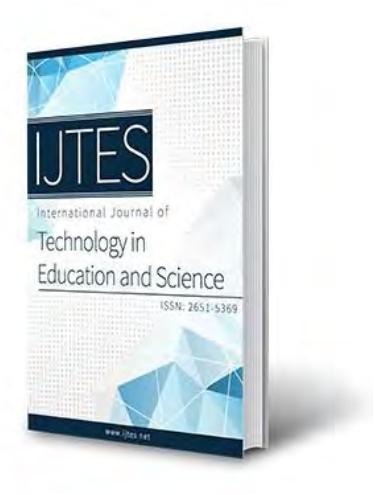

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Tetyana Kucher
University of North Texas, United States of America

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Principles and Best Practices of Designing Digital Game-Based Learning Environments

Tetyana Kucher

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Abstract

Playing games holds an important role in learning and development. While designing and using digital game-based learning (DGML) environments becomes more appealing to educators, there is a disconnect between the goals that educators try to achieve and the design strategies they utilize to achieve their goals. The inclusion of game elements alone is insufficient to improve students‟ learning, and it does not solve educational problems that DGBL environments are aimed to solve. The current state of research on the design of DGBL environments calls for an updated review of the best practices in recent years for developing DGBL environments, which prompted this literature review. It draws from successful examples of educators implementing learning games in classes, and it highlights five key principles that facilitate the effectiveness of DGBL: (1) interactivity, (2) immersiveness, (3) adaptive problem solving, (4) feedback, and (5) freedom of exploration. Practical examples are used to illustrate the effective implementation of these principles in DGBL environments and to underscore the significance of each component.

Introduction

The area of education has been increasingly affected by rapid technological developments. While technology plays an important role in our lives, the design of learning environments needs to reflect the environments of the children in order to be engaging, motivating, and consequently, effective. Children like to play games, and the concept of educational games has been drawing the attention of many scholars over the years (e.g., Brody, 1993; Carr et al., 2006; Kafai, 2006; Papert, 1993). As the interest in serious games for learning started to grow, researchers have been investigating not simply the use of games in an educational context, but the value of designing models of digital game-based learning (DGBL) environments (e.g., Alaswad & Nadolny, 2015; An & Bonk, 2009; Gee, 2005; Kiili, 2005).

Well-designed DGBL environments have the potential to offer students situated learning while facilitating their engagement, motivation, and improving real-world skills (An & Bonk, 2009; Gee, 2005; Shaffer et. al., 2005). Many educators attempt to develop creative ways to design their classes by utilizing games and gaming elements. Educational games that are designed by the teachers and tailored specifically to the students‟ learning outcomes increase students‟ self-esteem and interest in the subjects (An & Cao, 2017).

The increasing interest in DGBL prompts educators to experiment with designs of their own learning environments using digital technologies and gaming principles. However, a gap in the literature exists regarding understanding DGBL development principles which makes it difficult for professionals to design and utilize digital games effectively. It often results in practices when teachers incorporate short-form game genres, such as drill-and-practice and puzzle games (Takeuchi & Vaala, 2014). Such activities do not constitute learning environments, but rather educational practices that incorporate certain gaming elements, and they do not take full advantage of the affordances of DGBL environments. The inclusion of gaming elements alone does not guarantee effective learning outcomes and does not solve educational problems that DGBL environments are aimed to solve. Therefore, creating an effective DGBL environment requires strong knowledge of foundational principles of digital game structure and development (Gee, 2005).

While technical knowledge is not necessary to design an idea for an educational game, it is important to understand the building blocks which are necessary to construct the learning environment with a well-balanced system of education and gaming. Too much gaming may lead to limited educational gains, and too much learning content may lead to boring and not engaging gaming experience. Balancing these two components is a challenging task for teachers because pedagogical expertise does not directly translate into game design (An, 2016; Johns et. al., 2018). Although there have been examples of successful DGBL environments designed by educators (e.g., Pesare et al., 2016; Setyaningrum et al., 2018; Sung & Hwang, 2013), there is a need for more research that would focus on the strategies and effective practices of building educational environments using gaming elements. The examples of successful DGBL implementation can help identify principles and strategies that will aid teachers in overcoming pedagogical challenges of combining educational materials and entertainment components to develop effective and engaging DGBL environments.

