Exploring the Educational Potential of a Game-Based Math Competition

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ABSTRACT

The main aim of this article was to investigate the educational potential of a game-based math game competition to engage students in training rational numbers. Finnish fourth (n = 59; \( M_{\text{age}} = 10.36 \)) and sixth graders (n = 105; \( M_{\text{age}} = 12.34 \)) participated in a math game competition relying on intra-classroom cooperation and inter-classroom competition. During a three-week period, the students were allowed to play a digital rational number game, which is founded on number line estimation task mechanics. The results indicated that students benefited significantly from participating in the competition and playing behaviour could be used to assess students rational number knowledge. Moreover, students were engaged in the competition and the results revealed that intrinsically motivating factors such as enjoyment and perceived learning gains predicted students’ willingness to participate in math game competitions again. This article provides empirical support that educational game competition can be an effective, engaging, and a fair instructional approach.

KEYWORDS
Assessment, Competition, Game-Based Learning, Number Line, Playing Experience Rational Numbers

INTRODUCTION

Numerical competencies have increasing importance for success in modern society (Siegler & Braithwaite 2017). In fact, Parsons and Byrner (2005) argued that, insufficient mathematical competencies might be even more detrimental to individual career prospects than reading or spelling deficiencies. Knowledge about rational numbers or fractions, respectively, seems to be particularly relevant as proficiency with fractions is strongly associated with high school students’ current math achievement and is predictive of future math achievement and algebra performance (e.g., Bailey, Hoard, Nugent, & Geary, 2012; Booth & Newton, 2012). However, students often struggle to learn this challenging domain in mathematics education (Gigerenzer, 2002; Siegler, Fazio, Bailey, & Zhou, 2013 for a review). Therefore, more effective and engaging ways to teach basic numerical skills, such as rational number magnitude understanding, that form the foundation to learn more complex mathematics are needed. Devlin (2013) has argued that video games can provide new interfaces to learn mathematics that are far easier and more natural to use than symbolic expressions that we have used to employ primarily. Thus, digital learning games have the potential to provide effective ways of training mathematics and can also engage persons who are anxious about mathematics. In line with this, previous research has indicated that digital learning games can be used to support mathematics.
instruction (e.g., Ninaus et al. 2017; Kiili & Ketamo 2017; Fazio, Kennedy, & Siegler 2016; Bakker, van den Heuvel-Panhuizen, & Robitzsch 2015; Riconscente 2013).

Today there is a large number of mathematics learning games on the market (e.g., Apple’s App Store lists over 20,000). However, the majority of these math games do not utilize the real power of game-based learning, but focus on traditional drill to develop mastery of basic skills and procedures. Most importantly, they often lack empirical evaluation of their actual effects. Therefore, in an era of digitalization of education, teachers face huge challenges to select good games from the different market places that slows down the diffusion of game-based learning and decreases the possible benefits of digitalization. According to Liu et al. (2015) game campaigns and competitions provide possibilities to raise awareness of games and can be used to distribute games to schools. That is, such campaigns might be used to raise awareness of games with an high educational value and support teachers in selecting appropriate games for learning to be used in their classrooms. This is particularly relevant in teaching fractions and rational numbers as they are considered to be one of the most challenging problems in mathematics education (National Mathematics Advisory Panel, 2008). Therefore, the current paper employs a math game competition in order to raise awareness about number line based Semideus games that have shown to be a valid assessment tool of rational number knowledge (Ninaus et al. 2017; Kiili & Ketamo 2017). In the following, we will first consider the meaning of competitive aspects in game-based learning and report the few previous results of educational game competitions. After that, we provide a brief summary on the empirical foundations of the employed Semideus game to foster conceptual rational number knowledge. Finally, we describe the aims and hypotheses of the current study.

**Competition in Game-Based Learning**

Competition is a common element in games and can affect outcomes and user experience of an educational intervention. For instance, Plass, O’keefe, Homer, Case, Hayward, Stein, and Perlin, (2013) investigated how competitive and social aspects in an educational mathematics video game impact in-game learning outcomes and motivation. They identified that although a social game mode increased situational interest and future intentions to play the game, only the competitive game mode enhanced in-game performance compared to individual play. Moreover, the results indicated that both competitive and collaborative game modes increased enjoyment compared to individual play. In line with these results, Cagiltay, Ozcelik, and Ozcelik (2015) found out that competitive aspects in a serious game significantly improved motivation and learning outcomes.

One way to add competitive aspect to educational games is to organize a competition around the game. Liu et al. (2015) have argued that educational game campaigns or competitions, respectively, could be used to scale educational technology solutions. However, such methods have not been widely used yet. According to Liu et al. (2015) a campaign is a focused, widespread event where students from several schools engage in a learning activity over a short time span. In particular, Liu et al. (2015) studied the usefulness of educational game competitions by organizing three large-scale algebra challenges/competitions in the USA and Norway in which participants played a mathematics game called Dragonbox Adaptive. The game was an evolution from the existing game Dragonbox by adding adaptive features and embedded assessment levels to assess player’s mastery on the subject. Moreover, a dashboard for monitoring mastery, number of solved equations, and playtime at the class-, school-, or district-level were provided for teachers and administrators.

All the three game competitions had the same collaborative goal. That is, the overall objective was to solve a prespecified number of equations across all students participating in the competition. The progress towards the goal was presented in real-time on the competition website. The competitive goal of the three competitions varied. One rewarded a tablet device for classes that had the highest overall mastery rate. The other rewarded a tablet for classes completing as many equations as possible and the third had no competitive aspect and reward at all. Liu et al. (2015) found that the completed equations goal caused longer playing times and motivated players more than mastery rate and no
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