The Effects of Video Games on Creativity: A Systematic Review

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Abstract

Creativity contributes to both personal and societal growth. Recently, new methods for assessing and fostering creativity using video games have been proposed and tested. In this chapter, we start by presenting the multifarious definitions and theories of creativity. We then examine the effects of video games on creativity via empirical studies, and discuss how video games can be useful for improving creativity. Our main findings show that not all video games can enhance creativity—some game genres have more potential to enhance creativity than others. Specifically, video games that have most potential for enhancing creativity are those that facilitate flow, allow the players to co-create the game, and enhance players' intrinsic motivation. We conclude with some specific suggestions on ways to increase creativity in videos games.

Keywords: Creativity, video games, creativity assessment, creativity instruction, stealth assessment, 21st century skills

Creativity is an important part of humans' lives, and has been viewed as a key factor in moving civilizations forward (Hennessey & Amabile, 2010). For instance, according to the World Economic Forum (Gray, 2016), creativity is one of the ten most important skills people need to be successful in the fourth industrial revolution. The individual, social, and economic importance of creativity has led to increased interest of scientists and psychologists in studying the nature, assessment, and improvement of creativity (Hennessey & Amabile, 2010).

On an individual level, creativity plays a vital role in solving everyday problems related to one's job or life in general (Sternberg & Lubart, 1996). At the societal level, creativity can lead to new scientific breakthroughs, conflict resolutions, and life-changing inventions (Ashton, 2011). Moreover, in a world of numerous startups and entrepreneurship opportunities, companies need creativity to survive. Therefore, creativity is fundamental to a thriving economy (Sternberg & Lubart, 1996).

From an educational perspective, creativity has been included in Bloom's revised taxonomy of educational learning objectives (Bloom, 1956; Krathwohl, 2002). Creativity is placed at the highest level of learning objectives in Bloom's taxonomy—higher than remembering, understanding, applying, analyzing, and evaluating. Krathwohl (2002) defines the creating category of learning objectives as "putting elements together to form a novel, coherent whole or make an original product" (p. 215). This elevation of creativity was one of the reasons that led PISA (Programme of International Student Assessment) to begin developing an assessment of creative thinking for PISA 2021.

Although the construct of creativity has been around for millennia, creativity research is not that old. Since the 1950s, starting with Guilford's APA presidential address, psychologists and learning scientists have approached creativity from various perspectives. In recent years, new methods for assessing and fostering creativity have been proposed and tested—for example, using video games. In fact, research related to game-based assessment and improvement of creativity is burgeoning, but there are still many unanswered questions.

In this chapter, we (1) briefly present various definitions and theories of creativity; (2) examine the effects of video games on creativity via empirical studies; (3) discuss how video games can be useful for improving creativity, and (4) suggest new approaches to increase creativity in videos games.

What is Creativity?

One simple definition of creativity refers to any product (e.g., idea, solution, art, story) that is novel and appropriate (Amabile, 1988; Kaufman & Sternberg, 2007). A novel product is new (e.g., something that no one has thought of before). An appropriate product is logical, practical, and valuable. The combination of both components (novel and appropriate) makes a product creative. For example, using the airscrew of an airplane to build an air turbine to generate electricity in a remote village can be a novel idea, but would be inappropriate if the village is located in a non-windy area.

Further review of the creativity literature suggests that we are facing a hard-to-define and multifaceted phenomenon. For instance, in addition to just examining the product of creativity, researchers have also looked at creative processes and relevant personality dimensions (Feist, 1999, 2010; Rhodes, 1961). They have developed multiple theories of creativity, specified various moderators of it (e.g., age, gender, culture), and defined creativity in different contexts (e.g., industry, education, sports). In this section, we briefly review creativity theories and models, specifically related to video games.

Creativity Theories and Models Related to Video Games

Some theories aim to operationalize creativity in terms of cognitive processes that will enable the measurement of creativity. These types of theories use a psychometric (less contextualized) approach to understanding creativity (Sternberg, 2006). For example, Guilford’s theory of creativity (1956) operationalized creativity as divergent thinking with four sub-facets: *flexibility* (e.g., the number of categories or themes used when solving a problem or the ability to come up with relevant ideas from different categories or themes); *fluency* (the ability to produce a large number of relevant ideas); *originality* (the ability to produce ideas that are statistically rare); and *elaboration* (the ability to implement an idea in detail and high quality). Such operationalization helps in the design of creativity assessments in various environments such as video games, with items targeting each sub-facet of creativity (e.g., Shute & Wang, 2016).

Torrance (1993) built on Guilford's theory of creativity, describing creative thinking as "the process of sensing difficulties, problems, gaps in information, missing elements, something askew; making guesses and formulating hypotheses about these deficiencies; evaluating and testing these guesses and hypotheses; possibly revising and retesting them; and, last, communicating the results." (p. 233). In general, he defined creativity as an everyday phenomenon rather than an unreachable state that only geniuses can achieve (Torrance, 1993). This is what Richards (1990) refers to as *everyday creativity*. One area in which everyday creativity frequently happens is when people play video games. For example, creative individuals tend to think of novel solutions for a game level or test various options in their mind and then chose the best, most creative one. Less creative individuals tend to be efficient, using common solutions to solve game levels. The literature of metacognition of creativity suggests that creative individuals should also know when not to be creative (Kaufman & Beghetto, 2013).

Other theories of creativity are categorized under a confluence or componential approach to understanding creativity (Sternberg, 2006). These theories examine the components that need to happen or exist in confluence so that creativity can emerge (Sternberg, 2006). For example, Amabile's (1988) componential theory of creativity, includes three major inter-related components: (1) *domain-relevant skills* (i.e., sufficient knowledge and experience in the relevant domain or domains), (2) *creativity-relevant processes* (e.g., divergent thinking and being able to make remote associations), and (3) *intrinsic task motivation* (i.e., interest in engaging with the activity, or an intrinsic sense of challenge). The relationships among these three components is multiplicative rather than additive, which means the existence of all these three components is essential for creativity—i.e., creativity is not possible in the absence of one of the components.

Amabile and Pratt (2016) later included moderators in the social theory of creativity. These moderators are not necessary for creativity but can enhance it (or undermine it when they don't exist): (1) *synergistic extrinsic motivation* (e.g., reward and recognition that can increase intrinsic motivation); (2) *a sense of progress in creative idea development* (i.e., when a task needs creativity and when it's achieved, progress is made); (3) *work or task meaningfulness* (i.e., the extent to which one perceives a task or problem as positive or significant); and (4) *affect* (i.e., positive or negative mood which can lead to more or less creativity, respectively).

The componential theory of creativity can be used as a powerful explanation for why some video games (we discuss those games in the next sections of this chapter) have high potential for fostering creativity. For example, apart from relevant knowledge and skills needed, one needs high task intrinsic motivation to be creative. Video games are intrinsically motivating (Gee, 2005) that's why people from different ages can spend hours on end playing video games. Moreover, in well-designed videos games, players often follow a story line by completing game levels, gaining certain statuses, and achieving different goals (Shute & Ke, 2012). All of these events make the players feel the sense of progress that Amabile and Pratt (2016) addressed. Additionally, this theory suggests that positive or negative mood can influence creativity. Video games are usually played for fun which leads to a boost in people's affective state (e.g., Hutton & Sundar, 2010).

One of the models we discuss in this paper related to video games is the 4-C model of creativity (Kaufman & Beghetto, 2009). According to this model, creativity can be seen as comprised of four levels: (a) *mini-c* creativity, which includes creativity that is personally meaningful (e.g., creative interpretation of some event, action, and/or experience); (b) *little-c,* or everyday creativity (e.g., Richards, 1990); (c) *Pro-c,* which is effortful creativity, leading to a professional level of expertise which is higher than the little-c creativity; and (d) *Big-C* creativity, representing the work of great individuals whose creations are still used decades or even centuries later (e.g., Simonton, 1991). Moreover, as Kaufman and Beghetto point out, although rare, we can expect to see a progression from mini-c to Big-C or at least to Pro-c during one's lifespan. This promising spectrum of creativity motivates different groups of scientists to focus on one type of creativity (e.g., improving little-c creativity in schools) with the hope of helping people to produce higher types of creativity later in life (e.g., Pro-c creativity in academia or industry). We believe that video games can be useful and promising vehicles for both assessing and enhancing little-c creativity.

