

Using Digital Games to Enhance 21st-Century Skills Development in K-12 Education: A Systematic Review

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Abstract: In today's rapidly evolving landscape, 21st-century skills such as creativity and problem-solving are indispensable. Digital games present a promising medium to cultivate these essential competencies. In this systematic review, we examine the impact of digital games on nurturing K-12 students' 21st-century skills, drawing on a rigorous analysis of 81 selected studies. This paper offers a synthesis of our initial findings.

Introduction

Equipping our children with 21st-century skills is crucial for their success in today's dynamic job market and beyond (P21 Framework Definitions, 2009). These skills encompass a broad spectrum including learning and innovation abilities (e.g., critical thinking, creativity, collaboration, and communication), proficiency in information, media, and technology (World Economic Forum, 2016). However, disconnect between school curricula and the demands of the 21st-century is one of fundamental issues in educational systems (Squire, 2005). To address this issue, well-designed digital games are emerging as promising vehicles for fostering 21st-century skills (Gee, 2003). Essential attributes of such digital games include ongoing interactive problem-solving, specific goals and rules, adaptive challenges, player autonomy, timely feedback, uncertainty, and sensory stimuli (Shute & Ke, 2012). However, the efficacy of digital games in nurturing 21st-century skills is still debated. While some studies present mixed or negative findings (e.g., Dindar, 2018), others report positive outcomes (e.g., Connolly et al., 2012; Sitzmann et al., 2011). This systematic review aims to identify key trends in using digital games to foster 21st-century skills, while also exploring the effectiveness of digital games and considering design aspects crucial for targeting such skills. To that end, we address the following research questions: (1) Which 21st-century skills are targeted by digital games? (2) What game genres effectively foster learners' 21st-century skills? (3) Which design elements of digital games have been emphasized in studies? (4) What learning theories have informed studies' game design? and (5) What impact do digital games have on the development of 21st-century skills?

Method

Following the PRISMA guidelines (Moher et al., 2009), we conducted a systematic review of the relevant literature to identify studies on digital games and 21st-century skills. We searched various databases and used tailored search strings (e.g., ("game" AND "learning" AND "21st century skills" AND "K-12"); ("digital game") AND ("education") AND ("21st-century skills")). The inclusion criteria were studies that focused on 21st-century skills, in K-12 context, and were published between 2014 -2023 in English. This range was chosen because a previous study on the same topic was conducted in 2016 which included studies from 2010 to 2014 (Qian & Clark, 2016). Therefore, the aim of the current review is to examine studies published after 2014, expand the scope of the research questions asked by Qian and Clark (2016), and provide an updated understanding of the effects of digital games on 21st-century skills. The exclusion criteria were non-English studies published before 2014 or studies with low quality. Two researchers independently screened the abstracts and full text of the articles, resulting in 81 studies for review, including 14 hand-searched studies. A spreadsheet was then used to extract and synthesize the data, with separate columns for each paper's variables. The information from each paper was independently extracted by the two researchers. A content analysis (in-depth reading of each paper) was performed to gain a deeper understanding of each study and answer the research questions. The researchers met and resolved their disagreements through iterative discussions to reach 100% agreement.

Results

Our systematic review encompassed 81 studies on the use of digital games to develop 21st-century skills, involving participants ranging from first graders to high school students. In relation to RQ1, our findings revealed that the primary skills targeted across these studies were problem-solving ($n = 19$), creativity ($n = 16$), collaboration ($n = 13$), critical thinking ($n = 11$), and communication ($n = 7$). A notable number of these studies ($n = 15$) explored the interplay among multiple skills. Addressing RQ2, the digital game genres cited within the

81 studies were as follows: serious games ($n = 22$), simulations ($n = 12$), adventures ($n = 10$), sandboxes ($n = 8$), puzzles ($n = 7$), role-playing ($n = 3$), strategies ($n = 3$), board games ($n = 2$), problem-solving games ($n = 2$), action games ($n = 2$), and other genres ($n = 10$). Regarding RQ3, studies have emphasized various design elements in digital games, including game mechanics, visual aesthetics, narrative, incentives, musical score, and learning objectives integrated with relevant content and skills. To address RQ4 we found learning theories such as behaviorist, cognitive, constructivism, and motivational and psychological have informed studies' game design. Finally, our finding regarding RQ5 shows that overall research indicates a positive impact of digital games on 21st-century skills development.

Discussion and conclusion

The aim of this systematic review was to provide educators with a roadmap for using digital games and designers with guidance for creating games that effectively enhance 21st-century skills among K-12 students. The review examined 81 studies and found that digital games have an overall positive impact on developing problem-solving, creativity, collaboration, critical thinking, and communication skills. The most common game genres used were serious games, simulations, adventures, sandboxes, puzzles, role-playing, strategies, board games, problem-solving games, and action games. This diverse range of genres highlights the potential for various types of games to foster 21st-century skills. The studies emphasized various design elements, such as game mechanics, visual aesthetics, narrative, incentives, musical score, and learning objectives, which are crucial for the effectiveness of digital games in promoting 21st-century skills. Understanding the role of these design elements is essential for creating engaging and educational games. Learning theories, including behaviorist, cognitive, constructivism, and motivational and psychological theories, have informed game design in the studies. To effectively use digital games for fostering 21st-century skills, educators, researchers, and designers should carefully select game genres, learning theories, and game design elements that align with the targeted skill development. This systematic review contributes to the growing body of research on the use of digital games for developing 21st-century skills and provides a comprehensive map connecting game genres, design elements, and learning theories, empowering stakeholders to harness the potential of digital games for fostering critical skills in K-12 students.

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