Serious Games and Game-Based Learning

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Contents

Abstract

This chapter summarizes theory and empirical research concerned with the use of serious games and game-based learning in educational contexts. Relevant characteristics and theoretical foundations of the value of games are assessed. The reviewed empirical findings indicate a strong effect of serious games and game-based learning on learner motivation, affect, and cognitive outcomes. However, the direction of their impact is not always straightforward as it depends on the interplay of conditions including the game type, design features, learner characteristics, and learning activities. This chapter suggests that developers and educators take this interplay into account to ensure optimal learner experiences when developing or choosing serious games or game-based learning approaches for educational purposes.

Keywords

Serious games · Game-based learning · Design issues

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Introduction

Serious games and game-based learning are popular methods for teaching and learning. While the value of games and play for learning has a long history in classroom-based contexts, the interest in games for digital and distance education has emerged over the last decade. Based on the enthusiasm this generation's students exhibit for games, they appear to have high motivational value, but in the context of teaching and learning, they are recognized as being much more than motivational tools. To a certain extent, games are argued to support the development of knowledge and skills that are otherwise hard to teach. They allow educators to virtually model real-world tasks in which students are able to interact, which gives students a sense of learning by doing or, in the case of games, learning by playing. Games further encourage students to take risks and to try different ways of learning and thinking with lower consequences of failure (Gee, 2003). Games' immediate response to actions might offer the kind of feedback mechanism to students that digital and distance education sometimes require, so that students can reflect on their difficulties.

Based on these advantages, games are intended to be useful learning tools by engaging learners on cognitive, affective, motivational-behavioral, and social levels (Plass, Homer, Mayer, & Kinzer, 2020; Prensky, 2001). Thus, the current tendency to integrate game-based learning approaches in digital and distance education acknowledges the emergence of new learning experiences that games may offer in order to enhance learning.

In this chapter, the understanding and the role of serious games and game-based learning are analyzed and discussed. The theoretical foundation for the success of games is outlined, and current empirical contributions are reviewed. Essential design features that impact the learning effectiveness of serious games and game-based learning are highlighted. Finally, this chapter closes with a reflection on the value of games for learning and directions for future research.

Definition and Characteristics of Serious Games and Game-Based Learning

Games can be defined as "a system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome" (Salen, Tekinbaş, & Zimmerman, 2004, p. 5). Digital commercial games were developed primarily for fun, entertainment, and recreation. In contrast, the objective of serious games and game-based learning is to use the entertaining quality of games for the purpose of learning (Connolly, Boyle, MacArthur, Hainey, & Boyle, 2012; Michael & Chen, 2006; Wouters, van Nimwegen, van Oostendorp, & van der Spek, 2013). While it can be argued that any game provides learning opportunities, such as gaining technical knowledge and developing motor skills (i.e., the development of body movements related to balance), the explicit function of serious games and game-based learning is to help students (1) acquire new knowledge and skill about an

important subject matter, (2) practice existing knowledge and skills, (3) develop learning and innovation skills, and/or (4) prepare for future learning (Plass et al., 2020).

The term "serious game" has a long tradition, starting with Abt (1987), and includes digital and non-digital games in various contexts such as business, industry, marketing, healthcare, and education (Michael & Chen, 2006). With the growing development of technology, however, the understanding of serious games is mostly from a digital point of view, in which they are defined as examples of interactive learning technologies that offer learning experiences through fully animated elements that are under learners' control (Rieber, 2005). The term "serious game" is often mentioned in the literature as synonymous with the term "game-based learning." Game-based learning, however, can be seen as an approach to teaching in educational contexts (Becker, 2021). With a specific learning goal in mind, a learning task is redesigned to make learning more interesting and more effective. This involves the use of serious games in the learning process, seen as a tool of game-based learning.

Common to both the use of serious games in specific contexts and the game-based learning approach in general is the use of games' inherent entertaining characteristics to deliver specific goals, outcomes, and experiences. Games provide rich sensory experiences through combinations of text, graphics, dynamic animations, audio, and haptics. Many games contain a story narrative with characters that involve the players. They consist of a constructed competitive setting with an incentive structure following a clearly defined goal that challenges the players (Graesser, Chipman, & Leeming, 2009). The most commonly cited entertaining characteristic of a game is its interactive nature. A game's story only evolves through interaction with the player's behavior. Therefore, as described in the input-process-output game model (Garris, Ahlers, & Driskell, 2017), feedback is half of the interactive game cycle, as the player's input and the game's output assert reciprocal influence. For example, games use visual and auditory feedback to let players know if certain actions have succeeded or failed.