The goal of this brief review of creativity theories and models was to show how complex and multifaceted creativity is and how some creativity theories and models may be related to video games. The complexity of creativity makes it hard to fully assess and support creativity. Our aim of this chapter is to describe a possible method for assessing and improving creativity, specifically little-c creativity using video games.

The Effect of Video Games on Creativity

In this section, we review empirical studies that have investigated the effects of video games on creativity. We conducted this systematic review with the following four questions in mind:

1. What approaches are being used to investigate video games' effects on creativity?
2. Which game genres and particular games have been used to improve creativity?
3. What are the main effects of video games on creativity?
4. How do certain genres of games as well as specific games enhance creativity?

Methodology and Results

To collect the studies for our review, we used keyword strings such as (“creativity” AND “video games” OR “digital games”) in the in the title, abstract, or subject headings of the documents, and searched several databases: *Google Scholar*, ERIC, and *Web of Science*, as well as specific journals focusing on creativity, such as: *Creativity Research Journal*, *Journal of Creative Behavior*, and *Thinking Skills and Creativity*. Occasionally, we looked for resources in the references section of collected papers. Finally, we searched for Master’s theses and Ph.D. dissertations using the same keywords in the *ProQuest Dissertations & Theses Global* database.

After the first round of screening and selection, we selected high-quality studies (from 2006 to 2019) and ended up with 16 studies (Table 1) of which 10 are journal articles, 3 are conference papers, 1 is a book chapter, 1 is a Master’s thesis, and 1 is a Ph.D. dissertation. The studies were conducted in several countries in North America, Asia, and Europe with a broad range of ages starting from preschoolers to graduate students.

Table 1

Empirical Studies Investigating the Effect of Video Games on Creativity.

1st Author (year)	Country	Age (EL)	Game	Genre	Main Findings
Jackson (2012)	USA	12 (5^{th})	205 games	MG	Videogame playing, regardless of the game genre, predicted creativity.
Hamlen (2009)	USA	9 to 11 (4^{th} - 5^{th})	NR	MG	No significant relationship was found between time playing video games, regardless of the game genre, and creativity.
Hamlen (2013)	USA	9 to 11 (4^{th} - 5^{th})	NR	MG	A negative relationship with the level of creativity and time spent playing video games.
Fessakis (2013)	USA	4 to 6 (PS)	Crayon Physics	Puzzle	A statistically significant increase in the average fluency measure, but not in originality.
Hsiao (2006)	Taiwan	9 and 10 (4^{th})	RMG	Puzzle	Positive relationship between divergent thinking and divergent feeling with gameplay.

Hsiao (2014)	Taiwan	11 to 12 (5th)	RMG	Puzzle	Significant improvement of creativity from pre- to posttest compared to the control group.
Blanco-Herrera (2019)	USA	18 to 33 (UG & G)	Minecraft NASCAR	Sandbox Racing	A significant correlation between creativity and game play habits. Those who played *Minecraft* without instruction showed significantly higher scores on post-game creativity measures compared to those who played *Minecraft* with instructions (i.e., "be creative"), those who played a driving game, or those who watched a television show.
Cipollone (2014)	USA	9 and 10 (HS)	Minecraft	Sandbox	The open nature of *Minecraft* can provide students with many opportunities to show and enhance their creativity—especially using machinima projects.
Checa-Romero (2018)	Spain	12 to 15 (HS)	Minecraft	Sandbox	Significant improvement of creativity from pretest to posttest with a moderate effect size.
Karsenti (2017)	Canada	8 to 11 (3rd - 6th)	Minecraft	Sandbox	The results from 10 qualitative data collection sources showed that one of the benefits of *Minecraft* was to increase creativity.
Sáez-López (2015)	USA & Spain	11to 14 (MS)	Minecraft	Sandbox	The participants reported the application of various 21st-century literacy skills, including creativity. 96% of the participants thought that *Minecraft* enhances creativity.
Moffat (2017)	UK	18 to 30 (UG)	Minecraft Portal 2 Serious Sam	Sandbox Puzzle Shooting	Combining all the three groups, playing the games showed significant improvement in all creativity measures.
Hewett (2016)	USA	14 to 20 (HS)	Minecraft	Sandbox	97% of the participants thought that the project done in *Minecraft* challenged them to be creative and innovative.

Inchamnan (2013)	Australia	18 to 34 (UG)	Portal 2 I-Fluid Braid	Puzzle	Game playing activities significantly enhanced the creative potential of computer games.
Kim (2016)	South Korea	NR (UG)	SimCity	Simulation	83% of the students believed *SimCity* provided them with an opportunity to develop creativity.
John (2015)	USA	14 to 18 (HS)	WoW Skyrim Final Fantasy etc.	DRPG	In response to a survey, 65% of participants did *not* believe that games influenced their creativity while 47% believed that gamers are creative.

Notes. EL = education level, NR = not reported, PS = preschool, MS = middle school, HS = high school, UG = undergraduate, G = graduate, RMG = researcher-made game, MG = multiple genres (between 7 to 14 genres), WoW = World of Warcraft, DRPG = digital role-playing games.

Research Approaches

In this section, we answer the first research question of our review: *What approaches are being used to investigate video games' effects on creativity?* Depending on the purpose and research questions undergirding these 16 studies, three main categories emerged. The first category includes *correlational studies* that did not involve any gameplay. Instead, these studies used surveys for data collection to learn about participants' gaming backgrounds (e.g., hours spent playing video games per week, and most frequently played video games). Then, using a creativity test (e.g., a creativity test based on TTCT; Torrance, 1972), researchers measured participants' creativity. Correlational analyses answer questions such as: "Is playing video games associated with higher creativity?" or "Are gamers more creative than non-gamers?"

The second category relates to *observation and perception studies*. In observational studies, researchers observed participants' creative behaviors and attitudes while they played a video game to determine any growth in participants' creativity over time. In perception studies, after playing a video game, the participants would answer questions regarding how they perceived that particular gaming experience (e.g., playing the video game or completing a task in the video game). These studies reported the percentage of agreement/disagreement among participants on various survey items, such as, “I believe playing ‘game X’ helped me improve my creativity.”

The third category of research on video games and creativity includes *experimental and quasi-experimental studies*. Studies in this category investigated the effectiveness of one or more video games on participants’ creativity *after* gameplay. Pretest and posttest comparisons (typically using creativity tests such as the TTCT) provided evidence for video games’ effectiveness in promoting creativity. However, a couple of studies in this category used observational techniques (e.g., in person or via screen recording) to collect data on participants’ creativity while playing video games.

Each of these three categories has its pros and cons. For example, correlational and perception studies rely heavily on self-report measures, rendering the validity of the findings questionable. However, these studies are cost- and time-effective, informative, easy to conduct, and thus can include large sample sizes. Experimental and quasi-experimental studies are generally more costly than survey-type studies, and may suffer from small sample sizes. But using performance-based measures of creativity, findings from such experimental studies could provide more valid findings compared to the correlational and perception studies. Using findings derived from all three categories will enable us to triangulate the evidence regarding the effectiveness of video games relative to creativity. Next, we discuss our findings regarding our second research question: *Which game genres and particular games have been used to improve creativity?*

Game Genres and Games with Creativity Potential

In this section, we present various game genres as well as specific games used by researchers in various studies. The specific findings of these studies are discussed in detail in the following section. As mentioned above, correlational studies do not generally focus on any specific game genre. Instead, participants in those studies simply report the games they have played, and researchers categorize those games by genre. For example, Hamlen (2009) and Jackson et al. (2012) reported that the games their participants frequently play resided in fourteen and six game genres, respectively. The fourteen genres reported by Hamlen (2009) were subsequently categorized (by playing frequency) into four categories: (1) Action and Sports, (2) Simulation, (3) Racing, Platform, Music, Adventure, Digital Role-Play, Survival Horror, and Puzzle, and (4) Massively Multiplayer Online Game, Strategy, Traditional, and Educational.

Similarly, Jackson et al. (2012) categorized 205 reported games into five genres (categorized from most to least popular): (1) Violent, (2) Action-adventure and Sports, (3) Interpersonal (games that involved caring for others; e.g., *Sims* or *Animal Crossing*), and (4) Racing/driving. According to Jackson et al. (2012), playing video games, regardless of the game genre, was significantly correlated with all of the six creativity measures (based on figural TTCT) used in the study except for the racing/driving genre which was only significantly correlated with two of the six measures of creativity.

