widespread. Many claims have been made about the benefits of learning with educational games versus more traditional approaches (Gee, 2003; Prensky, 2006; Squire & Jenkins, 2003). Furthermore, teachers believe that computer-based games can be effective. For instance, a 2014 survey found that 55% of 513 teachers who use games in the classroom use them at least once a week (Gamesandlearning.org, 2015). Given the obvious appeal of computer-based games more generally – the computer game industry is growing much faster than the U.S. economy as a whole (Siwek, 2010) and 97% of students aged 12 through 17 play video games regularly (Lenhart et al, 2008) – it is easy to understand and embrace the enthusiasm about and promise of computer games as a way to engage kids and lead to meaningful learning.

Yet, while strong claims have been made about the potential of educational computer games, those claims are, thus far, based on relatively weak evidence (Hannifin & Vermillion, 2008; Honey & Hilton, 2011; Mayer, 2014; O'Neil & Perez, 2008; Tobias & Fletcher, 2011). For instance, Mayer (2014) extensively collected and evaluated the published scientific evidence in which an educational game was compared to a more traditional instructional approach (so-called media comparison studies).

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He eliminated all of the studies that did not meet rigorous scientific study criteria, such as comparing an experimental (game) and control (non-game) condition with the same academic content, inclusion of a dependent measure that involves academic outcome, and reports of means, standard deviations, and sample sizes for the learning outcomes. Mayer's evaluation uncovered only 16 rigorous studies in science and 5 in mathematics[1]. While 12 of the 16 studies in science showed learning benefits for the games group (mean $d = 0.69$), only 3 of the 5 studies in math showed learning benefits for the games, with a negligible effect size of 0.03.

Other meta-analyses of educational games have reported positive results for educational games more generally, but not for mathematics educational games more specifically (Clark, Tanner-Smith, & Killingsworth, 2015; Sitzmann, 2011; Vogel et al., 2006; Wouters, van Nimwegen, van Oostendorp, & van der Spek, 2013). For instance, Clark et al. (2015), in a review of 69 sound, empirical studies (filtered from over 1000 studies reported in published papers), found that computer-based educational games were associated with a 0.33 standard deviation improvement over non-game comparison conditions. Clark et al. (2015) emphasize that educational games are designed in many different ways, vary on a variety of dimensions, so they argue more for the importance of how the variations in game designs lead to different learning outcomes (called value-added studies of games by Mayer, 2014) and less on media comparisons within content domains (e.g., mathematics). Thus, they do not separately evaluate the evidence of digital games in the domain of mathematics. However, they reach the same general conclusion of Mayer, saying: "methodological rigor needs to be increased in research on games for learning" (Clark et al., 2015, pp. 35).

In other words, the research field of educational games is still nascent, with limited empirical evidence about the effectiveness of games, especially in the domain of mathematics. In fact, educational technology researchers have only recently begun to investigate ways to inject the learning of traditional subjects into computer games (Aleven, Myers, Easterday, & Ogan, 2010; Conati & Manske, 2009; Habgood & Ainsworth, 2011; Lomas, Patel, Forlizzi, & Koedinger, 2013; McNamara, Jackson, & Graesser, 2010; Risconscente, 2013). While there is certainly reason for the excitement about educational games, and many educational technologists are increasingly investigating the potential of games for learning, it is important that more rigorous studies be conducted to determine whether the excitement is justified. The educational game and study presented in this paper represents a step in that direction.

DECIMAL POINT: A GAME FOR LEARNING DECIMALS

Our educational game, a single-player game that has been under development for three years (Forlizzi et al., 2014), is based on an amusement park metaphor and is targeted at middle-school students. The game is called "Decimal Point: The Fantastically Fabulous World of Fractional Fun" (for short, "Decimal Point"). As shown in Figure 1, the student travels sequentially to different theme areas (e.g., Haunted House, Wild West, Space Adventure, Old-time Amusement Park), playing a variety of mini-games within each theme area targeted at learning decimals and relevant to that area's leitmotif (e.g., Enter If You Dare in the Haunted House; Bronco Lasso in the Wild West; Space Raider in Space Adventure; Balloon Pop! in the Old-time Amusement Park). The student's progress through the park is tracked, and students are visually prompted for the next game they will play. In Figure 1, the student has already played all of the mini-games up to but not including the Old-Time Amusement Park, indicated by the colored circles. The student is prompted to pick the next mini-game, Balloon Pop!, indicated by the pulsating red circle around that mini-game (see the middle of Figure 1).

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