Theoretical Foundations

The theoretical foundations of what makes the use of serious games and game-based learning psychologically successful can be described from motivational, affective, cognitive, and sociocultural perspectives.

Motivational perspective. The need to motivate learners to stay engaged over long learning periods has been often used in the literature as the main and most important argument for the use of games in educational contexts (Plass, Homer, & Kinzer, 2015). A number of theorists (e.g., Malone & Lepper, 1987; Rigby & Ryan, 2011) have proposed explanations for why games should be motivating, mostly through the inherent game characteristics described above, which apply a range of existing motivational approaches. For instance, the interactive and competitive nature of games increases motivational constructs such as interest, intrinsic

motivation, and what Csikszentmihalyi (e.g., 2008) has described as a state of flow, i.e., an extended time spent on a task with intense concentration in a way that perception of time and fatigue disappear. Ideally, the provision of challenge at the zone of proximal development (Vygotsky, 1978), i.e., the matching of challenge difficulty to student ability, satisfies the specific intrinsic needs of competence, autonomy, and relatedness. These three physiological needs comprise the major components of the Player Experience of Need Satisfaction model (Rigby & Ryan, 2011), which has been developed in order to identify game characteristics that are most satisfying. From the perspective of self-determination theory (Deci & Ryan, 1985; Ryan & Deci, 2002), the fulfillment of these learner needs is essential for intrinsic motivation and self-efficacy and leads to action-related behavior in terms of learning.

Affective perspective. By exploring what make games fun, Loftus and Loftus (1983) stated that active player engagement, associated with the right balance in challenge as described above, may also affect players' emotions. Ravaja, Saari, Salminen, Laarni, and Kallinen (2006) found enjoyment related to an exchange between success (acquiring in-game goods) and failure (such as falling over the edge of the game board). This result can be explained through the control-value theory (CVT) of achievement emotions (Pekrun, 2006; Pekrun & Perry, 2014): An optimal challenge (rather than being too hard or too easy) might foster perceived controllability, which, in turn, is linked to positive emotional experiences. Moreover, described in the literature as emotional design (Plass & Kaplan, 2016), a strong narrative and aesthetic visual and auditive design are examples of game features that influence emotions. (For a detailed overview of affective foundations of game-based learning, see Loderer, Pekrun, and Plass (2020).)

Sociocultural perspective. Social learning theories (e.g., Bandura, 1977; Piaget, 1964; Vygotsky, 1978) posit that learning consists of the construction and application of knowledge through direct experience of success and failure and through interaction with others, both of which are characteristics of games. For example, the game Mad City Mystery immerses students in an authentic scientific inquiry of a mysterious death, where teams of students experience social practices of being investigators by actually "practicing inquiry and argumentation skills" (Squire & Jan, 2007). The possibility to interact with the game system, with in-game characters, or with other students integral to the learning process helps to develop skills for collaboration and cooperation – skills which are seen as necessary for the twenty-first-century workforce (De Freitas, Rebolledo-Mendez, Liarokapis, Magoulas, & Poulovassilis, 2010).

Cognitive perspective. By virtue of their motivational, affective, and sociocultural properties described above, games have been intended to foster learning. In the overall context of multimedia learning, both motivation and emotions have been found to be important prerequisites for and mediators of cognitive processes and outcomes (Astleitner & Wiesner, 2004; Leutner, 2014; Moreno & Mayer, 2007; Plass & Kaplan, 2016). Fostering motivational concepts and inducing positive emotions through certain game mechanics could serve as facilitators for cognitive generative processing during learning, including the selection of relevant learning

information, its arrangement into a coherent structure, and its integration with prior knowledge relevant for the academic content conveyed through a game (Mayer, 2014).

Based on this overview of different but related theoretical perspectives, it is clear that high expectations exist for games to foster motivation, positive emotions, and deeper learning through their inherent characteristics (Habgood & Ainsworth, 2011). The next section reviews whether games could fulfill these expectations, based on empirical findings from game research.