In contrast, perception, experimental, and quasi-experimental studies typically involved game genres with a higher potential for improving creativity. For participants assigned to an active control group (i.e., participants who also played a video game, but not the treatment game), they were assigned to play a game genre with a lower potential for creativity (e.g., a racing or a shooting game). Genres with the potential to improve creativity include *sandbox*, *puzzle*, and *simulation* games.

Sandbox games do not have a linear narrative that the player has to follow (Squire, 2007). Instead, the player can freely experiment in the game environment and build his or her own world. One example of a sandbox game is *Minecraft* (Figure 1), which is one of the most popular games of all time with 91 million people playing it every month (Peckham, 2016; Gilbert, 2018).

Figure 1. *Minecraft* game environment (from Peckham, 2016)

Minecraft has four game modes. In the *survival* mode, the player has a life bar and must "mine" resources from the 3D LEGO-like environment and fight enemies to survive. In the *spectator* mode, the player can explore the worlds created by others without the need to fight for survival or without being seen by others. In the *adventure* mode, players can play and interact with worlds created by others. Finally, in the *create* mode, the player can freely explore and create his own world. Players in *Minecraft* have re-built real-world locations and buildings as well as fantasy worlds from their creativity and imagination (see Levy, 2014 for 14 amazing creations in *Minecraft*). Seven out of sixteen studies in our review (Blanco-Herrera et al., 2019;

Checa-Romero & Pascual Gómez, 2018; Cipollone et al., 2014; Hewett, 2016; Karsenti & Bugmann, 2017; Moffat et al., 2017; Sáez-López et al., 2015) used *Minecraft* as the targeted game for enhancing creativity.

The next genre with high potential for improving creativity is puzzle games. Unlike sandbox games, puzzle games have a clear storyline with increasing challenges to overcome and puzzles or problems to solve (Granic, Lobel, & Engels, 2013). *Portal 2* is a popular first-person puzzle game with a clear goal—the player is locked in a room and needs to find the way out (Figure 2). In different levels of the game, the player can use various tools to escape the room and go to the next level. Two of the studies in our review used *Portal 2* to improve creativity (Inchamnan et al., 2013; Moffat et al., 2017).

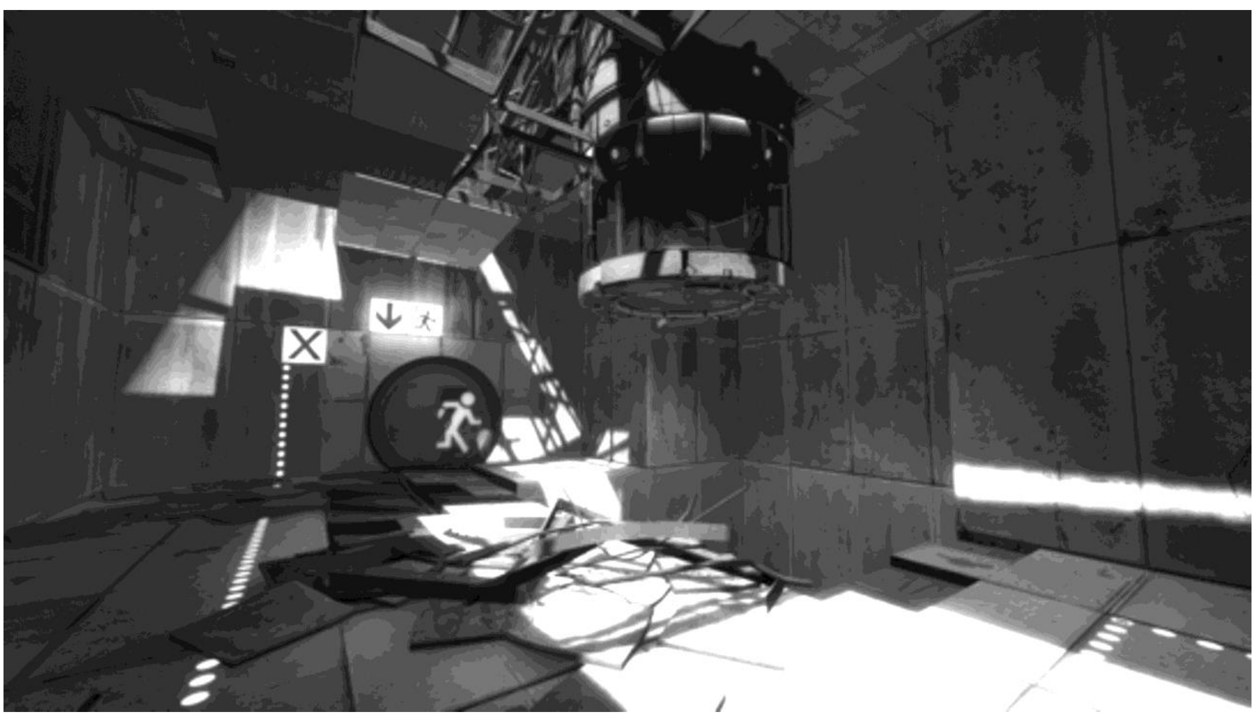

Figure 2. Screenshot from *Portal 2* (picture from Portal 2, 2011)

Another puzzle game used to improve creativity in the studies we examined is *Crayon Physics Deluxe* (Kloonigames, 2014). This is a 2D game with a drawing-with-crayon-like interface (Figure 3) in which the player has to hit a star with a ball by drawing objects and creating simple physics machines (e.g., ramp, lever) and using the laws of physics. One study in the collection of studies we reviewed used this game as a means for improving creativity (Fessakis, & Lappas, 2013).

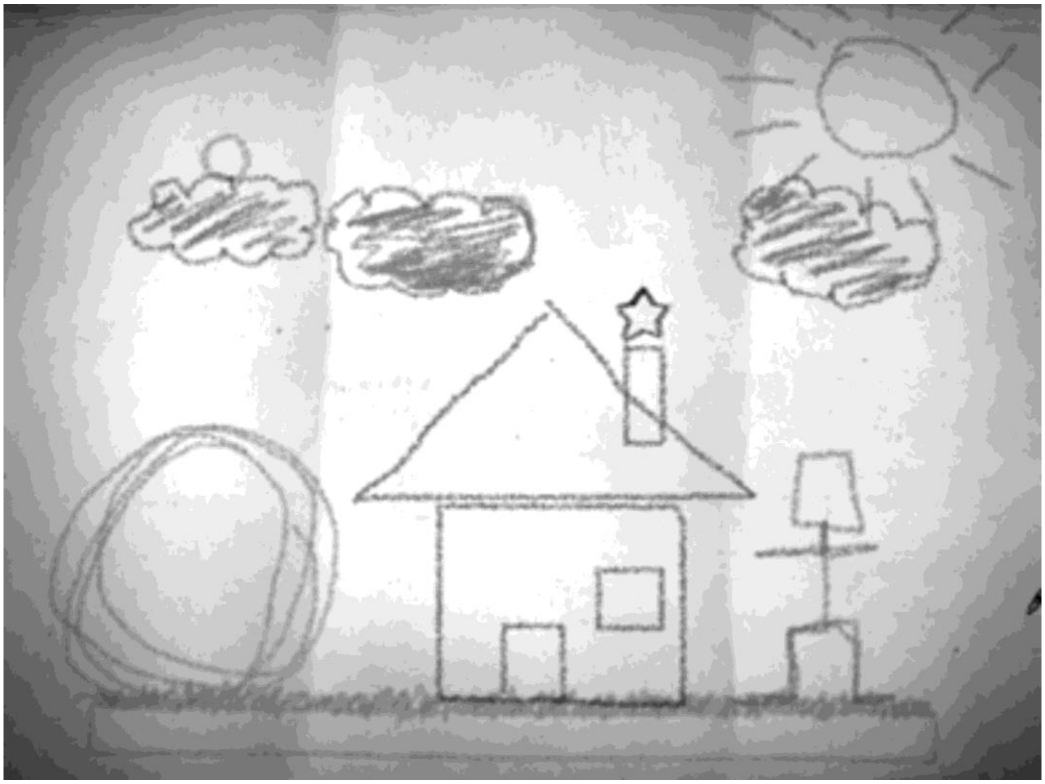

Figure 3. Screenshot of a level in *Crayon Physics Deluxe* (from Kloonigames, 2014)

The last genre with high potential for creativity is simulation games. Simulation games are digital, artificial, immersive environments (2D or 3D) in which the players receive instructions (based on a scenario in a real or fictional world), make decisions, often create new in-game environments, and learn the consequences of their decisions and actions (Sitzmann, 2011). *SimCity* (Electronic Arts Inc., 2019), is a popular, open-ended city-building simulation game (Figure 4). In *SimCity*, players can assume the role of urban planners, policymakers, and geographic experts when they build their own cities. The residences of the cities are the "Sims" who can benefit or suffer from the living conditions of the cities created by the players—just like the real world. One of the studies we examined used *SimCity* in an urban geography course and investigated the game's potential for enhancing students geographic creativity (Kim & Shin, 2016).

