CHAPTER

7

Teaching Creativity: Theoretical Models and Applications

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OUTLINE

I have not failed 10,000 times. I have not failed once. I have succeeded in proving that those 10,000 ways will not work. When I have eliminated the way that will not work, I will find the way that will work.
—Attributed to Thomas Edison (Furr, 2011)

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Although Edison's quote is contrary to intuition, and contrary to the voice of self-criticism, its subversion of the status quo is exciting. It is a voice of enthusiasm, a rejection of dejection, and an affirmation of a future of possibility.

Some modern entrepreneurs also embrace the idea of failure to encourage innovation. The authors of the video-game-centered web show Extra Credits say "Fail faster." They assert that designers can get caught up trying to perfect their ideas before trying them. They state that "The later you fail, the more expensive your failure will be … Your ideas can't be precious" (Portnow, Floyd, & Theus, 2014).

Edison and the Extra Credits hosts are saying the same thing: that you should embrace the testing of your ideas, and not be discouraged when they don't perform as expected. By finding flaws in your attempts, you will find ways to improve them, taking the lessons of a thousand flawed designs to create a better work.

Sometimes, however, our own feedback is flawed. It can be hard to look past our own preconceived expectations and emotional investment, and to give ourselves the honest criticism we need. If we do not have the time, mental resources, or motivation, we may not even identify the need for it. We also may not have access to anyone we can ask to evaluate our ideas. Alone, we may struggle in trying to stretch our creative muscles and practice the ideation/evaluation skills we need for creativity.

With the rise in technology, new tools for testing and feedback have also risen. Video games, an increasingly ubiquitous form of entertainment, are promising tools for practicing the ideation/evaluation cycle. The designing and playing of video games involve guessing, thinking, testing, and repeated opportunities for failure or success.

Video games are excellent teachers (see Gentile, Groves, & Gentile, 2014 for discussion on this topic). Well-made video games are inherently engaging, are widely available, and often offer immediate feedback throughout game play. They also may create a unique state, often called "flow," where practice is most effective (Nakamura & Csikszentmihalyi, 2002).

In this chapter, we will address the idea of considering video games for serious purposes. We address how video games teach, describing a model of learning, and how video games follow learning principles. We describe the idea of flow, and what mechanics of video games lead to this potentially high-learning state. We will cover how the learning model and flow state can foster creativity. Finally, we offer suggestions for how the game and learning principles can be used to foster creativity through games and in the classroom.

NOT YOUR EVERYDAY GAMES

When you're playing simple, fun, and seemingly addictive video games like *Candy Crush Saga* it's hard to think of video games as anything but entertainment. You might play them on public transport, in line at the bank, or in between business meetings. Nonetheless, many people are turning to video games for serious purposes. With games like *Re-Mission 2* (HopeLab, TRI, Realtime Associates, 2008), children playing a third-person shooter with jetpacks and gooey explosions aren't just having fun. They are playing a game that will help them learn more about and better manage their cancer (Kato, Cole, Bradlyn, & Pollock, 2008). Serious games (games designed for a purpose other than pure entertainment; Micheal & Chen, 2005) have been designed to tackle the challenges faced by our society.

Video game therapies have been designed to help surgery patients distract themselves from the pain of their procedures (Flynn & Lange, 2010). Some clinicians and researchers are treating psychological and physical disorders directly with virtual reality games (Hodges, Anderson, Burdea, Hoffmann, & Rothbaum, 2001). These treatments range from systematic desensitization exposure therapy for those with post-traumatic stress disorder to physical rehabilitation for those with severe physical trauma (Rothbaum, Hodges, Ready, Graap, & Alarcon, 2001; Sveistrup et al., 2003). The military uses video game tools to aid soldiers preparing for combat (Raybourn, Deagle, Mendini, & Heneghan, 2005).

Another well-publicized use of serious video games has come from the University of Washington, where researchers have used video games to crowdsource science. Reshaping and fitting protein molecules together as is needed for AIDS and cancer research is usually a very time-consuming and difficult problem, but researchers have turned it into a puzzle video game, where individuals and teams from around the world play together to find solutions (Eiben et al., 2012). In the game *Fold-it*, players try to reshape protein molecules to produce demonstrations of how these molecules interact in real life. The reshaping process maximizes efficiency and minimizes problems—bonding them, inhibiting certain structures, resizing them, etc. They have had success using the thousands of free work hours from players who enjoyed the game, using the results of this play to discover and publish about the nature of these diseases.