Gamification v. Digital Game-Based Learning

In the context of using games for education, the concepts of gamification and DGBL are often misrepresented as interchangeable constructs that have similar goals. Therefore, before stepping into the discussion about the guidelines of DGBL development, it is important to clarify the distinctions between gamification and DGBL. Gamification is a system that refers to the application of game mechanics in a non-gaming setting (Deterding et al., 2011). While gamification generates significant interest among educators (Nah et al., 2014), it has been rapidly adopted in the spheres of marketing, business, management, and ecology initiatives (Stott & Neustaedter, 2013). The adoption of gamification principles traditionally includes the use of interconnected game elements such as point and leveling systems, leaderboards, badges, bonuses, and others (Chou, 2015; Kapp, 2012).

DGBL relates to the strategies of systematic use of stand-alone games to enhance students" learning experience (Vandercruysse et al., 2012). Such game-based learning activities are isolated from one another and are not a part of a large gaming system with interconnected elements. In some cases, DGBL is offered through a gaming environment developed specifically for the learning topic (e.g., Arachchilage et al., 2016), and in other, teachers may adapt an existing game to fit desired learning goals, even if the game has not been originally designed for

learning (e.g., Ranalli, 2008). While gamification turns the entire learning process into a gaming event, DGBL uses a game as a part of the learning process.

Both strategies pursue similar learning goals and promote engagement and sustained motivation in learning. Gamification and DGBL environments are designed to solve an educational problem as well as to motivate and engage students, but they differ in their approaches. However, gamification requires the structure of the entire learning sequence to be adapted to the gaming system, and DGBL calls for a small-scale adaptation which can be tailored to specific learning topics and units without the need to create a gamified system. Therefore, DGBL environments allow greater flexibility in implementation and modification of learning to make it responsive to individual students‟ needs and learning goals. This paper overviews common features identified in previous literature and exemplifies these futures in studies that demonstrate successful implementation of DGBL environments.

Design Principles

Previous literature focused on effective educational games designed by educators, and they outlined key principles of successful DGBL designs. The articles reviewed in the process were published in high-ranking peer-reviewed journals focusing on research and development in educational technology. Common themes, features, and repeated patterns were identified which shaped the elements that were reproduced in different DGBL environments. The articles that described effective practices of designing DGBL environments in education included the following common characteristics:

- Interactivity
- Immersiveness
- Adaptive problem solving
- Feedback
- Freedom of exploration

These principles derived from successful implementation of digital gaming elements in learning, and they provide suggestions and strategies for incorporation of these elements based on real-life examples. The examples outlined in this paper show how each of these elements are effectively adopted in educational games and may offer ideas for the development of future DGBL designs.

Interactivity

The effectiveness of a DGBL environment may be achieved through an appropriate level of meaningful interactivity offered to learners. Interaction within DGBL environments may occur between a player and the game content (e.g., Barab et al., 2007; Huizenga et. al., 2009), and among multiple players (e.g., Maraffi et al., 2017). Games that offer meaningful interactions demonstratively maintain high levels of engagement in students and positively contribute to their performance on tests when compared to regular project-based instruction (e.g., An & Bonk, 2009; Barab et. al, 2007).

A notable example of meaningful interactivity between players and the digital game content is offered by Huizenga et al. (2009). In their study, researchers used a digital game called *Frequency 1550* designed to teach a history lesson about Medieval Ages. The game offered an elaborate and engaging storyline with the goal to gain citizenship in the city of Amsterdam via attainment of the required 366 points, or „days of citizenship". 211 students in the control group were learning with this game for three weeks, and as they were playing, they were gaining points by completing content-related tasks using their smartphones, internet connection, and GPS navigation. This study reports that students who were involved in the game attained higher scores than the students who were exposed to regular project-based instruction, confirming the effectiveness of game-based instructional design with the specific emphasis on content interactivity.