Figure 4. Screenshot of a city in *SimCity* (Electronic Arts Inc., 2019)

The rest of the games in our review are similarly categorized under these three genres (i.e., sandbox, puzzle, and simulation games). Also note that some other games used in control groups in our targeted studies (e.g., the racing game *NASCAR*, or the shooting game *Serious Sam*) were hypothesized to have no or little impact on students' creativity. However, the results were sometimes surprising (we discuss those findings in the next section). We now discuss the specific findings of the studies we reviewed to answer our third research question: *What are the main effects of video games on creativity?*

The Effects of Video Games on Creativity

In this section, we summarize the findings of our sixteen studies comprising three different categories: correlational studies, observational and perception studies, and experimental and quasi-experimental studies. The findings of the correlational studies are mixed. Hamlen (2009) conducted a study to investigate the relationship between the time students play video games per week and their creativity—measured by the TTCT. The participants in Hamlen's study were 105 fourth and fifth graders enrolled in four suburban elementary schools in the US. Participants first completed a questionnaire about their gaming background (e.g., the amount of time they usually spend playing video games per week, the video games they play, and the devices they play those games on). Then, they completed the TTCT. The results of a multivariate regression analysis showed no relationship between time spent playing video games and students' creativity scores (F (6, 96) = 1.2, p > .05)—holding gender and grade-in-school constant.

In a similar correlational study, Jackson and colleagues (2012) investigated the relationship between students' use of information technology (i.e., computers, the Internet, cellphones, and video games) and creativity. The 491 fifth-grade students who participated in this study were from 20 middle schools across Michigan, and an after-school center for underserved groups in Detroit. Students completed a survey about demographic and socioeconomic characteristics, IT questions (e.g., the amount of time using a type of technology, the most frequently played video game), and a six-item figural test developed based on the TTCT (e.g., one item was an egg-shape line drawing presented on a blank sheet of paper, and the participants had to draw an object using that shape). Unlike what Hamlen found, results showed a positive and significant correlation between the time spent by students playing video games and all six test items of creativity (with a .01 level of significance). However, the correlation should not be misconstrued as causation. Finally, there were no significant relationships between creativity scores and use of other technologies.

Hamlen (2013) later criticized Jackson et al.'s (2012) study by saying that the creativity test items in that study were completed at home, and thus, the results may not be reliable. She also pointed out that her previous study (i.e., Hamlen, 2009) was conducted in a timed and controlled laboratory environment with the presence of researchers. Hamlen (2013) re-analyzed her 2009 study's data, investigating the factors that predicted time spent playing video games. Specifically, she examined the factors (including demographic data, gameplay strategies and skills, and creativity) that predicted time spent playing video games during a typical week. The results of a regression analysis showed a negative relationship between creativity (i.e., a composite variable in the regression model comprised of verbal fluency, verbal originality, verbal flexibility, figural originality, and figural fluency) and the number of hours spent playing video games. That is, the lower the level of creativity, the more time a student spends playing video games in a typical week (β = -.19, t = –2.70, p = .008)—holding other variables constant.

Hamlen (2009; 2013) and Jackson et al. (2012) both investigated the effects of video gameplay on creativity. Apart from certain flaws in the methodologies used in these studies (e.g., use of self-report measures and at-home surveys), it seems that considering video games from all genres as equally potential for enhancing creativity (Jackson, 2012) or as equally irrelevant to the enhancement of creativity (Hamlen, 2009) can be both informative and misleading. In response to the findings of these correlational studies, the results seem mixed—(a) more gameplay leads to *more* creativity from Jackson et al.'s study, vs. (b) more gameplay is associated with *less* creativity from Hamlen's research. To disambiguate the findings from correlational studies, we now discuss findings using other research approaches—observation and perception studies.

Inchamnan, Wyeth, and Johnson (2013) investigated the impact of three puzzle video games (*Portal 2*, *I-Fluid*, and *Braid*) on nineteen undergraduate students' creativity behavior related to task motivation (e.g., set breaking, enjoyment), domain-related skills (e.g., showing uncertainty or confidence), and creativity-related skills (e.g., wide focus, concrete focus, and analogy making) (18- to 33-year-olds; M_{age} = 23.79, *SD* = 4.35). Using a measure for assessing video games creativity potential, Inchamnan et al. (2013) aimed to see which of the three games had more potential for creativity. The video games' creativity potential measure (Inchamnan et al., 2012) assesses video games' creativity potential in terms of task motivation, domain-related skills, and creativity-related skills (Amabile, 1988) shown by players during gameplay. For example, if the players show high task motivation during gameplay, it is likely that the game has a high potential for enhancing creativity.

In this study, students played each game for 15 minutes (45 minutes of gameplay in total) in different orders—i.e., some started with *Portal 2*, some with *I-Fluid*, and some with *Braid*. Results showed that game-playing activities (game mechanics) significantly impacted the creative potential of video games regarding task motivation, domain-related skills, and creativity-related skills. Although the three games did not show the same level of creativity potential, all of the games showed positive creativity potential – helping students to demonstrate their task motivation, domain-related skills, and creativity-related skills. These results provide evidence for the potential of puzzle games for improving creativity.

In another study, Cipollone and colleagues (2014) used *Minecraft*—a sandbox game—in an English literature class as a tool for creating machinima (i.e., movies created using the digital world in *Minecraft*). Twenty high-school students divided into five groups worked on a class project creating machinimas. Students could play in *Minecraft*, capture their play via screen-capture software, and then edit the captured videos to complete their projects. The authors' observations indicated that *Minecraft* could be used as a space for students to express themselves and potentially foster their creativity in ways that would typically be more costly if done in reality. Similarly, Karsenti and Bugmann (2017) investigated the educational potential of *Minecraft* in an exploratory study involving 118 elementary-school students in Canada. The researchers created ten game levels with increasing difficulty in *Minecraft*. Karsenti and collogues listed 25 educational benefits of *Minecraft* based on the qualitative data they collected. The third most important benefit listed was that *Minecraft* helped students express their creativity.

Asking participants about their perception of the game after four weeks of playing *Minecraft*[1], Hewett (2016) examined sixty-six high school students' responses about using their "21st-century skills." The vast majority of the students (97%) reported that using *Minecraft* to complete the class project challenged them to be creative and innovative. Using a similar approach, Sáez-López et al. (2015) reported that 96.1% of their participants (205 middle school students from the U.S. and Spain) thought that "building in this environment [i.e., *Minecraft*] developed [their] creativity."

Kim and Shin (2016) used the game *SimCity* (a simulation game) in an urban geography course. Thirty-three undergraduate students participated in their study in South Korea. Using a questionnaire, Kim and Shin investigated how the students perceived using *SimCity* in that course. Results showed that 83% of the students believed *SimCity* provided them with an

[1] Note that the author did not specifically mention the time students spent playing *Minecraft,* she only mentioned that students used *Minecraft* or their class project during class time for four weeks.

opportunity to develop their creativity. However, John (2015) found different results. In an ethnographical study, John included 97 high-school students from a major city on the east coast of the U.S. who played one or more digital role-playing video games (e.g., *World of Warcraft*, *Skyrim*, and *Final Fantasy*). John (2015) stated that responding to a survey item, 64.6% of the participants did *not* believe that games influenced their creativity. In the same study, 46.9% of the participants believed gamers are creative thinkers.

These observational and perception studies show the potential of some puzzle games, a sandbox game, a simulation game, as well as some conflicting results about the potential of digital role-playing games. However, more rigorous experimental studies are needed to further investigate the effectiveness of such video games across various settings, contexts, and genres.