Empirical Contributions

The research literature that investigates the effects of game-based learning (including computer and video games for learning, serious games, and the concepts of gamification and play) can be organized into cognitive consequences research, media comparison research, and value-added research (Mayer, 2014, 2020). Based on empirical studies using one of the three research approaches, a number of meta-analyses and empirical reviews have been conducted of the effects that game-based learning could have, particularly on motivation and on cognitive learning outcomes (e.g., Clark, Tanner-Smith, & Killingsworth, 2016; Connolly et al., 2012; Sailer & Homner, 2020; Wouters et al., 2013). A meta-analysis (Sailer & Homner, 2020) synthesizing 38 studies that use a consequence research approach by focusing on the effect of gamification for motivation, learning processes, and outcomes demonstrated a positive impact of gamification on cognitive learning outcomes, whereas the effect on behavioral outcomes (i.e., technical, motor skills, performance on specific transfer task) and on motivational variables (i.e., (intrinsic) motivation, preferences, attitudes, engagement, confidence, and self-efficacy) was less stable.

By determining whether there is evidence that learning from games can be more effective than learning from conventional media, in a meta-analysis of 65 studies that used a media comparison approach, Sitzmann (2011) found a positive effect of simulation games on self-efficacy and on conceptual, declarative, and procedural knowledge for the specific group of adult workforce trainees compared to alternative nongame instruction media. The meta-analysis of Wouters et al. (2013) identified 39 studies that investigated the effect of serious games on motivation and on learning outcomes for a wide range of age groups, from children to adults. No significant difference in motivation was found, but there was a positive impact of serious games compared to other more conventional instructional media such as lectures, reading, drill, and practice or hypertext-learning environments on learning outcomes including retention and cognitive skills. However, there was a wide-ranging effect size indicating that in some cases, games can be as effective and in other cases more effective than learning with conventional instruction media. Given two examples of inconclusive results in the context of higher education, Ebner and Holzinger (2007) examined motivation, enjoyment, and learning outcome between the use of the online game Internal Force Master (IFM) and traditional teaching in a math lecture on structural concrete at Master's level, involving 121 seventh-semester students.

The results showed that the use of the game fostered motivation and enjoyment. However, the student group who learned with the online game did not receive higher learning outcomes compared to the group who learned structural concrete in the traditional math course. Nonsignificant differences in learning outcomes between the two groups were found. In contrast, Crocco, Offenholley, and Hernandez (2016) reported an increase in motivation, enjoyment, and an improvement in learning of 440 undergraduate students who learned with games in English and science courses. Especially in science, games have been demonstrated to foster higher learning outcomes compared to conventional media (Mayer, 2020).

Overall, these contradictory findings from research using either a cognitive, affective, and motivational consequences approach, or a media comparison approach, suggest that there is no single and clear answer to the question of whether games positively influence motivation, affect, or cognitive outcomes. A discussion of games' effectiveness seems to be complicated by the fact that empirical studies in the context of serious games, gamification, and game-based learning vary in study populations, game type, academic content, and learning goals.

The inconclusive results further may refer to another problematic aspect discussed by Mayer (2020), who adapted the cognitive theory of multimedia learning (Mayer, 2009) and cognitive load theory (Sweller, Ayres, & Kalyuga, 2011) to describe how learners learn academic content when using digital games. Games have the potential to promote learner motivation, reflected in learners engaging with the material, which can foster generative processing. At the same time, however, they may create extraneous processing caused by the distracting features, even though these help learners to maintain a high level of motivation. Given the limited cognitive capacity of the human information processing system, as result of extraneous processing, there may be no cognitive capacity left for essential and generative processing which is needed for meaningful learning. Therefore, when designing games, there is a need for a balance of features that foster motivation but do not increase irrelevant extraneous processing (Mayer, 2020). This statement is supported by Clark et al.'s (2016) meta-analysis of 69 studies of the learning effect of digital games, which illustrated that only considering the genre of a learning environment is not sufficient to understand its impact on learning. Rather, more closely investigating instructional design features in interaction with learner characteristics may help to improve games' learning effectiveness and may guide game designers. Thus, besides research based on a media comparison or a consequence approach, a different line of research, i.e., value-added research, focuses on the question of how and what kind of design features in games may influence motivation, affect, and learning outcomes. The following section provides an overview of this question.