In a similar approach, the People's Lab of MSLGROUP is using video games to spread a social message. They employ a social network game called *Half the Sky* to educate people on the plight of oppressed women trying to establish economic security in Africa. Not only does this game allow people to live virtually through the difficulties suffered by oppressed women, they also use it to connect the gamers to real people that need help. The game is integrated with Facebook and other social media, allowing the players to make donations online. Users can also spread news of the program to their friends through links and "shares." *Half the Sky* has successfully been able to raise awareness for an important social issue, create a free accessible platform from which people can learn, connect with, and donate to those in need, as well as continually spread the creators' message through the world (Makhija, 2013).

These examples illustrate a growing trend of serious games as tools for learning, health, and communication. Video games can be incredibly successful not only in the fields of medical applications, scientific endeavors, and social outreach exemplified above, but also in the field of education because video games themselves are incredibly effective teachers. Even when games are solely designed for entertainment they teach players real-world skills and lessons.

When people play prosocial video games they show more prosocial thoughts and behavior (Gentile et al., 2009; Greitemeyer, Osswald, & Brauer, 2010). When people play violent video games they show significant increased levels of aggression (Anderson, Gentile, & Buckley, 2007; Anderson et al., 2010; Gentile, Lynch, Linder, & Walsh, 2004). When people play action video games, games that require quick reactions to a variety of visual cues, they benefit from faster reaction times and increased performance in a range of visual-spatial cognitive tasks (Achtman, Green, & Bavelier, 2008; Dye, Green, & Bavelier, 2009; Green & Bavelier, 2003). When people play real-time strategy (RTS) video games, which require storing and processing of multiple short- and long-term goals while simultaneously attending to new cues, they show gains in working memory (Basak, Boot, Voss, & Kramer, 2008; Basak, Voss, Erickson, Boot, & Kramer, 2011; Kühn, Gleich, Lorenz, Lindenberger, & Gallinat, 2014). The focused repetition of ideas, expectations, and skills in video games create an exemplary teacher (Gentile & Gentile, 2008).

A MODEL FOR LEARNING PROCESSES IN GAMES

The way people learn in video games can be described using the general learning model (GLM). An overview of this model can be found in Figure 1. The GLM is a model of human learning that incorporates biological, social, and cognitive factors. A single cycle of the GLM serves as a representation of an individual learning episode. The amount of time it takes for one to progress through each stage is intentionally vague. The entire cycle may be completed within seconds, but could take several minutes. This single cycle contains three stages.

The first stage of a GLM cycle begins with two forms of input, including all the qualities of the environment and of the person in a given situation. The person input includes all persistent qualities of the individual that are carried with them into each given moment: genetic predispositions,

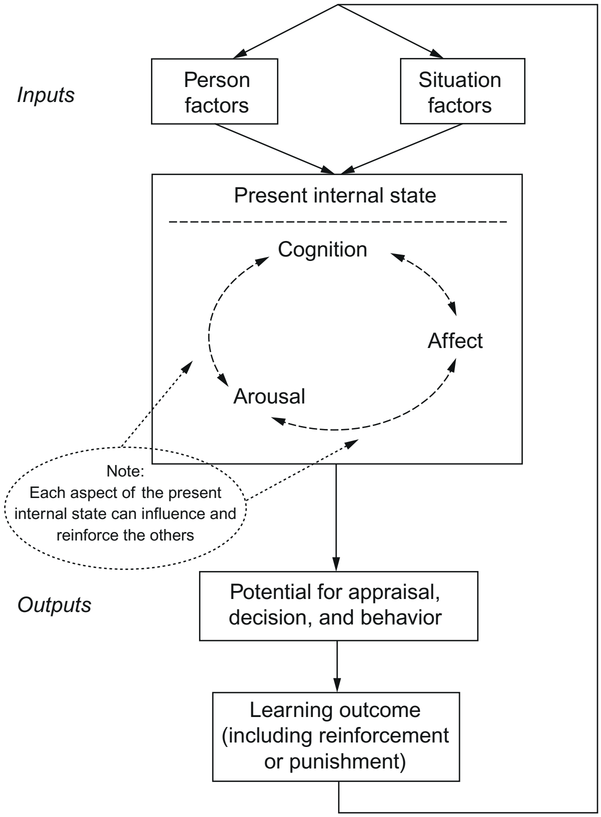

FIGURE 1 Short-term process overview of general learning model. *Gentile et al. (2014)*.

stable personality traits, mood, sex, short- and long-term goals, attentional resources, etc. The environment includes all of the qualities of the present situation: all of the characteristics and affordances of the physical environment, as well as other external factors like social influence. These qualities interact to influence the opportunity for learning.