The results of experimental and quasi-experimental studies tend to agree on the positive effects of certain video games on creativity. Additionally, there were some unexpected findings reported. In an experimental study, Moffat, Crombie, and Shabalina (2017) compared three games (a sandbox game—*Minecraft*, a puzzle game—*Portal 2*, and a shooting game—*Serious Sam*) on participants' creativity, which was measured by the TTCT in both the pretest and posttest. The 21 participants were divided into three groups. Each group was assigned to play one of the three games. The researchers hypothesized that the *Minecraft* group would show a higher level of creativity on the posttest than the *Portal 2* group, and the *Portal 2* group would show a higher level of creativity than the *Serious Sam* group. Participants completed the pretest, played their assigned game for 30 minutes, and then completed the posttest. The results showed that none of the groups showed significant improvement from pretest to posttest on originality and fluency facets. However, two of the groups showed significant pretest-to-posttest improvement for flexibility—*Serious Sam* (t (11) = 2.25, $p < 0.05$), and *Portal 2* (t (10) = 3.29, p

< 0.01). When combining all the three groups, an overall significant improvement from pretest to posttest emerged (t (37) = 3.99, $p < 0.001$). Two of these findings were surprising. First, not only did not the *Minecraft* group improve their creativity from pretest to posttest, they showed negative (but not significant) results on the originality facet. Second, the *Serious Sam* group showed positive and significant improvements from pretest to posttest on the flexibility facet.

The authors pointed out that the unexpected results may be related to participants' affective states as they completed the posttest. That is, when playing a complicated game like *Minecraft* for only thirty minutes with no instruction, participants could get frustrated, and bring that frustration to the posttest with them. On the other hand, playing a more familiar shooting game could boost participants' affective states and thereby enhance their creativity on the posttest. These findings show the importance of allocating an appropriate time for playing open-ended games like *Minecraft*. This also reflects the importance of affect in producing creative products (Amabile & Pratt, 2016). Finally, the low sample size in this study could also be a reason for these unexpected findings.

In a more recent and larger study, with a sample size of 352 participants, Blanco-Herrera, Gentile, and Rokkum (2019) compared the impact of playing *Minecraft* with no instructions, playing *Minecraft* with instructions (i.e., to be creative), playing a racing game called *NASCAR*, and watching a TV show on undergraduate students of a Midwestern university. Participants were randomly assigned to one of the four groups. Participants played for 45 minutes in the game groups and watched an engaging TV show for the same amount of time in the TV-show group. They then completed measures of creativity: divergent thinking scale of alternative uses (Wallach & Kogan, 1965), convergent thinking remote association scale (Bowden & Jung-Beeman, 2003), and creative production alien drawing task (Kozbelt & Durmysheva, 2007).

Results showed that there was no significant effect of condition on the alternative uses scale or remote association scale. However, the condition effect was significant relative to the creative production alien drawing task (F (3, 294) = 7.74, $p < .01$)—controlling for the participants' GPA. Mean comparisons showed that the participants in the *Minecraft* group *with no instructions* scored significantly higher on the convergent thinking task than those in the Minecraft group with directions, those in the *NASCAR* condition, and those watching a TV show. As expected, both groups playing *Minecraft* did score higher than the other two groups on all of the creativity measures. However, the researchers hypothesized that the *Minecraft* group who were asked to be creative would do better than the one with no instructions. This unexpected finding, again, shows that the conditions under which people play these games are critical as they can affect participants' creativity. For example, participants' affective state could be negatively impacted in this study as it was hard for the participants to figure out how to use *Minecraft* in only 30 minutes. In that case, participants could have lower creativity scores on the posttest due to their low affective states. Many other possible reasons could be listed for these findings. Studies in which *Minecraft* was used for a longer time could shed some light on these findings.

To investigate the long-term effect of *Minecraft* on creativity, Checa-Romero and Pascual Gómez (2018) conducted a quasi-experimental study with 85 secondary school students from Alcalá de Henares in Spain. The authors developed an eight-week workshop as a part of a technology course in which students were introduced to *Minecraft* in a step-by-step manner. Students had to create a machinima of their "dream house" in *Minecraft* in two phases: (1) *classroom play with Minecraft* which included six workshop sessions to help students learn how to play *Minecraft* and how to create in this game, and (2) *audiovisual machinima product creation* in which the participants had to create a video to show their "dream house" to others.

Students completed a pretest and a posttest of creativity—the CREA test of creativity (Corbalán et al., 2003), which is designed to measure creativity through searching and solving problems (i.e., students received three illustrations had to come up with as many questions as possible related to those illustrations). Results showed a significant improvement in students' creativity from pretest to posttest (t = - 6.11, p < 0.05, Cohen's d = 0.45). Moreover, the final machinima products of the students also were scored (on a scale from 0 to 10) by technology teachers in each class. On average, students scored 6.71 on novelty, 7.67 on value, 7.38 on "truth" (i.e., assessing ideas/projects on whether or not they are true or false), and 7.0 on usefulness. The authors indicated that a planned use of games like *Minecraft* can increase students' creativity in class. However, they also pointed out the challenges for developing such workshops for teachers and students. These findings also showed that provided with proper guidance, and given enough time, students' creativity can improve using a game like *Minecraft*—contrasting with the results from some of our previously discussed short-term studies.

Moving from studies that examined the effectiveness of sandbox games on creativity, we now focus on the findings of three experiments using puzzles games. The first study is a small, case study with a pretest/posttest design. Fessakis and Lappas (2013) used the game *Crayon Physics Deluxe* in their study, with ten, 4- to 6-year-old preschoolers in Greece. Going through four stages, students first took a pretest of creativity developed to measure preschool students' creativity (i.e., the *Multidimensional Stimulus Fluency Measure* test, or MSFM; Moran, Milgram, Sawyers, & Fu, 1983). Then, to engage and motivate students, a story based on the fairytale "Snow White and the Seven Dwarfs" was delivered via digital storytelling software. In the next stage, students played the game *Crayon Physics Deluxe* in pairs (5 groups) with their teacher's guidance. For example, when a student was stuck in a level, the teacher would ask questions like, "Where do you think we should put this stone?" or would make suggestions like, "What about putting a stone over here?" Finally, during the last stage, the students completed the MSFM as a posttest.

The results from observations showed that the game was very engaging for the students—four pairs solved 14 levels in 44-71 minutes, and one pair (the youngest students) solved 10 levels in 38 minutes. Findings showed that overall, students scored significant higher on the posttest than the pretest for the fluency measure ($M_{pre\ fluency}$ = 14.5, SD = 4.25, $M_{post\ fluency}$ = 17.2, SD = 3.97, t = -3.36, df = 9, p = 0.004). However, the pretest to posttest improvement on the originality measure was not statistically significant ($M_{pre\ originality}$ = 20.5, SD = 8.14, $M_{post\ originality}$ = 24.9, SD = 7.50, t = -1.69, df = 9, p = 0.063). The authors noted that the non-significant finding of students' originality might be related to their lack of domain knowledge. Finally, the authors asserted that using a game like *Crayon Physics Deluxe* can be beneficial for enhancing students' problem-solving skills as well as creativity under proper guidance at this age.

The last two studies we review are related to two versions of a learning puzzle game developed by the researchers who conducted the studies to teach electricity and enhance creativity. In the first study, Hsiao and colleagues (2006) used the web-based puzzle game they developed in an elementary school in Taiwan to enhance 33 students' creativity. To our knowledge, the games we discussed so far were not specifically designed for creativity. However, this web-based game, following the cognitive-affective interaction model (Williams, 1986), was explicitly created to enhance students learning and creativity.

The cognitive-affective interaction model posits three dimensions for any learning environment that aims to enhance creativity. In dimension 1, the subject matter should be selected (in this study it was electricity). In dimension 2, creative thinking strategies should be designed and specified (the authors stated that they included these strategies in their game in the form of creative problem-solving missions to inspire students to think creatively). And in dimension 3, if designed well, the environment should foster the cognitive-related factors of creativity (i.e., fluency, flexibility, originality, and elaborative thinking), and affective-related factors (i.e., risk-taking, complexity, curiosity, and imagination). The authors evaluated the factors stated in dimension 3, after gameplay. To assess both students' creative thinking (cognitive) and creative feeling (affective) related factors, the researchers used a test of creativity (Lin & Wang, 1994) which was developed based on the *Creativity Assessment Packet* (Williams, 1986). This creativity assessment includes two subscales of divergent thinking (by asking students to complete 12 figures which then were scored on fluency, flexibility, originality, and elaboration) and divergent feeling (a 3-point Likert scale questionnaire of 50 items on curiosity, adventure, challenge, and imagination). They reported a positive relationship between the creative thinking scores from the game (i.e., students' performance data) and the divergent thinking and divergent feeling measures of creativity.