Interactivity between a player and the content can be further expanded by including inter-player interactions which can foster collaborative learning and even facilitate friendly competition among small groups of students. An example of such interactive environment within a DGBL context was described by Maraffi et al. (2017) who developed a game called *GeoQuest* designed to teach interdisciplinary science and humanities. In this collaborative game, all students followed the game path on a single screen as a team, or as groups of small teams. While all students interacted with the game using their own smartphones of tablets, only one answer could be accepted per team, and students needed to work together to make their decisions by discussing possible choices or by using the "majority voting system" (p. 424). Not only did this DGBL design provide students with engaging and interactive learning experience, but it also fostered peer collaboration and the sense of shared responsibility.

Immersiveness

In an effective DGBL environment, students are immersed in the game through the multisensory representation of the storyline and by being assigned a specific identity or a role. The formalization of a narrative is a major step needed to conceptualize a learning game. Multisensory integration of gaming components is often achieved through the inclusion of different effects in the game, such as music, sound effects, narrator"s speaking voice, photos, videos, animations, 2D or 3D graphics, and other media elements that help create a vivid scenario and an enjoyable learning context.

Immersive details and students" absorption in the activity may lead to the mental *state of flow* (Csikszentmihalyi, 1990), meaning that students would intrinsically enjoy the game and perceive the involvement in the game itself as its own reward (DeCharms, 1972; Deci, 1975; Nakamura & Csikszentmihalyi, 2002). For example, students in the study by Maraffi et al. (2017) interacted with videos, animations, music, and sound effects, and they engaged in hands-on activities while playing the computer role-playing game used in the class. They demonstrated high levels of emotional involvement along with the improvement of their learning skills which were attributed to their multisensory immersion in the game.

Previous literature outlined increased engagement in DGBL environments by immersing students in the game through the multisensory representation of the storyline, and by being assigned a specific identity or a role.

Studies show that role-playing and commitment to a character‟s identity positively affect students‟ motivation to succeed in the game and engagement with the in-game learning process (e.g., Arachchilage et al., 2016; Huizenga et. al., 2009; Papadakis, 2018). Therefore, students are more engaged and immersed in the game when their identity is adapted to the gaming context.

Learners may inherit a role of a static character (e.g., Arachchilage et al., 2016; Pesare et al., 2016), a unique role with different abilities attached to that role (e.g., Huizenga et al., 2009; Göbel et al., 2013), or customize their own character (e.g., Bal., 2019; Bretherton et al., 2016). In Göbel et al.‟s (2013) study, each student was assigned a character of a killer, an achiever, a socializer, or an explorer. Their roles determined their abilities in the game, and this personalization factor positively affected students‟ interest and motivation to learn. Huizenga et al. (2009) also successfully incorporated role-playing in their game by assigning different identities, rights, and statuses to students, such as a beggar, a merchant, or a priest. Students‟ unique roles in the game and their corresponding abilities affected their in-game decisions and reportedly contributed to their engagement in the learning process.

DGBL environments may also incorporate static characters placed in specific scenarios. For instance, in the study by Arachchilage et al. (2016), students were learning about phishing attacks and ways to protect themselves from online identity thefts by playing a mobile game and taking on a role of a fish. The goal of the game was to eat worms, and each worm was associated with a URL address. Inappropriate addresses, or phishing attacks, were considered fake worms which students needed to correctly identify and avoid. This game is a great example of the way in which an educational topic can be integrated into the DGBL setting without breaking the integrity of the gaming narrative. Educational games may also include realistic characters in simulated scenarios. For example, in the game used in Pesare et al.‟s (2016) study, learners were taking roles of doctors, and they had to treat patients by making the right diagnosis based on their reported symptoms. Even though these DGBL scenarios may be relatively simple, they contribute to students‟ interest and immersion in the game if they include a clearly defined character who has a specific goal and is represented with original graphic design and audio elements.