Information in the environment is detected by one's sensory organs. However, perception, or what the mind thinks is being detected, is an interaction between the environment and the person. Perception is a product of detection and learning. The process of perceiving is best considered both a top-down and bottom-up process (Gentile et al., 2014).

Once the situation is perceived, it can influence physiological arousal, affect (feelings or mood), and thinking (cognitions, including both conscious and nonconscious cognitions, such as spreading neural semantic priming). Each of these internal states is related and they can affect each other. For example, if someone is insulted, their arousal increases, they feel anger, and they think that the insult was unjustified. Thinking that it was unjustified—how they did nothing to deserve this, how that person is being completely unfair, how they can't believe anyone would ever do this!—Such thoughts can serve to further increase the feelings of anger and arousal.

Next, the internal states influence decision-making processes in which individuals select a response to the given situational event or context. In this stage, decisions can be made immediately (an impulsive action) or following reappraisal (a thoughtful action). Impulsive actions will usually occur when the individual does not possess the motivation or resources (e.g., time) to reappraise the situation. Impulsive actions will also occur if the individual has received positive feedback from similar responses in the past. This is usually the case with habitual actions like one's morning ritual. People usually don't think too hard about how they are getting ready in the morning, because it has always met their goals in the past and an unexpected failure (a freezing shower or a bad hair day) is unlikely to cause serious problems. However, if the individual thinks the outcome is important, and if the intended action risks an unsatisfying outcome, then reappraisal is more likely. Learning may also occur during this reappraisal process. For example, in completing a math problem, a student may decide to double-check their work—if a changed answer appears more correct (or is reinforced as correct, later, by an authority) the cognitive processes leading to the correction are reinforced. Similarly, if a student makes an impulsive decision, it may be reinforced later (the answer was correct) or punished (the answer was wrong). Impulsive actions that receive regular reinforcement create more deeply engrained habits, and increase the likelihood of similar impulsive actions in future cycles, while impulsive actions that receive regular punishment weaken, and are less likely to be repeated.

Through the processes described here, learning occurs at several stages and is reinforced throughout the cycle. In a simple example, when encountering a person in need, feelings of empathy, and concern may arise, which influence the likelihood of engaging in a helping response. If the helping response is rewarded, the individual may be more likely to identify others in need in the future (a perceptual learning effect), experience empathy and concern for such individuals, and repeat decisions to provide help. This example illustrates that, through repetition, individual learning cycles produce long-term changes in the person which are then carried across situational contexts.

The value of the GLM is in the modeling of learning. Video games have players rapidly and efficiently complete many learning cycles. They are a promising tool for practicing the process of creative production.

GAMES AND FLOW

One of the strengths of video games is that they are naturally interactive (Squire, 2003). This can help to transport the player into another "world," to have the player craving to play again, and to even lose track of time (this is similar to the research of information processing scholars on narrative transportation; i.e. Green & Brock, 2000). One theoretical construct that may help to explain how games can be so captivating is the commonly reported experience of flow. Flow is a state in which one loses track of time, has an extreme focus on the task at hand, finds the task rewarding, and performs optimally (Sherry, 2004). It can be argued that video games can induce this state because they excel at providing players with a task that is immediately rewarding and adapts to their skill level (Csikszentmihalyi, 1990). Understanding flow may be the key to understanding how the engaging power of games may be applied to both creative and general learning.

Flow experiences are reported in a variety of activities. It can happen while playing a sport, performing a piece of music, creating works of art, or simply playing a game with friends (Csikszentmihalyi & Csikzentmihaly, 1991). Some might refer to the state of flow as being "in the zone" while performing a task (Young & Pain, 1999). Flow states can be thought as an extreme form of engagement. Flow states and theories have been described differently, and although they have been popular, they also have typically been described so vaguely that they were largely impossible to test empirically. Some recent work, however, may provide novel approaches to understanding and measuring it. This section will focus on expanding upon and applying the Weber, Tamborini, Westcott-Baker, and Kantor (2009) conception of flow.