In another controlled experimental study, Hsiao, Chang, Lin, and Hu (2014) used an improved version of the game they developed in 2006 and called it ToES. ToES includes sixteen learning tasks (designed based on the cognitive-affective interaction model) that are supposed to enhance participants' creativity. Unlike the previous exploratory study with one group, in this quasi-experimental study, two fifth-grade classes (*n* = 51) were selected to participate in this study. One class was assigned as the experimental group (*n* = 27) who played the game, and the other class was assigned as the control group (*n* = 24) who did not play the game but were taught via traditional in-class instruction. The experiment took place in an electrical science class for nine weeks. The authors used the test of creativity with divergent thinking and divergent feeling subscales (an adapted version of *Creativity Assessment Packet*, Lin & Wang, 1994) for the pretest and the posttest.

Results showed that the experimental group scored significantly higher on the posttest than the pretest on both divergent thinking (t = 6.39, p < .001) and divergent feeling scales (t = 4.23, p < .001). The control group did not score higher on the posttest compared to the pretest on either the divergent thinking (t = 1.96, p > .05) or divergent feeling (t = −1.67, p > .05) scales. The results from an ANCOVA with the divergent thinking pretest as a covariate revealed a teaching strategy effect (game-based vs. traditional teaching) on the posttest divergent thinking scores (F (1,48) = 38.70, p < .0001, $adj\text{-}R^2$ = .48, η^2 = .45). The experimental group scored higher (M = 46.70, SD = 4.31) than the control group (M = 38.87, SD = 4.06) on the posttest of divergent thinking. A similar condition effect on the posttest (divergent feeling scale) was found as a result of an ANCOVA with divergent feeling pretest as a covariate (F (1,48) = 15.90, $adj\text{-}R^2$ = .72, η^2 = .25). The experimental group scored higher (M = 117.62, SD = 11.18) than the control group (M = 111.41, SD = 13.75) on the posttest for divergent feeling.

In summary, researchers have started examining the effectiveness of video games on creativity with a wide lens through correlational studies (Hamlen, 2009, 2013; Jackson et al., 2012). The findings of these studies are mixed—some showing positive effects of video games on creativity and some showing no or negative effects of video games on creativity. These studies are informative, however, in highlighting the need for a closer look at some specific game genres and even games needed for researchers in this area to disambiguate these mixed results.

Regarding the other studies we reviewed, they fall into two groups. The first group includes studies that tried to evaluate the potential of video games to foster creativity via observations (e.g., Inchamnan et al., 2013) or participants' perceptions (e.g., Hewett, 2016; Sáez-López et al., 2015). The second group consisted of experimental research studies comparing high potential games (e.g., *Minecraft*, *Portal 2*, *Crayon Physics Deluxe*) with games that were not expected to show significant effects on creativity (e.g., Blanco-Herrera et al., 2019; Fessakis, & Lappas, 2013). Based on the results of these studies, we can make the following conclusions. First, it is clear that not all video games enhance creativity. Second, certain genres—such as sandbox, puzzle, and simulation games—seem to hold the most potential to enhance creativity. Third, using games from across all game genres but under restricted conditions (e.g., short amount of time or with explicit directions to "be creative") are not likely to lead to creativity improvement. Finally, some games that are not expected to enhance creativity may indirectly lead to more creativity; for example, by boosting players affective states and eventually improving their creativity.

As a result of our review, we identified two main gaps in the research on video games and creativity. First, games that can potentially enhance creativity lack specific creativity supports within the game. Researchers in the field of human-computer interaction have conducted extensive research on applying creativity theories to design and develop creativity-support tools (Resnick et al., 2005; Shneiderman, 2007; 2009). That research has consequently been used by various software companies to develop creativity-support tools (e.g., *Adobe* products). The same application of support tools can be included in the design and development of video games. That is, creativity support tools can be developed that help players think of new ideas, or help them practice creative thinking in a more explicit way. Moreover, by including creativity supports (e.g., brainstorming tools) in video games, more people may be able to experience being creative.

Second, assessment of creativity in these studies usually involves traditional measures of creativity (e.g., TTCT). We need new assessments of creativity that can assess one's creativity based on performance data generated during gameplay (e.g., stealth assessment; Shute, 2011; Shute & Wang, 2016). Such assessments can collect specific data related to creativity (e.g., number of different solutions generated per level; originality of solutions) to provide valid inferences about people's creativity in real time. Then, those assessment results could be used diagnostically to enhance one's creativity (e.g., if the stealth assessment shows one is low on fluency but high on originality after playing some levels, the game can provide supports or challenges that can target fluency). We discuss this idea further in the Conclusions and Future Steps section.

Next, based on the studies we reviewed and other reliable sources from the literature, we attempt to answer our last research question: *How do certain game genres as well as specific games enhance creativity?*

How Do Video Games Enhance Creativity?

Csikszentmihalyi's flow theory states that when dealing with a task, one can enter the flow state when his or her abilities and the task's challenges are matched. In his book, Csikszentmihalyi (1997) explains how one can experience a flow state: when there are clear goals, immediate feedback, a balance between challenges and skills, one can concentrate on the task-at-hand, and there are no distractions. In this situation, there is no fear of failure. If the person keeps working on the task, self-consciousness disappears, he or she loses track of time, and doing the task becomes autotelic—which means that completing the task at hand becomes rewarding and the task itself becomes fulfilling. When one is in the flow state, creativity can happen (Csikszentmihalyi, 1997). Well-designed video games can facilitate the state of flow because they have clear goals, adaptive and increasing challenges, ongoing feedback, and give the player control in the game environment (Shute & Ke, 2012).

Video games with a high potential for enhancing creativity allow players to co-create the game (Gee, 2005). That is, the players are not just going through different levels to finish the game. Instead, video games that enhance creativity are open-ended and provide an environment in which the players can design new levels and express their creativity. For example, *Minecraft*, *Portal 2*, *Crayon Physics Deluxe*, *Little Big Planet*, *Physics Playground*, and others are sandbox and puzzle games with built-in level editors where players can design their own levels and expand the game via their creativity. Such openness (especially in sandbox games) permits players to go wild with their imagination, do what they want, and learn from their experience without fear of making mistakes. Amabile and Pratt (2016) indicate that an environment that supports creativity is one in which people do not have a fear of failure—and many video games provide such an environment for players.

Amabile (1988) and Csikszentmihalyi (1997) have both highlighted the importance of intrinsic motivation, the meaningfulness of tasks, and their impact on individuals' affect, and eventually on their creativity. Playing video games is an intrinsically motivating task. People play video games because it is fun or as Gee (2005) puts it, playing good video games is pleasantly frustrating. When a player escapes a room in *Portal 2* or searches for resources in *Minecraft* to build a spectacular castle, he or she may experience a fun and pleasantly frustrating experience. Eventually, when success occurs, the whole experience of gameplay—with all of its pleasant frustrations—will be very rewarding.

Conclusions and Future Steps

In this chapter, we briefly reviewed creativity definitions and theories of creativity related to video games. We also examined the effectiveness of video games on creativity via a systematic literature review, and finally discussed how video games could improve creativity. According to the literature, some video games directly enhance creativity (e.g., *Minecraft*, *Portal 2*) and some indirectly boost creativity through modifying players' affective state (e.g., *Serious Sam*). Moreover, the studies we included in our review were conducted with participants of very different ages—from preschool to graduate school. Given the highly successful video game industry and the importance of enhancing people's creativity, we—as educators, psychologists, scientists, policymakers, and parents—should not miss the opportunity that video games provide for enhancing creativity. There are ways with which we can improve video games' potential to enhance creativity.

One suggestion, as we briefly introduced above, is to use video games as creativity assessment vehicles. Shute (2011) introduced a new assessment methodology called stealth assessment. This involves the design, development, and weaving of assessments directly and invisibly into the fabric of any complex learning environment, particularly video games. During gameplay, players interact with the game environment and produce rich sequences of actions. In stealth assessment, the evidence needed to assess targeted skills (e.g., creativity) is thus provided by the players' interactions with the game itself. Inferences on competency states are stored in a dynamic model of the learner (at various grain sizes and at different time points). This contrasts with a typically singular outcome of activity—the norm in educational environments. Stealth assessment may also be used to support learning and maintain flow (Csikszentmihalyi, 1997).

