

# Trends of Instructional Research Using Biology Game: A Systematic Review of the Evidence during 2010-2019

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**Abstract:** Learning by using a game in science is becoming popular and it has been conducted in instructional research by many countries. Many researchers investigated instructional trends of using science games in several review articles. However, the review analysis emphasizing the use of educational game in biology is rarely found. As such, this paper aims to portray the trends of instructional research using biology games, both digital or non-digital, from 2010 to 2019 in Scopus indexed articles. Based on the reviews, the trends of game-based biology learning during the last ten years were raised gradually. In addition, the majority of the games used is simulation-like digital game. While most non-digital games were used is board game. The finding could be implied into development of technological and pedagogical solutions in a future of biology education.

**Keywords:** Serious game, educational game, game-based learning, digital game, biology gaming

## 1. Introduction

Many studies have used the potential of games to promote students' affective domain of learning and increase their cognitive performance (Srisawasdi & Panjaburee, 2019). Using games in science learning activity is not a new phenomenon in education. Games had been implemented in school education as learning tools (Anderson & Barnett, 2011). Some studies also reported that using a game as a learning tool (game-based learning) and gamification significantly increased student motivation for learning (Cózar-Gutiérrez & Sáez-López, 2016; Pesare et al., 2016). Johnson et al. (2012) explained that games can make learners motivated because it transforms the boring learning into interactive learning. In term of instructional research, many researchers proved that using games in science class gave several educational benefits. For instances, Khenissi et al. (2015) stated that the games helps learners to understand the concept. Moreover, games also can stimulate the formation of mental structures from natural phenomena to become long-lasting and also show significant effects on students' cognitive enhancement (Corredor et al., 2014; Khoiriah et al., 2016). Besides, games and simulations in science learning can improve learning quality in both formal and informal education (Muehrer et al., 2012). Also, Divjak & Tomić (2011) argued that a computer-based game affects attitude. Besides, games or ICT-based media can improve generic skills in science (Mulyani et al., 2016). As abovementioned, games have been chosen by educators and researchers in order to enhance the quality of instruction and to improve students' learning outcomes.

To review trends and direction of game-based learning in science, Li and Tsai (2013) conducted an investigation to examine the use of game in science education from 2002 to 2013. They reported that there is a surge of interest in the use of serious games in context of science education. Many games were utilized to promote scientific knowledge or conceptual learning, while less than one third were implemented to facilitate the students' problem-solving skills. Based on the previous review, there is no specific review analysis concerning the use of games in biology context before, and the research

related to biology game for learning still has many attractive things for educators and researchers. Therefore, this study aimed to review researchers on the use of educational biology games, and this systematic review is an essential for the future research. In this study, the questions were:

- How was the trend of using educational biology games from 2010 to 2019?
- What were the types of games published from 2010 to 2019?

## 2. Literature Review

### 2.1 *Game-based Learning (GBL)*

GBL refers to a student's engagement with educational materials with enjoyment, which defines by rules and artificial conflict (Salen & Zimmerman, 2010). Instead of learning to play the game, GBL means learning through the game (Siang Ang, Avni, & Zaphiris, 2008). While Simões et al. (2013) explained that GBL is using games both in leisure and serious about enhancing and supporting learning. Games which is used to attempt the learning objectives rather than only entertainment is called serious game (Vorderer & Ritterfeld, 2009).

GBL has several elements or characteristics which differentiate the game with non-game. It is explained that game is a media audio-visual composed of several characteristics such as fun characteristics, feedback, rewards, and challenges (Li & Tsai, 2013). Prensky (2001b) also stated that the game must have six elements, which are rules, goals, feedback, challenge, interaction, and story or representation. Whereas Plass et al. (2015) explained that there are several game elements to improve the students or player engagement, namely learning objectives, game mechanics, narrative, visual aesthetics, incentives, and musical score. While Alexiou & Schippers (2018) argued that the game elements that are nested within three main layers: the game system (rules, mechanics), narrative (theme, story, characters), and aesthetics (audio-visual elements, fidelity, aesthetic choices).

GBL has the primary foundation, which is cognitive, motivation, affective, and sociocultural engagement with the subject matter (Plass et al., 2015). In the cognitive foundations, designers should consider how the game elements affect cognitive processing where cognitive engagement starts with attention (Alexiou & Schippers, 2018). There are several ways to facilitate cognitive processing, such as using scaffolding and interaction design (Mayer, 2016). From the motivation foundations, designers must focus on using specific elements in their educational games to engage and motivate students. While affective and sociocultural foundations focus on emotions, beliefs, and social and cultural factors (Plass et al., 2015).