Historically, flow was described phenomenologically in situations where skill and challenge are balanced (Csikszentmihalyi, 1990). People became engaged by the challenge of demonstrating and improving their own skill and are rewarded as they successfully progress and learn (Vygotsky, 1987). Good video games adapt to the player's current skill level, optimizing this cycle of progression and reward. They do this through a variety of methods (Funk, Chan, Brouwer, & Curtiss, 2006). One of the simplest is the use of progressively complicated/harder levels. For example, in *Halo: Combat Evolved*, increasingly difficult game levels will include more enemies, different enemy types, and more combinations of enemy types that require deeper levels of strategy to defeat. The player progresses from fighting basic infantry to land vehicular combat, aerial combat, and storming a fortified position with their choice of vehicles and reinforcements against infantry, elite units, tanks, aerial combat units, and surprises. This forces the player to learn new strategies against the enemy types, to master those strategies, and then learn how to switch between strategies when appropriate.

Balance is crucial. If achieving success becomes too easy, the player progresses with little effort. They feel little reward for accomplishing such a small task again and again, and ultimately become bored (Csikszentmihalyi & Csikzentmihaly, 1991). On the other hand, if achieving success is too difficult, the player sees little chance, if any, to progress and is frustrated. Balancing effort and reward provides the player with an opportunity to gain growth and development from earnest effort. The player is not only explicitly rewarded within the game, but is also intrinsically rewarded with feelings of success and competence.

It is possible that the immediate feedback within games serves to prevent the flow state from being interrupted. The player knows immediately if their current tactic is working. If they are rewarded or punished depending on their performance, they can immediately adapt and continue playing. They can progress at their own pace, and feel greater control over their own progression. Because of this, immediate feedback keeps the player engaged as their actions have direct, observable effects.

Yet, even with immediate feedback, not every action is rewarded, or rewarded equally. A fixed reward schedule (that is, one that happens every single time you do something) is not as motivating as a variable reward schedule (such as slot machines, which reward at random intervals) (e.g., Skinner, 1957; Watson & Skinner, 2001). Many games tend to implement scaled variable and fixed reinforcement alongside the immediate feedback to keep the game as engaging as possible. For example, in *Destiny* (Activision, 2014), players are awarded a certain amount of experience points for defeating enemies. However, every enemy that is defeated has a random chance of dropping an item, and any enemy can drop items of any quality (with more desirable items being rarer). In this game, every enemy defeated gives players a fixed experience point reinforce while also providing a variable "loot" reward system. The "loot" mechanic is remarkably similar to what is seen in slot machines. Defeating enemies is the lever and the game items are the prize. It is common to see players fixate on playing this video game "slot machine" for hours in hopes of hitting a jackpot. This is one of the video game mechanics that likely increases the risk of behavioral addiction to games, such as massive multiplayer online role-playing games (Gentile, 2009).

Immediate feedback with variable reinforcement is not the only tool that video games use to engage flow. At a deeper level, they also use progression and progression feedback for long-term engagement. Skill trees in *World of Warcraft* (Blizzard Entertainment, 2004) allow players to see the growth of their character within a game over time, to measure that growth, and to foresee the rewards that come with this progress. This is also done with progress bars, badges, maps, unlockable content, achievements, quests, and more. The *Call of Duty: Modern Warfare 2* (Activision, 2009) franchise implemented these systems to great success in their multiplayer to give players goals and clear ways to achieve them. A player would see an exciting weapon that could only be used once the player had achieved a certain "level." A progress bar kept track of their leveling progress, badges gave players supplementary goals that granted extra experience, and achievements kept giving them rewards on their path to unlocking their desired gear. These visible markers served to give the player a variety of new goals, to offer a guide to achieving these goals, to show them how much they have accomplished, and to allow them to display their achievements to other players.

These extrinsic reward systems must be used with care and balance. If the game gives the player too much in the way of structure and continuous rewards then the game risks becoming something of a Skinner box simulation (Skinner, 1957). The player simply performs as the game tells them they should, and not much is gained from the experience.

From the perspective of the GLM, the flow experience can be described as the result of the short-term learning processes becoming optimal, fixated on a singular task, and uninterrupted. This can produce more efficient and rapid cycling, maximizing the player's learning potential.

CREATIVITY

Creativity can be thought of as a cyclic process of ideation and evaluation (Lubart, 2001). This approach to creativity is characterized by a period of ideation—coming up with ideas—followed by practical evaluation on the merit of the ideas.

Ideation relies on the process of divergent thinking, which holds four distinct aspects: fluency of ideas, flexibility of categories, elaboration, and originality (Guilford, 1967). Fluency of ideas describes the total number of disparate ideas the creative person can create, flexibility of categories is how many different types of categories those ideas can be organized into, elaboration is how detailed those ideas are, and originality is how uncommon a particular idea is. Ideation in games can take the form of trying different tactics in a strategy game, constructing in-game objects, approaching a group of enemies from a different angle, or just deciding on how to classify winning in the game.