Shute and her colleagues have assessed creativity using a game they developed called *Physics Playground* (*PP*; Shute, Almond, & Rahimi, 2019). *PP* is a 2D web-based game designed to assess and support students' conceptual physics understanding. In *PP*, players draw various objects on the screen using a mouse, and once drawn, these objects become "alive" and interact with other objects. By playing *PP*, students improve their qualitative understanding of Newtonian mechanics and how physical objects interact. Students can be creative in their solutions, and they can also use the game's level editor to design their own creative levels. Defining a creativity model with its sub-constructs of fluency, flexibility, and originality, and identifying the in-game indicators that provide evidence for those sub-constructs (e.g., the number of unique solutions to a level can be an indicator of fluency), Shute and her colleagues assessed creativity via stealth assessment in *Physics Playground* (Kim & Shute, 2015; Shute & Rahimi, in press; Shute & Wang, 2016). The results of their validation study showed that the stealth assessment of creativity significantly correlated with the external measure of creativity they used (i.e., the Alternative Uses Test; Wallach & Kogan, 1965). Following the same methods of creativity assessment, game designers can diagnostically assess players creativity and provide the proper support to enhance creativity.

Another path video game designers and researchers can take is to design next-generation video games specifically for enhancing creativity. Those games may be designed based on creativity theories to include the aspects that foster creativity and avoid the ones that hinder creativity. We discussed one example of such an approach in our review (Hsiao et al., 2014; Hsiao et al., 2006). Video games for creativity should be able to facilitate creative thinking processes when one is engaged in deriving a creative solution or product. To achieve these goals, we need more research with rigorous experimental methodologies to examine the effect(s) of video games on creativity.

One way to improve video games' potential to enhance creativity is through designing, developing, and testing various theory-driven creativity support systems in games. For example, inspired by the research conducted by Shneiderman (2009), we are currently planning a study to investigate the effectiveness of two types of creativity supports embedded within *Physics Playground's* level editor. We are currently developing two support systems based on two schools of thought related to enhancing creativity—Inspirationalism and Structuralism (Shneiderman, 2009). Inspirationalists believe that creativity may be enhanced by getting inspired from reviewing the prior work by others in the area, using brainstorming tools and strategies, making remote associations, using analogies, and other techniques and tools intended to inspire one to be more creative. Structuralists believe that people can enhance their creativity if they follow an order or do things in a specific order. We will investigate if inspirational supports (i.e., access to the previous levels, a brainstorming tool, and remote association support), structural supports (i.e., step-by-step guideline throughout the level design process), or both supports are effective in enhancing students' creativity.

Ideally, video games equipped with effective creativity support systems and valid and reliable assessments can be used as useful tools for enhancing people's creativity. Current research on assessing and enhancing people's creativity using video games is a promising, yet young, area of research for creativity researchers that we hope to hear more from in the near future.

References

Amabile, T. M. (1988). A model of creativity and innovation in organizations. In B. S. Cummings (Ed.), *Research in organizational behavior* (pp. 123–167). JAI Press.

Amabile, T. M., & Pratt, M. G. (2016). The dynamic componential model of creativity and innovation in organizations: Making progress, making meaning. *Research in Organizational Behavior*, *36*, 157–183. https://doi.org/10.1016/j.riob.2016.10.001

Ashton, D. (2011). Media work and the creative industries. *Education + Training*. https://doi.org/10.1108/00400911111159494

Blanco-Herrera, J. A., Gentile, D. A., & Rokkum, J. N. (2019). Video games can increase creativity, but with caveats. *Creativity Research Journal*, *31*(2), 119–131. https://doi.org/10.1080/10400419.2019.1594524

Bloom, B. S. (Ed.). (1956). *Taxonomy of educational objectives, Handbook 1: Cognitive domain* (2nd edition). Addison-Wesley Longman Ltd.

Bowden, E. M., & Jung-Beeman, M. (2003). Normative data for 144 compound remote associate problems. *Behavior Research Methods, Instruments, & Computers*, *35*(4), 634–639. https://doi.org/10.3758/BF03195543

Checa-Romero, M., & Pascual Gómez, I. (2018). Minecraft and machinima in action: Development of creativity in the classroom. *Technology, Pedagogy and Education*, *27*(5), 625–637. https://doi.org/10.1080/1475939X.2018.1537933

Cipollone, M., Schifter, C. C., & Moffat, R. A. (2014). Minecraft as a creative tool: A aase study. *International Journal of Game-Based Learning*, *4*(2), 1–14. https://doi.org/10.4018/ijgbl.2014040101

Corbalán, J., Martínez, F., Donolo, D., Alonso, C., Tejerina, M., & Limiñana, M. R. (2003). *CREA. Creative intelligence, a cognitive measure of creativity*. TEA Editions.

Electronic Arts Inc. (2019). *SimCity™ official site*. SimCity™ Official Site. https://www.ea.com/games/simcity/simcity

Feist, G. J. (1999). The influence of personality on artistic and scientific creativity. In R. J. Sternberg (Ed.), *Handbook of creativity* (pp. 273–296). Cambridge University Press.

Feist, G. J. (2010). The function of personality in creativity: The nature and nurture of the creative personality. In J. C. Kaufman & R. J. Sternberg (Eds.), *The cambridge handbook of creativity* (pp. 113–130).

Fessakis, G., & Lappas, D. (2013). Cultivating preschoolers creativity using guided interaction with problem solving computer games. In C. Carvallo & P. Escudeiro (Eds.), *Proceedings of the 7th European Conference on Games Based Learning (ECGBL2013)* (Vol. 2, pp. 763–770).

Gee, J. P. (2005). Learning by design: Good video games as learning machines. *E-Learning and Digital Media*, *2*(1), 5–16.

Gilbert, B. (2018). *"Minecraft" is still one of the biggest games in the world, with over 91 million people playing monthly*. Business Insider. https://www.businessinsider.com/minecraft-has-74-million-monthly-players-2018-1

Granic, I., Lobel, A., & Engels, R. C. M. E. (2013). The benefits of playing video games. *American Psychologist*, *69*(1), 1–13.

Gray, A. (2016). The 10 skills you need to thrive in the Fourth Industrial Revolution. *World Economic Forum*. https://www.weforum.org/agenda/2016/01/the-10-skills-you-need-to-thrive-in-the-fourth-industrial-revolution/

Guilford, J. P. (1956). The structure of intellect. *Psychological Bulletin*, *53*(4), 267. https://doi.org/10.1037/h0040755

Hamlen, K. R. (2009). Relationships between computer and video game play and creativity among upper elementary school students. *Journal of Educational Computing Research, 40*(1), 1–21. https://doi.org/10.2190/EC.40.1.a

Hamlen, K. R. (2013). Trends in children's video game play: Practical but not creative thinking. *Journal of Educational Computing Research*, *49*(3), 277–291. https://doi.org/10.2190/EC.49.3.a

Hennessey, B. A., & Amabile, T. M. (2010). Creativity. *Annual Review of Psychology*, *61*(1), 569–598. https://doi.org/10.1146/annurev.psych.093008.100416

Hewett, K. J. E. (2016). *The Minecraft project: Predictors for academic success and 21st century skills gamers are learning through video game experiences* [Ph.D., Texas A&M University - Corpus Christi]. https://search.proquest.com/pqdtglobal/docview/1861722622/abstract/5FB16F0873F3439EPQ/6

Hsiao, H., Chang, C.-S., Lin, C.-Y., & Hu, P.-M. (2014). Development of children's creativity and manual skills within digital game-based learning environment. *Journal of Computer Assisted Learning*, *30*(4), 377–395. https://doi.org/10.1111/jcal.12057

Hsiao, H.-S., Wong, K.-H., Wang, M.-J., Yu, K.-C., Chang, K.-E., & Sung, Y.-T. (2006). Using cognitive affective interaction model to construct on-line game for creativity. In Z. Pan, R. Aylett, H. Diener, X. Jin, S. Göbel, & L. Li (Eds.), *Technologies for E-Learning and Digital Entertainment* (Vol. 3942, pp. 409–418). Springer Berlin Heidelberg. https://doi.org/10.1007/11736639_52

Hutton, E., & Sundar, S. S. (2010). Can video games enhance creativity? Effects of emotion generated by dance dance revolution. *Creativity Research Journal*, *22*(3), 294–303. https://doi.org/10.1080/10400419.2010.503540

Inchamnan, W., Wyeth, P., & Johnson, D. (2013). Does activity in computer game play have an impact on creative behaviour? *2013 IEEE International Games Innovation Conference (IGIC)*, 77–84. https://doi.org/10.1109/IGIC.2013.6659169

Inchamnan, W., Wyeth, P., Johnson, D., & Conroy, D. (2012). A method for measuring the creative potential of computer games. In M. Herrlich, R. Malaka, & M. Masuch (Eds.), *International Conference on Entertainment Computing—ICEC 2012* (Vol. 7522, pp. 270–283). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-33542-6_23

Jackson, L. A., Witt, E. A., Games, A. I., Fitzgerald, H. E., von Eye, A., & Zhao, Y. (2012). Information technology use and creativity: Findings from the Children and Technology Project. *Computers in Human Behavior, 28*(2), 370–376. https://doi.org/10.1016/j.chb.2011.10.006

John, L. E. (2015). *Casting magic missile: The effect of role-playing video games on creative thinking* [M.A.T., The George Washington University]. https://search.proquest.com/pqdtglobal/docview/1658197966/abstract/5FB16F0873F3439EPQ/11

Karsenti, T., & Bugmann, J. (2017). Exploring the educational potential of Minecraft: The case of 118 elementary-school students. *International Association for Development of the Information Society*, 175–179.