Design Features Influencing Motivation, Affect, and Learning Outcomes in Games

There have been a few theoretical attempts to summarize typical game design features and their interplay with relevant aspects of learning. In terms of how to improve motivational aspects of learning, the instructional design approach suggested by Malone and Lepper (1987) and the attention, relevance, confidence, and satisfaction (ARCS) model (Keller, 1987; Keller & Suzuki, 2004), for example, have been adapted to the context of gamification (e.g., Hamzah, Ali, Saman, Yusoff, & Yacob, 2015). In their integrative model of emotional foundations of game-based learning, Loderer et al. (2020) used the basic structure of the CVT in order to systematize and describe affective functions of certain game-based learning features such as aesthetic design, narrative, incentives, or feedback. A theoretical attempt that maps these game features onto theoretical components of motivational, emotional, cognitive, and social aspects of learning is the integrated design framework for playful learning (Plass et al., 2015).

While a detailed description of each of these attempts is beyond the scope of this chapter, particular game design features that the value-added research has shown to influence the effectiveness of games will now be briefly summarized.

Mode of play: competition and collaboration. In their comprehensive literature review of the effect of design features of game-based learning, Clark et al. (2016) found competition to be more effective when it is augmented with social interaction of learners. In other words, when learners collaborated in groups to compete against the gaming system, the learning outcome was higher compared to those games using single competitive game designs. Similar results were found in the review of gamification conducted by Sailer and Homner (2020). These findings overwhelmingly demonstrate the effectiveness of collaboration and cooperation over exclusively competitive game settings, which might cause social pressure and have a destructive effect on participation.

However, competition has also been shown to potentially increase enjoyment, situational interest (Plass et al., 2013), intrinsic and extrinsic goal orientation (Vandercruysse, Vandewaetere, Cornillie, & Clarebout, 2013), and positive attitudes toward the academic content (Ke & Grabowski, 2007). The outcome of competition might vary for different types of learners depending on prior knowledge and preference to compete (Riemer & Schrader, 2020). While some students will see that they have no chance of achieving a high ranking and become demotivated, others may be motivated to climb the leaderboards (Abu-Dawood, 2016).

Learner control. As part of interactivity, learner control refers to the potential of a game to allow the users to handle flexibly the technology or the gaming systems (Bryant & Love, 1996). It includes the extent to which users are allowed to manage directions of gameplay activities, adjust task difficulty, or customize an avatar. In addition to the concept of control being an attribute of the game itself, it can also be defined as a psychological factor, which reflects the user's perceived competence to influence or master certain aspects of the gaming system (Klimmt, Hartmann, & Frey, 2007). Schrader and Nett (2018) designed Liver Defense, a serious game in

which the learner must successfully defend the human liver from incoming substances such as ammonia, alcohol, and pharmaceuticals, by creating liver cells and enzymes that are specialized to break down each substance. The goal of the game is to help students to learn about functionalities of the human liver. By comparing three different levels of task difficulty, students reported higher perception of being in control, higher enjoyment, and lower frustration when learning with both low and moderate difficulty levels compared to high difficulty. This finding can be linked to CVT, which predicts that the experience of enjoyment is supported if learners perceive an activity as being controllable. In turn, if activities cannot be handled successfully, frustration might be experienced. However, as also shown by Schrader and Nett (2018), the differences in control perception and in emotions between the three difficulty versions disappeared with increased practice time, yielding nonsignificant results in both affective and cognitive outcomes. Based on this finding, it can be noted that games should become complex as players may welcome gradual increments in the difficulty level. This is also an integral part of flow theory, indicating that the challenge should constantly match learner's ability (Abuhamdeh & Csikszentmihalyi, 2012; Nebel, Beege, Schneider, & Rey, 2020). To fulfill this recommendation of adaptivity, there is a need for continuous measurement of learner experience during gameplay; this is discussed as a methodological challenge for further game research.

Aesthetic and narrative design. A number of universal aesthetic characteristics specifically linked to learner's affect and motivation can be adapted to game-based learning. These include the visual aesthetic design and auditive design. Research on the effects of colors and shapes in games on learners' affect, for example, showed that warm colors and round shapes induced positive emotions (Um, Plass, Hayward, & Homer, 2012). Research investigating the effect of music in games has shown that a musical score positively impacts motivation and enjoyment (Lipscomb & Zehnder, 2004). However, there are mixed results regarding students memorizing facts in a virtual learning environment with and without background music (Fassbender, Richards, Bilgin, Thompson, & Heiden, 2012).