While in most digital games students inherit pre-defined identities, some DGBL environments immerse players in the game by allowing character customization options such as choosing their own appearance, characteristics, or abilities (e.g., Bal, 2019; Bretherton et al., 2016). In an online application *Storium* developed to teach English writing, students could choose an avatar for their role and build their character‟s features such as profession, strengths, and weaknesses (Bal, 2019). These personalization options help students create unique characters for themselves and amplify the sense of immersion and engagement in the game which also positively affects their motivation.

Adaptive Problem Solving

Many cognitive psychologists report that engaging students in solving real world problems positively affects their learning gains (e.g., Mayer, 1992; Merrill & Gilbert, 2008). The challenge to resolve these problems needs

to be effectively aligned with the student‟s ability and skill level to ensure effective learning. Therefore, I coined the term *adaptive problem solving* to accurately reflect this need. Effective DGBL environment should present learners with a set of challenging problems, and they need to continue solving these problems until they have virtually automated their solutions (Gee, 2005). Bereiter and Scardamalia (1993) referred to this process as *Cycle of Expertise*. They claimed that "new mastery is consolidated through repetition (with variation), only to be challenged again" (p. 318). In a traditional school setting, students who require extra time to consolidate often do not get this opportunity, and it prevents them from mastering certain skills and obtaining the knowledge while other students might not get enough challenge.

A well-designed DGBL should offer skill-level adjustments to the problems that students are facing which will ensure gradual learning for all students (Wilson et al., 2009) and create *motivational tension* (Driskell & Dwyer, 1984) when the challenge of the game is optimal for students‟ skills. For example, Sung et al. (2016) used a collaborative mobile learning system based on a problem-solving approach to study local culture. Students in their study learned by visiting certain physical locations, scanning QR codes of the targets, and then completing some tasks or answering questions. The game system adjusted to students‟ responses and provided hints to guide learners if they were struggling to find the right answers. By following students‟ self-paced learning and repeating the tasks that students struggled with, the game design helped learners complete the Cycle of Expertise by consolidating their knowledge through repetition and problem solving.

In another example, students practiced mathematics skills by playing an educational game called *GeoGame Adventure* (Setyaningrum et al., 2018). This game design was based on four stages of problem-solving procedures introduced by Polya (1988): (1) identifying the problem, (2) devising a course of action to solve the problem, (3) applying the plan to solve the problem, and (4) interpreting the solution and checking to see if all the available information was used to solve the problem. Each level in the game followed the procedure developed based on the problem-solving method. This DGBL combined with problem-solving approach led to greater achievement of learning outcomes when compared to traditional textbook-based problem solving.

Feedback

As in any form of learning, quality feedback helps students evaluate their progress, recognize their strengths, and identify areas that need improvement (Charles et al., 2009). Effective feedback should provide timely and relevant information on students‟ progress towards their learning goals. Shute (2008) outlines different types of feedback depending on their length, specificity, timing, and complexity that are frequently used in traditional learning environments. In the context of DGBL, feedback may also take form of point accumulation, level progression, receiving new titles or acquisition of magic objects which provide some visible progress for even relatively small successes, and it reportedly leads to stronger self-efficacy, greater persistence, and commitment to future accomplishments (Mayo, 2009).

Burgers et al. (2015) studied positive and negative feedback and their variations used for game-based learning. 157 adult learners were playing a brain-training game called *Concentration* in which they were required to

match picture pairs as quickly as they could. They tested the effects of positive and negative feedback in three forms:

1. *Descriptive* (e.g., "You achieved the goal" or "You did not achieve the goal),
2. *Comparative* (e.g., "You completed the game in a time below the average" or "You completed the game in a time above the average"), and
3. *Evaluative* (e.g., "Well done! Keep it up!" or "Poorly done! Try to be faster next time!").