### 2.2 *Digital Game-based Learning (DGBL)*

The advancement of computer and multimedia technologies provides students with opportunities to experience various situations, and to cope with problems encountered in daily life through DGBL (Tapingkae, Panjaburee, Hwang, & Srisawasdi, 2020). The definition of DGBL refers to the use of games for expected learning outcomes, which is the development of GBL in line with the rising of computers (Loh et al., 2015; Sanchez, 2019). Also, it is explained that DGBL is a combination of serious learning, fun, engagement, and interactive entertainment (Prensky, 2001a).

DGBL can achieve a constructivist learning goal by the constructivist conditions (Alexiou & Schippers, 2018). Although the foundation is similar to GBL, DGBL not only using specific games but using various such as games and gameplays, subjects and disciplines, and a variety of educational practices (Loh et al., 2015). Another research found that digital games significantly improved student learning compare to non-game conditions (Qian & Clark, 2016).

The foundations and game elements of DGBL same as GBL. To engage the students in DGBL, the designer must consider the game elements. Game elements influence in supporting learning and enhancing intrinsic motivation. Emotional engagement can be improved by narrative elements, while cognitive engagement can be enhanced by the challenge in-game mechanics (Alexiou & Schippers, 2018).

### *2.3 Gamification for Learning*

In term of educational concept, gamification is not the same as the GBL or DGBL. Gamification is using game elements such as incentive systems to motivate and engage the players in the task or to continue particular behavior. GBL is known by using video games as learning tools (Loh et al., 2015.; Plass et al., 2015; Simões et al., 2013). Also, Kim, Song, Lockee and Burton (2018) stated that gamification related to the activities to solve the problems in learning and education. Simões et al. (2013) indicated that gamification in learning and teaching also includes serious games.

Instead of fun and enjoyment, gamification as an instructional approach is designed to enhance the effectiveness of student learning. The benefit of gamification is to increase student engagement and motivation, learning performance and academic achievement, improve recall and retention also to provide feedback on students' progress and activity (Kim, Song, Lockee, & Burton, 2018). While for teachers the gamification helps to create challenges, set up the objectives, choose the proper game mechanics to be applied in the learning activity, recognize the students' progress and use the competition to enhance valuable behaviors (Simões et al., 2013).

### *2.4 Previous Studies of Game-based Learning*

A study about the trends in GBL cannot be separated from the previous research. As stated in (Cheng et al., 2015), fewer studies explicitly introduced the educational theoretical foundations for using serious games in science education or the instructional strategies coupled with the use of serious games. Also, several studies reveal that in the future, using GBL can promote the development of 21st-century skills (Qian & Clark, 2016). Another study result is that there is a high interest in using serious games in science from 2002 to 2013. At the time the role-playing game/ adventure was the most popular games based on the empirical studies (Cheng et al., 2015). While some studies underline the game mechanics or design must be considered when developed the game. As stated in Alexiou & Schippers (2018), outlines the role of narrative, aesthetics, and core game mechanics in facilitating higher learning outcomes through intrinsic motivation and engagement. While another research suggested that in designing a game, the challenges should be able to keep up learners' growing abilities and learning in GBL environments (Hamari et al., 2016).

## **3. Method**

### *3.1 Data Collection*

The study conducted by examining research papers in Scopus database from 2010 to 2019. By searching keywords (game) or (gamification) or (gamifying) and (learning) and (biology). A total of 257 papers were eligible for this study. Then, the unrelated topic papers were excluded from analysis become 127 papers. From 127 articles, there were 80 papers that irrelevance with the study. The final results received 47 papers. The documents were analyzed scrutiny to ensure reliability. Figure 1 displays the steps of selecting papers for data collection.

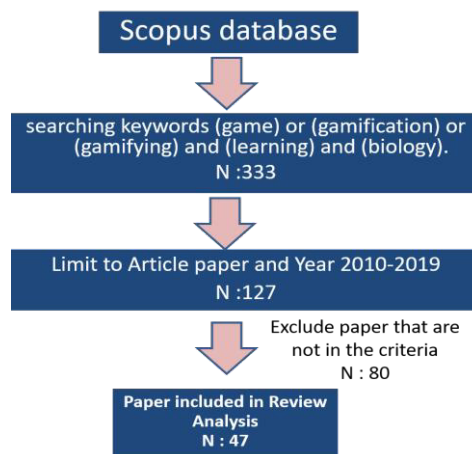


Figure 1. Steps of selecting articles

### 3.2 Coding Schemes

As stated in Chang and Hwang (2019), there are three major foci using game in science education which are game-used, pedagogical used and research method. In this study, to investigate the using game in biology learning include several dimensions namely the countries, major journal publishing, game types, learning strategies, research methods and the topics in biology game.