Evaluations should judge both the appropriateness of a solution and whether it can be feasibly implemented. Evaluation stands as a form of convergent thinking, or the ability to derive the most appropriate answer for a well-defined question (Cropley, 2006). Evaluation in games can be immediate and can come from varied sources. Depending on the game, evaluation can come from peers, enemies in the game, or the rules of the game itself. The game can easily tell the player their idea failed by having the player fail, die, or lose immediately. It can also do the same by increasing the difficulty of the game after a failed action. Other players of the game can give feedback as well, either in the game or outside of it. Due to the nature of video games, players often receive feedback or evaluation quickly. This allows players to repeat many ideation and evaluation cycles rapidly.

This rapid cycling is similar to how flow was described. Similar to flow, the game must allow the player to have meaningful choices. If the game does not balance meaningful choices or other game mechanics besides the Skinner box reinforcements, the game can result in detriments to creativity because it does not let the player ideate (Beghetto, 2013). There would be only one right answer, and hence no room for alternative solutions, trial and error, or ideation and evaluation.

The more times someone can cycle through the process of ideation and evaluation, the more chances they have of being successful in a creative pursuit. Additionally, the more practice they have in each step of the process, the more likely they are to succeed in that step (Basadur, Graen, & Green, 1982). As video games and their attendant mechanics have players rapidly and efficiently complete many learning cycles, they are a promising tool for practicing both ideation and evaluation, reinforcing the regular use of these processes in the player. Although theoretically reasonable, very little research exists testing these hypotheses.

GAME ELEMENTS FOR CREATIVITY: APPLIED EXAMPLES

Video games may be a valuable tool for training ideation and evaluation, but game elements can also be applied to traditional learning settings. In a traditional math class, students are given a lecture on a topic, go over some examples, and then are assigned homework to continue practicing on their own. Students are expected to listen to the teacher for the duration of the lecture, to take notes, to understand the examples (or to know when they are confused), to ask appropriate clarifying questions, to participate with expected and nontangential answers, and then to complete the homework correctly as assigned. However, this format may be improved with the adoption of certain game elements. We will use educational examples, such as the partnership between Khan Academy and the Los Altos school district, to exemplify approaches to education that have benefited from the use of game elements. (It is worth noting that in the first year of the Khan Academy and Los Altos school district partnership, the district saw an increase of 73% in the number of students who passed the California Standards Test; Kronholz, 2012.) We will also use examples of video games that use the same elements to illustrate their use in the gaming context. Each section will offer a game element, give examples, and explain its utility in training and improving creativity.

Pace Matching

Pace matching refers to the mirroring of an individual's comprehension level to match that which is demanded by the environment. The interactive nature of video games lends itself to pace matching. The player decides how much and how fast to progress in the game. They can choose to play below, at, or above their own skill level. They have the opportunity to practice their skills again and again until they succeed. They can replay parts of the game they want to improve in, and if the player does not have the necessary skills they need to be successful, they will not progress. Yet, they can always try again until their pace matches that of the game (or they turn down the difficulty so the game pace matches them).

The difficulty settings in *Dance Dance Revolution* (DDR) games (Konami, 1998) are a great example of pace matching. Low difficulties and beginning songs start with relatively few moves at low speeds. The player can choose either to pick more or less difficult songs or change the overall difficulty setting. Increasing overall difficulty gives the player more moves at a faster pace. Different songs let the player not only choose different styles, but also slightly different variations in difficulty.

Some games are more forward in encouraging appropriate pace selection. In the game *Devil May Cry* (Capcom, 2001), the game defaults to normal difficulty. But if the player dies a certain number of times on the same level, the game asks if the player would like to try it on easy mode.

Pace matching in the GLM can be described as a match between environmental demands and the perception and decision-making ability of the person. Pace matching occurs when the person is able to attend to the environmental stimulus, respond accordingly, receive timely feedback, and attend to that feedback. In a game, this means the player understands the demands of the game (DDR says hit the right arrow), the player reacts according to the game demands (player steps on right arrow), the game reads the response and makes the player aware (right arrow icon lights up on the screen), and the player sees the effects of an action (player sees that they received the points for hitting the right arrow). Pace matching may allow users to complete learning cycles of the GLM at a pace that is comfortable for them and makes each cycle more effective. It also can fill the flow requirement of matching difficulty with ability, allowing players, or students, to maintain the flow state longer.