In terms of narrative design, the inclusion of a narrative for situating and anchoring learning in context has been demonstrated to lead to increased positive arousal compared to games without a narrative (Echeverria, Barrios, Nussbaum, Améstica, & Leclerc, 2012; Schneider, Lang, Shin, & Bradley, 2004). The design of human-like game characters with which players identify further leads to positive emotions during play (Hefner, Klimmt, & Vorderer, 2007).

While aesthetic design and strong narratives foster emotional and motivational aspects, Clark et al. (2016) found in their meta-analysis that an aggregate contextualized variable created from visual and narrative game features had a small but significant negative impact on learning outcomes. This result refers to the design problematic designers and educators are challenged with: Visual and auditive complexity and rich narratives might foster motivation and positive emotions that are important for learning. However, these might also distract learners, require nonessential cognitive processing, and hinder learning. Therefore, game design should

balance motivating elements and align these with content and learning goals in a manner that does not unnecessarily add to the learner's cognitive load.

Feedback and support. Feedback and support are pedagogical components implemented in games. Feedback is instantly and immediately provided as learners see the outcome of their actions, often in the form of scores, experience points, badges, or power-ups. Examples of support include the provision of explanations in feedback; navigation through the game via on-screen messages, hints, or prompts; or feedback via an avatar (Arroyo, Muldner, Burleson, & Woolf, 2014; Leemkuil & de Jong, 2011; Mayer & Johnson, 2010). All of these features encourage learners to reflect upon and re-evaluate their in-game behavior and strategies.

There is significant evidence suggesting that the implementation of feedback and support is necessary to foster motivation and learning (e.g., Erhel & Jamet, 2013; Rieber, 2005; Yaman, Nerdel, & Bayrhuber, 2008). However, there is a large discussion on how to design and how to integrate feedback and support in order to support students most effectively. Rigby and Ryan (2011) found that feedback that informs about progress during gameplay is more motivating than feedback that only indicates success and failure by the number of points and rewards. The meta-analysis of Clark et al. (2016) found feedback in games especially useful for learning outcomes when it was individually adaptive. Mayer and Johnson (2010) found that integrating support via additional on-screen explanations resulted in greater transfer of the learned academic content.

However, the frequency and amount of feedback and support may determine learner motivation. The addition of frequent support may disrupt game flow and might result in a loss of perceived autonomy and control (Vrugte & de Jong, 2011). For learners with extensive prior knowledge who could succeed with little to no support, it might have a detrimental effect (Tobias, Fletcher, Dai, & Wind, 2011). Thus, support should be carefully incorporated into the environment based on student prior knowledge (Mayer, 2020). Approaches that adapt support to the individual learner by intervening only where necessary may help to avoid loss of the motivational qualities of a game-based learning approach (Janning, Schatten, & Schmidt-Thieme, 2016).

Conclusion

A game-based learning approach, including the use of serious games, is a powerful driver to motivate students rather than just providing them with information. Given the importance of motivation for learning outcomes, the use of games for education and their value for digital and distance education is currently generating much discussion.

This chapter has described theoretical foundations for the potential of games from motivational as well as affective, cognitive, and sociocultural perspectives. This highlights that games need to be understood from many interrelated views. The empirical literature, including media comparison research; cognitive, affective, motivational, and sociocultural consequence research; and value-added research,

was reviewed. Based on value-added experiments that aim to identify which design features improve game-based learning and which do not, future design issues that educators should consider when choosing or developing games for learning were highlighted. Although promising, there are neither concrete design feature characteristics nor a combination of features that will always result in optimal learning under every condition.

Future research needs to determine conditions under which games are effective in order to strengthen the evidence for their positive value. For example, research that goes beyond short-term laboratory studies and actually integrates serious games and game-based learning approaches into naturalistic educational contexts (including their embedment in diverse learning activities) to study their effects over a longer time might contribute to a deeper understanding. What is more, research should be expanded to assess not only the final outcomes of learning with games.

Relatively, little attention has been paid so far to actually investigate in the development of learner-relevant factors such as motivation and affect during playing, their interplay, and their mediating role to cognitive processes. This presupposes also methods to detect changes in learner-relevant factors during learning. Emerson, Cloude, Azevedo, and Lester (2020) demonstrated that a multimodal learning analytic approach that incorporates student gameplay, eye-tracking, and facial expression data could predict student interest and performance outcomes. The possibility of continuous assessment of student behavior during gameplay without interrupting the gameplay holds significant promise for detecting suboptimal learning experiences in order to provide adaptive support on time.

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