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How competition and heterogeneous collaboration interact in prevocational game-based mathematics education

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ABSTRACT

The present study addresses the effectiveness of an educational mathematics game for improving proportional reasoning in students from prevocational education. Though in theory game-based learning is promising, research shows that results are ambiguous and that we should look into ways to support game-based learning. The current study explored two factors (i.e., collaboration and competition) that have been associated with motivational and cognitive effects, and have potential to optimize game-based learning. In a fully crossed design, four conditions were examined: collaboration and competition, collaboration control, competition control, and control. It was found that, over all, gameplay did improve students' proportional reasoning skills but that learning effects did not differ between conditions. However, when students' ability levels were taken into account, an interaction between collaboration and competition was found. For below-average students, the effect of collaboration was modified by competition, showing a negative effect of competition on domain knowledge gains in a collaborative learning situation. In contrast, for above-average students, the data demonstrated a trend that suggests a positive effect of competition on domain knowledge gain in a collaborative learning situation.

1. Computer-games as a mathematical tool for prevocational students

In the United States of America and Europe government has set goals regarding students' expected level of proficiency in mathematics (e.g., the 'no child left behind act') (Commissie voor onderwijs cultuur en wetenschapsbeleid, 2010; Heinrich, 2015). But reports show that students and schools fail to meet these goals (CvE, 2014; Heinrich, 2015). Therefore, it is important to find methods of improving students' academic achievement in mathematics. Research shows that mathematical training significantly improves the performance of higher and average-performing students, but that the needs of lower achievers are not always addressed successfully (Jitendra et al., 2007; Schoenfeld, 2002). Furthermore, most research on mathematical education addresses primary school or university students, or specific groups of learning-disabled students. Research addressing other levels of education, such as prevocational education, seems scarce.

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Prevocational education is a less advanced level of secondary education in which students are specifically prepared for intermediate vocational education. Students who attend the prevocational track show wide variety in their cognitive abilities and potential. Underachieving prevocational students have often struggled with subjects such as mathematics for years, and teachers in the prevocational track are therefore dealing with demotivated or apprehensive students who are unwilling to participate in education. Kramarski (2013) emphasizes the need for alternative training programs to help this group of students (from less-advanced levels of education) to conceptualize mathematical topics and to increase their engagement and experiences of success. Based on recent findings on the affordances of educational mathematics games (Kebritchi, Hirumi, & Bai, 2010; Shin, Sutherland, Norris, & Soloway, 2012; ter Vrugte et al., 2015; Young et al., 2012), we assume that computer game-based learning has the potential to meet this need.

Educational computer games are not just attractive for education because of their motivational components (e.g., Papastergiou, 2009; Paras & Bizzocchi, 2005; Squire, 2003); the interactive representations that games encompass can directly enhance learning outcomes (Habgood & Ainsworth, 2011). Computer games also make a diversity of vivid, comprehensive, and realistic problem-solving contexts easily accessible. This can help teachers to create settings in which otherwise abstract educational subjects can be made concrete, without needing to take field-trips, gather hands-on material, or rely on language to simulate context. All of this can support the accessibility of the mathematical subject matter for students who are not well equipped to learn mathematics topics, as is often the case for students such as those in prevocational education.

2. Competition as motivator

The motivational component of games, as indicated above, makes them an appealing alternative instructional approach for prevocational students. A key element that is assumed to foster motivation during gameplay is competition. Competition makes games feel like play and stimulates engagement and persistence in the learning activity (Malone & Lepper, 1987). Though competition seems to be a key motivational element, there is limited research that addresses the empirical effectiveness of competition in games (Van Eck & Dempsey, 2002; Vandercruysse, Vandewaetere, Cornillie, & Clarebout, 2013).

Competition comes in many forms. One can compete against the system, against oneself, or against others (Alessi & Trollip, 2001). Computer games incorporate one or more of these forms in a variety of ways. For example, players can compete against time, improve on previous high scores, acquire high scores that give them access to higher levels or special features, and beat other players. Positive effects of competition that, in turn, can facilitate learning, are held to arise from the creation of an additional challenge, generating excitement, engagement and motivation (Cheng, Wu, Liao, & Chan, 2009; Malone & Lepper, 1987).

Competition during game-based learning has been found to positively affect game performance (Plass et al., 2013), learning (Kollöffel & de Jong, in press), and the quality of learning (DeLeeuw & Mayer, 2011). However, we must bear in mind that making competitive elements more salient can also lead to negative effects. Social comparison during competition can cause less secure learners' performance to be undermined, and could induce tension, anxiety and feelings of frustration and inferiority in these learners, all of which can diminish their performance (Cheng et al., 2009). In addition, Van Eck and Dempsey (2002) found that the addition of competition affected the otherwise positive effects of contextualized advisement, demonstrating that competition can distract students from otherwise beneficial learning content and support.

3. Collaboration as support

When designing educational games, it must be kept in mind that empirical evidence on the educational value of serious games is ambiguous, and that evidence supporting their expected effectiveness remains limited (Girard, Ecalle, & Magnan, 2013; Young et al., 2012). Researchers and designers experience difficulties designing educational games that maintain motivational integrity, and even when researchers succeed in designing a motivational educational game, learning is not guaranteed (Garris, Ahlers, & Driskell, 2002). To be effective, educational games need to include support that can help to make explicit the knowledge involved (Leemkuil & de Jong, 2012), and, when necessary, can help students to acquire the relevant information (Leemkuil, de Jong, de Hoog, & Christoph, 2003; O'Neil, Wainess, & Baker, 2005).

The diversity of the population in prevocational education, may create a particular challenge for the design of an effective learning environment. Even support structures that have proven to be successful in other contexts, domains, or levels of education do not guarantee the success of an educational game in prevocational education. This has been demonstrated in the study by ter Vrugte et al. (2015), which investigated whether the addition of reflection prompts and procedural information could enhance prevocational students' knowledge acquisition during game play. Even though reflection is often mentioned as a successful measure for stimulating knowledge acquisition and making knowledge explicit (e.g., Barab, Thomas, Dodge, Carteaux, & Tuzun, 2005; Ke, 2008; Wouters, Paas, & van Merriënboer, 2008), and it has been proven to be successful when integrated in game-based learning (Johnson & Mayer, 2010), results from the study by ter Vrugte et al. (2015) did not demonstrate any added value of reflection prompts or procedural information in a mathematics game for prevocational students. They explain that this might be due to the cognitive skills that reflection requires, or that the support might not have been provided frequently enough or at the right moments. We suggest collaboration as a continuous and adaptive form of support that can help students to extend and make explicit their knowledge during game-based learning.