In a standard classroom, even though the top third of students have an average learning rate at least three times faster than those in the bottom third, the teacher introduces the material at one pace (Gentile & Lalley, 2003; Gentile, Voelkl, Mt. Pleasant, & Monaco, 1995). This could force the teacher into a pace that is ineffective for the majority of the class. Without any outside support, like tutors, some children may start seeing the classroom as a negative place, characterized by either boredom or frustration instead of as a place of knowledge and achievement. One way the Khan Academy partnership tackled the problem of pace matching was to "flip" the classroom, making video lectures to be viewed at home, while classroom time is devoted to practice problems that would normally be assigned as homework. This way, the student has control over the pace of the lecture. They can pause it, speed it up, or repeat it as needed. Practicing problems in the classroom allows the teacher to float between students, answering questions and assisting with individual student problem areas as needed (Kronholz, 2012).

An example of a more explicitly creative video game that benefits from pace matching is *Prison Architect*, currently in alpha (Introversion Studios, 2012). The game relies on the ideation of possible designs, and the evaluation of those designs through the continual testing of your security by the prisoners. In a standard game without money cheats, the player starts with a small number of funds and must build a small prison, generally with the lowest security (easiest) prisoners. They may adjust this further by turning continuous intake, or the constant arrival of more prisoners, on or off. As more prisoners arrive, the design must become more elaborate. As you add prisoners of increasing difficulty (medium and maximum security, even the occasional supermax), the player must improve designs to address new and more difficult problems. Yet, if it becomes too hard, the player can either reduce the difficulty of incoming prisoners, turn off continuous intake entirely, or even sell the current prison and enter his or her next scenario with more money; they are thus able to meet the demands of greater difficulty levels. The game allows regular cycling of learning processes, can induce a state of flow through high engagement and challenge adjustment, and creates an ideal environment for ideation followed by rapid, visible evaluation.

Instruction, Practice, Feedback

In video games, players are instructed in skills and given feedback while they practice them. They are told pressing the "A" button is for jumping, they are allowed to press a button, and they see that the character on the screen jumps. They are usually given some sort of object to jump on, across, or over. This immediate application allows the player to understand the usefulness of a skill. The game structure may require jumping for progression through the game or provide other rewards. This basic practice with instruction and immediate feedback allows for rapid and lasting learning. "A" is for jumping, which allows the character to jump, jumping can traverse obstacles, and traversing those obstacles can be rewarded with prizes or progression.

The game *Portal* (Valve Corporation, 2007) is a very popular title that incorporates this instruction, practice, and feedback well. In it, the player is given a tool that will create two portals in solid walls. If the player walks into one, they come out the other. The game explicitly teaches the player how to make these holes, and then offers problems with set goals that test the player's ability to use the mechanic effectively. When the player makes a mistake, death ensues and the player gets to try again. When the player succeeds, they are congratulated and move on to a more difficult problem. The melding of instruction, practice, and feedback allows for rapid cycling through the GLM because it gives players rapid feedback on their actions, lets them adjust accordingly, and provides feedback on those adjustments. It also makes the player an active learner in the game, encouraging engagement and continued attempts.

In a typical math class, the instruction (lecture), the practice (homework), and the feedback (graded work) are separated by days or even weeks. The flipped classroom described above hastens this instruction/practice/feedback cycle. First, the platform in which they watch the video lecture, KhanAcademy.org, links the student directly to practice problems on the material of the lecture. Second, given that the teacher no longer gives a general lecture for everyone, the teacher is free to work individually with students, answer questions, and supply additional problem-solving techniques the student can apply immediately. Third, the problems students are working on are automatically graded so students are immediately aware of deficiencies in their work. The electronic format also provides the teacher with formative data on how each student is performing in each subject and their subtopics, enabling even more focused feedback in the future.

Fold-it (Eiben et al., 2012), the protein-shaping game mentioned earlier, is an excellent example of instruction, structured practice, and immediate feedback. The tutorial begins with simple proteins and explains a single tool that can be used to manipulate it. The player tries the tool, and elements of the protein change or light up to indicate failure or success. The game then continues with instruction for another tool, and another cycle of practice and feedback. Players improve their knowledge base while simultaneously being required to use the acquired skills in novel ways. Ideation and evaluation are the goal, and *Fold-it* combines individual player improvements into a massive pool of possible new approaches to serious disease.