### 3.3 Game Types

The game is classified into eight categories which are Action, Adventure, Fighting, Puzzle, Role Playing, Simulations, Sports, and Strategy (Prensky, 2001c). While Renken, Peffer, Otrell-Cass, Girault, & Chiocarriello (2016) divide types into six categories, namely adventure games, role-playing games, action games, simulations, and strategy games, and virtual worlds.

Before we classify into those categories, in this review, the researchers divided games into three mains, which are digital games, non-digital games, and gamification. Digital games refer to computer games, while non-digital games refer to non-computer games. Gamification refers to use of game mechanics in the activity to solve the problems. In this review, games are categorized into nine types, which are adventure game, role-playing game, puzzle game, action game, simulations, strategy game, virtual world, quiz, and augmented reality.

## 4. Results and Discussion

### 4.1 Documents Per Year

Based on the documents per year (see Fig.2), paper publishing related educational biology games increased gradually. During the time, there are some peak points, which are in 2013, 2016, and 2018. The highest number was in 2018 stood at ten papers. Although there is a decline of 50% in 2017, overall, the graph shows the improvement trend.

In a discussion, the trend is in line with the previous research from 2007 to 2013 (Cheng et al., 2015), which stated that at the time, the number of articles published rose significantly. It was stated that educators in science education started to investigate the effectiveness of serious games. The other research also gives the same results (Cheng et al., 2015; Qian & Clark, 2016). Currently, it can be predicted that the interest of research in the future will continue to rise.

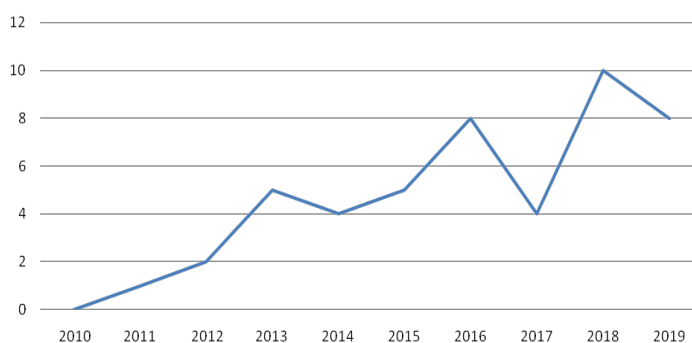


Figure 2. Article published by year from 2010 to 2019

#### 4.2 Types of Games

As stated by Prensky (2001c), there are several kinds of games. In this research, almost over 60% of papers investigated were digital games, while non-digital games and gamification were around 36% and 4% respectively. (see Fig.3).

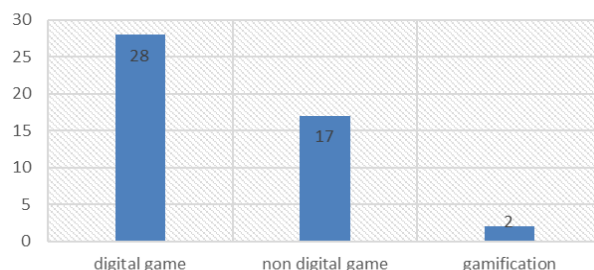


Figure 3. Numbers of type game published from 2010 to 2019

To discuss the result obtained, the increasing development of digital game is influenced by the development of ICT and current learner's characteristics, who are digital natives (living in the technology era) (Prensky, 2001a). Students prefer to use the technology (game) to learn instead of the traditional way.

This research also found gamification and non-digital game. During nine years, research about gamification still low, though it is interesting to be implemented. Gamification is one of the alternatives to provide enjoyment and challenging learning. The trend of gamification is similar to the previous research, which has small numbers during 2010-2014 (Qian & Clark, 2016).

### 5. Conclusions

Based on the main aims, the research focuses on the trends in using educational biology games from 2010 to 2019. It can be concluded that over the period the number of publications rises gradually, the use of digital games was dominant instead of the non-digital game. Further suggestion to develop educational biology game is that educators and researchers must consider the trends and types of the game. There is a significant opportunity to develop a biology game for education because the educational biology game is not many provided.

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