Kaufman, J. C., & Beghetto, R. A. (2009). Beyond big and little: The four-c model of creativity. *Review of General Psychology*, *13*(1), 1–12. https://doi.org/10.1037/a0013688

Kaufman, J. C., & Beghetto, R. A. (2013). In Praise of Clark Kent: Creative Metacognition and the Importance of Teaching Kids When (Not) to Be Creative. *Roeper Review*, *35*(3), 155–165. https://doi.org/10.1080/02783193.2013.799413

Kaufman, J. C., & Sternberg, R. J. (2007). Resource review: Creativity. *Change*, *39*(4), 55–58. JSTOR.

Kim, M., & Shin, J. (2016). The pedagogical benefits of SimCity in urban geography education. *Journal of Geography*, *115*(2), 39–50. https://doi.org/10.1080/00221341.2015.1061585

Kim, Y. J., & Shute, V. J. (2015). Opportunities and challenges in assessing and supporting creativity in video games. In *Video Games and Creativity* (pp. 99–117). Elsevier. https://doi.org/10.1016/B978-0-12-801462-2.00005-9

Kloonigames. (2014). *Crayon Physics Deluxe*. http://www.crayonphysics.com/

Kozbelt, A., & Durmysheva, Y. (2007). Understanding creativity judgments of invented alien creatures: The roles of invariants and other predictors. *The Journal of Creative Behavior*, *41*(4), 223–248. https://doi.org/10.1002/j.2162-6057.2007.tb01072.x

Krathwohl, D. R. (2002). A revision of Bloom's taxonomy: An overview. *Theory Into Practice*, *41*(4), 212–218. https://doi.org/10.1207/s15430421tip4104_2

Levy, K. (2014). *14 amazing creations people vave built In the game Minecraft, which Microsoft just bought for $2.5 billion*. Business Insider. https://www.businessinsider.com/amazing-things-people-made-in-minecraft-2014-9

Lin, X.-T., & Wang, M.-R. (1994). *Creativity assessment packet*. Psychological Publishing.

Moffat, D. C., Crombie, W., & Shabalina, O. (2017). Some video games can increase the player's creativity. *International Journal of Game-Based Learning (IJGBL)*, *7*(2), 35–46. https://doi.org/10.4018/IJGBL.2017040103

Moran, J. D., Milgram, R. M., Sawyers, J. K., & Fu, V. R. (1983). Original thinking in preschool children. *Child Development*, *54*(4), 921–926. JSTOR. https://doi.org/10.2307/1129896

Peckham, M. (2016). *Minecraft Is Now the Second Best-Selling Game of All Time*. Time. https://time.com/4354135/minecraft-bestelling/

Portal 2. (2011). *Official Portal 2 website*. http://www.thinkwithportals.com/media_10.php

Resnick, M., Myers, B., Nakakoji, K., Shneiderman, B., Pausch, R., Selker, T., & Eisenberg, M. (2005). Design principles for tools to support creative thinking. In B. Schneiderman, G. Fischer, M. Czerwinski, B. Myers, & M. Resnick (Eds.), *Creativity support tools: A workshop sponsored by the National Science Foundation* (pp. 25–35).

Rhodes, M. (1961). An analysis of creativity. *The Phi Delta Kappan*, *42*(7), 305–310. JSTOR.

Richards, R. (1990). Everyday creativity, eminent creativity, and health: “Afterview”; for CRJ Issues on creativity and health. *Creativity Research Journal*, *3*(4), 300–326. https://doi.org/10.1080/10400419009534363

Sáez-López, J., Miller, J., Vázquez-Cano, E., & Domínguez-Garrido, M. (2015). Exploring application, attitudes and integration of video games: MinecraftEdu in middle school. *Journal of Educational Technology & Society*, *18*(3), 114–128.

Shneiderman, B. (2009). Creativity support tools: A grand challenge for HCI researchers. In M. Redondo, C. Bravo, & M. Ortega (Eds.), *Engineering the user interface* (pp. 1–9). Springer London. https://doi.org/10.1007/978-1-84800-136-7_1

Shneiderman, Ben. (2007). Creativity support tools: Accelerating discovery and innovation. *Communications of the ACM*, *50*(12), 20–32. https://doi.org/10.1145/1323688.1323689

Shute, V., Almond, R., & Rahimi, S. (2019). *Physics Playground* (Version 1.3) [Computer software]. https://pluto.coe.fsu.edu/ppteam/pp-links/

Shute, V. J. (2011). Stealth assessment in computer-based games to support learning. In S. Tobias & J. D. Fletcher (Eds.), *Computer games and instruction* (pp. 503–524). Information Age Publishers.

Shute, V. J., & Ke, F. (2012). Games, learning, and assessment. In D. Ifenthaler, D. Eseryel, & X. Ge (Eds.), *Assessment in Game-Based Learning: Foundations, Innovations, and Perspectives* (pp. 43–58). Springer New York. https://doi.org/10.1007/978-1-4614-3546-4_4

Shute, V., & Rahimi, S. (in press). Stealth assessment of creativity using video games. *Computer in Human Behavior*, *Special Issue*.

Shute, Valerie, & Wang, L. (2016). Assessing and supporting hard-to-measure constructs in video games. In A. A. Rupp & J. P. Leighton (Eds.), *The Handbook of Cognition and Assessment* (pp. 535–562). John Wiley & Sons, Inc. https://doi.org/10.1002/9781118956588.ch22

Simonton, D. K. (1991). Emergence and realization of genius: The lives and works of 120 classical composers. *Journal of Personality and Social Psychology*, *61*(5), 829–840. https://doi.org/10.1037/0022-3514.61.5.829

Sitzmann, T. (2011). A meta-analytic examination of the instructional effectiveness of computer-based simulation games. *Personnel Psychology*, *64*(2), 489–528. https://doi.org/10.1111/j.1744-6570.2011.01190.x

Squire, K. (2007). Open-ended video games: A model for developing learning for the interactive age. In K. Salen (Ed.), *The Ecology of Games: Connecting Youth, Games, and Learning*. The MIT Press.

Sternberg, R. J. (2006). The Rainbow Project: Enhancing the SAT through assessments of analytical, practical, and creative skills. *Intelligence*, *34*(4), 321–350. https://doi.org/10.1016/j.intell.2006.01.002

Sternberg, R. J., & Lubart, T. I. (1996). Investing in creativity. *American Psychologist*, *51*(7), 677. https://doi.org/10.1037/0003-066X.51.7.677

Torrance, E. P. (1972). Predictive validity of the Torrance tests of creative thinking. *The Journal of Creative Behavior*, *6*(4), 236–262. https://doi.org/10.1002/j.2162-6057.1972.tb00936.x

Torrance, E. P. (1993). Understanding creativity: Where to start? *Psychological Inquiry*, *4*(3), 232–234. https://doi.org/10.1207/s15327965pli0403_17

Wallach, M. A., & Kogan, N. (1965). *Modes of thinking in young children*. Holt, Rinehart & Winston.

Williams, F. E. (1986). The cognitive-affective interaction model for enriching gifted programs. In J. S. Renzulli (Ed.), *Systems and Models for Developing Programs for the Gifted and Talented*. Creative Learning Center.