Developing Automaticity

Much like math, video games depend on mastery and automaticity of basic skills learned in early levels to progress successfully in later levels. Video games achieve this by giving the player massed practice of every new skill (that is, a concentrated amount of practice at one sitting) and distributing further practice of that skill throughout the game. Basic skills within games are heavily practiced in early stages (overlearned) and, later, more difficult stages can only be completed if the skills developed earlier in the game have become automatized (a product of overlearning). This automatization frees cognitive resources so that players are able to focus on more novel, difficult demands of the game's level. One can only master the double-jump ledge-grab flip after mastering the basic jump. If you have to analyze the basic jump every time you do it, you may die.

RTS games, like *Warcraft 3* (Blizzard Entertainment, 2004), serve as excellent examples of the role of automaticity in learning. These games require that players collect resources, use those resources to build structures that produce military units, and ultimately create an army used to defeat a computerized opponent. First, players have to learn basic concepts such as how to use the controls and a host of actions that must be executed to win. More basic actions (e.g., using the controls) are automatized first and become foundational for automatizing more complex tasks (e.g., collecting resources). Finally, the game requires that each skill is collectively exercised and challenges the player to use everything they learned to overcome progressively difficult scenarios and foes. Players tend to expand their learning of the game by playing against other humans, which requires higher level strategy and adaptation, all of which is impossible without the ability to automatize and build upon a number of skills—a process that is facilitated by the mechanics of the game.

One popular game that has been used for serious purposes is the RTS game, *Starcraft II: Wings of liberty* (Blizzard Entertainment, 2010). In it, players are subject to extensive practice in managing resources, including dozens, even hundreds, of mobile units. At first, this practice is the focus of play, with minor skirmishes that are mainly used to introduce new units or skills and teach you how to manage them. However, for advanced players, these skills become automatized. Competitive players can achieve such automaticity, and such attendant speed, that they manage their units through 500-600 actions per minute (Lejacq, 2013). Meanwhile, either a game campaign or other players pose challenges that scale in difficulty. A player either advances through increasingly difficult missions, or players compete against players incrementally better than they played before, matched to their skill level. Strategies must adapt to new scenarios and new strategies, and the quality of those strategies is immediately evident in a victory, or flames, death, and defeat. Ideation and evaluation are key, but depend on the automaticity of basic skills to allow higher-level thought.

In the classroom, a student who has overlearned basic arithmetic will find algebra easier than one who is still struggling with each step of the equation. Typical math homework attempts to use massed practice by assigning large problem sets using the same operation. However, they can fall short of distributing the practice throughout the year, instead moving on to new and unrelated operations. They may also fail to sequence the difficulty well, as students vary in how hard or easy they find a skill is to attain—for one student, fractions may be easier than decimals, so fractions should come first. But if decimals come first, the student is frustrated by the material s/he doesn't understand and impaired in learning the material that would otherwise come easily from sequencing that is matched better to his or her current understanding. Further, the delayed feedback associated with the traditional classroom prevents students from identifying both faulty and correct understandings of the material. They may have received an A or they may have received an F, but this result is left unknown for days or even weeks. Perhaps most importantly, traditional classrooms almost never offer correct distributed practice, or regular use of the same skill over time (regular reviews, homework that includes problems from previous modules, etc.). Without this, students may achieve mastery, but cannot develop automaticity.

In contrast, the adaptive programming in the Khan Academy website requires students to answer several problems correctly to progress, allowing students to develop a mastery of the content, but furthermore requires future distributed practice to maintain that mastery and move toward automaticity. Adaptive programming is also a means of pace matching the practice. Those who comprehend the subject well do not receive a series of redundantly easy problems, and those that are struggling get more practice with easier problems until they can achieve mastery. All this is done without adding additional burden to the teacher.

Utility of Failure

True failure does not come from the inability to succeed, but from the inability to try again. Failing in games is natural, which is why save points and repeating missions or puzzles are built into them. Some games, like *Super time force* (Capybara Games, 2014), actually make death a crucial part of the game. In this game, death or failure means respawning with another life like it would in most other games, but the previous life is not erased. All of the actions of the previous life (jumping at point A, shooting at point B) are recorded, and played back with full impact in future attempts. This results in a player being able to plan for failure. They can use a previous life just to pave the way for success in a future one. For example, one character has a shield they can deploy to block incoming fire, another character has a strong far-range shot. The player could choose to spend one life with the shield character to just deploy defensive areas, where in a future life they can use the character with the long shot to shoot from. Failure is no longer a judgment on ability, it becomes an opportunity to learn and learning how to fail to achieve future success becomes a priority.