Positive evaluative feedback helped students perceive themselves as more competent and autonomous, which also increased their motivation. Because learners‟ intrinsic motivation is fundamental for effective learning (Deci & Ryan, 2000), incorporating high-quality evaluative feedback in game-based learning can serve as an important motivator that can lead to greater learning outcomes.

Depending on the nature of the game, different types of feedback may be employed to achieve a positive effect. For example, Erhel and Jamet (2013) presented a multimedia game that helped students learn about diseases associated with aging, such as Alzheimer‟s and Parkinson‟s diseases. They found that Knowledge of Correct Response (KCR) feedback (Shute, 2008) improved students‟ motivation and reduced their fear of failure when combined with an entertainment instruction. In another example, students played an arcade-type game about electrical circuits where they were required to demonstrate hands-on problem-solving skills (Mayer & Johnson, 2010). Learners who received explanative feedback performed significantly better than those who were not provided any explanation about their right or wrong answers. Feedback is a powerful motivational tool that can improve students‟ performance when appropriately used. Effective educational games need to be designed in a way that would provide students opportunities to adequately evaluate their progress by adopting specific types of feedback according to different types DGBL environments and their learning purposes.

Freedom of Exploration

Research shows that moderate risk can heighten students‟ motivation and engage otherwise disinterested learners (Devonshire et al., 2014). However, while the traditional definition of *risk* involves potential negative consequences (Gullone & Moore, 2000), digital games can offer students opportunities for exploration and risk-taking without the fear of making an error. In a well-designed DGBL environment, players are encouraged to explore, take risks, and try new things. In a game, failure is a good thing, because when faced with a challenge, players use initial failures as ways to recognize patterns and gain feedback about the progress being made.

Too often schools allow little to no space for risk, exploration, and failure (An & Bonk, 2009). In DGBL environments, when players are exposed to problems, they are encouraged to explore different ways to resolve them and find the most appropriate solutions. (e.g., Maraffi et al., 2017; Pesare et al., 2016; Setyaningrum et al., 2018). Engaging and motivating educational games are designed in a way that reduce the severity of consequences if students make an error, such as, students‟ grades do not depend on their performance in the game, and they get a chance to play again and change their gaming behavior to succeed. It encourages students to take risks and explore actions and alternative solutions to the problem until they come to the correct decision (Gee, 2005).

Pesare et al. (2016) described a digital simulation game in which students took on roles of doctors who needed to correctly diagnose their patients‟ illnesses. They were able to play the game several times and get more comfortable with making their decisions as well as increase their success rate. In clinical training, incorrect diagnosis can have severe consequences for both the patient and the student. In a classroom setting, students‟ ability to make the right decision is often tested using graded assignments. Making errors is a natural part of learning, and anxiety related to making a mistake often hinders students‟ success. DGBL allows students to release the pressure, explore, try out their decisions, and learn from their own mistakes.

Conclusion

Designing an effective DGBL environment that can engage and motivate students as well as facilitate their learning is a challenging task. In many cases, teachers‟ pedagogical expertise does not directly translate into game design, and it leaves educators puzzled regarding the effective ways to introduce learning games in a class and what elements of games and learning should be prioritized. While there is no one correct way to design DGBL that would guarantee its effectiveness for all students, previous research can offer successful examples of digital games incorporated in classrooms that share common principles. The implementation and the effectiveness of these principles depend on students‟ goals, interests, subject matters, available resources, but they constitute a solid foundation for designing or adapting a digital game according to the desired learning objectives. The good practices outlined in this paper provide insights into the potential to combine different technologies, learning contexts, scenarios, and goals. As educational technologies continue to develop, more tools will be available for teachers to experiment with and uncover additional benefits and effective practices of using digital-based games.

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Author Information

Tetyana Kucher

https://orcid.org/0000-0002-6260-1579

University of North Texas

Denton, Texas 76201

United States of America

Contact e-mail: *tetyana.kucher@unt.edu*