In contrast, many grading systems and skills assessments in schools do not treat student failures as learning opportunities. They can even discourage students from trying to learn. For example, if a student somehow finds they have a grade of 10% halfway through the semester, there is usually very little they can do to improve their grade to a level they might want. This system gives the student no incentive to keep trying; it promotes surrender and learned helplessness. However, if grading worked similarly to the progression systems within video games, there would be multiple opportunities and multiple paths this student could take and s/he would still receive incentive to keep studying or trying to achieve the desired grade. A grade system like this would involve assignments and assessments that would be taken multiple times over (this has been done in schools when classes adopt a mastery learning approach; Gentile & Lalley, 2003). A system used by Khan Academy shows how this can be done with math problems without necessarily adopting a full mastery learning approach. The work is graded automatically, and the question bank is enormous. If the goal is for the student to learn, it should not matter if they learned it from a lecture or from continuous trial and error in assignments. Second, there should be multiple possible assignments, more than can be possibly done, totaling more points than needed for a desired grade. This gives the student choice and agency in what they practice, and in how they earn their grade. The method also possesses an additional benefit in placing emphasis on the role of effort in learning, rather than attributions for success based on raw ability. Because options for success are always present, students may be less likely to fall prey to learned helplessness (Ames, 1992).

This type of system also encourages divergent thinking. It lets people know that failure is a learning opportunity, and they should try something else. It can let students experiment with new ways of completing assignments, because the goal is eventual mastery of the material instead of the grade (Beghetto, 2013). When failure is not terminal, the student can try again. They can ideate again. This is the basis for the product design principle of rapid prototyping. In rapid prototyping, the idea is to get a working, just barely functional, version of the product created as soon as possible. It is then tested, evaluated, and pushed to its breaking point. The designers learn from how the prototype fails to make an even better prototype, which is again tested, evaluated, and pushed. The designers try to run through this cycle of ideation and evaluation as much as possible, each cycle, each failure leading to a better product.

Sandbox or Free Play

Sandbox mode is a popular game mechanic in which players have no explicit goals and no instructions—they are simply given a set of tools and allowed to play with them how they want and to whatever purpose they want (Olson, 2010). This is a common mode in games that simulate city-building, and has been incorporated not as a mode but as an option in open-world games.

This kind of free play is one of the most basic forms of creative education. Children in kindergarten are given easels and finger-paint without anyone telling them the “right” thing to create. Early music classes may begin with cardboard paper-towel rolls filled with beans and tape on either end, with the children left to shake wildly, beat rhythmically on a hand, or incorporate into roll-shaking dance moves.

Free play can also be achieved in classes outside the arts. An engineering teacher may bring in a box of found parts and tell his class to build something, anything. An English teacher may set time aside for writing, requiring nothing more than pen on paper, leaving topic and form to be defined by the students. Science fairs do this as well—students must play with science, but what they create, and what they test, is up to them.

Games may be able to use free play to foster creativity. For example, *Minecraft* is a game focused around the player's ability to mine resources from their environment and to construct objects and structures. The player ideates and has freedom to construct his or her ideas of protective shelter during the game's day time. During the game's night time, the explosive monsters test the effectiveness of a player's shelter and thereby provide a form of evaluation. If the player survived, they at least know their ideas were good enough, and probably gained some insight into what can be improved. If they didn't, they can restart and try again. The game has players naturally practice a creative ideation/evaluation process in their game play.

CONCLUSION

Edison suggested that ideas are valuable, whether they suit our needs or not. Evaluating ideas leads us to improve our next idea. If we practice divergent thinking, we are better able to engage in useful convergent thinking and develop a useful product.

Video games are and can be used for serious purposes. Models of learning and engagement shed light on the processes needed to learn to proactively exercise creativity. Video games are a powerful tool for learning, because they take advantage of these processes through an accessible and entertaining platform.

We concluded with several examples of video game elements that may be used to foster creativity and learning both through games and through game-like classroom methods. These may stand as exemplars for educators who want to improve creativity in their students. Further game mechanics may be identified and adapted as well, shaping future educational techniques.

Video games are powerful teachers. Yet the spirit of video games, their designers and players, may be the most important part of developing creativity. If we can try 10,000 ways to make a light bulb, making an effort to fail as fast as we can, we may ingrain the habit of creativity, preparing the way for a more creative world, and setting us on a path to a culture of discovery.

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