Opportunities and challenges in assessing and supporting creativity in video games

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Abstract

Many games offer players opportunities to express their creativity, from posting their clever solutions in online forums, to beating particular boss levels, to creating their own levels using built-in level editors. Yet there is scant evidence supporting the link between video games and creativity. This is partially due to the difficulty of measuring creativity. In this chapter, we will (a) review the current literature of creativity, (b) discuss affordances of video games for creativity development using popular commercial games as examples, and (c) illustrate how one can assess and support creativity using creativity assessments in our game, Physics Playground (formerly known as Newton's Playground), as an example.

Introduction

Creativity as a 21st Century Skill

Young Americans' readiness for the 21st Century global economy is a growing societal concern (Bybee & Fuchs, 2006; Florida, 2002; Friedman, 2005). Friedman's *The World is Flat* (2005) is a well-known example of the literature that describes the world economy's rapid evolution toward completely open, global competition, and the United States' potential loss of global competitiveness as a result. In the same vein, Levy and colleagues (Autor, Levy, & Murnane, 2003; Levy & Murnane, 2004) report that advancements in computer technology are replacing routine cognitive tasks and manual labor, with jobs requiring creative thinking and complex communication skills. Therefore, to gain global competitiveness in the 21st Century, society must prepare its younger generation with knowledge and skills that are fundamentally different from those in previous centuries. In a survey conducted by the Partnership for 21st Century Skills (2007), the general public expressed similar views: 99% of voters responded that 21st Century skills such as creativity and collaboration were important for the nation's economic growth, and that school education needs to (and should) support those skills.

Despite the clear need to support 21st Century skills, business leaders and educators are concerned that young people are inadequately prepared with the requisite skills to succeed in a 21st-Century economy, even after completing a high school or college education (Casner-Lotto & Barrington, 2006; Symonds, Schwartz, & Ferguson, 2011). For instance, 431 business leaders were interviewed in an effort to understand employers' views on work-readiness and "21st-Century skills" in recent graduates, and they generally agreed that high school and college graduates lacked both basic and applied skills. A majority (75%) of the business leaders also pointed out that creativity is one of the most important skills (Casner-Lotto & Barrington, 2006)

Creativity generally refers to the ability to produce ideas or solutions that are novel yet appropriate for the problem (Lubart, 1994). Creativity has been of research interest to psychologists for over 50 years, and is now particularly recognized as one of the essential skills needed to succeed in the 21st Century (e.g., the Partnership for 21st Century Skills, 2007). As Resnick (2007) argues, we are living in a *creative society* where one's success is based on the ability to think and act creatively. However, despite the recognized importance of creativity, current school systems do not adequately prepare younger people to become creative thinkers (Hargreaves, 2003; Sawyer, 2006).

Video Games and Creativity

One medium that has affordances to support creativity in young people is video games. Playing video games is one of the most popular activities for people of all ages in the United States. Fifty eight percentages of all Americans play video games and the average game player's age is 30. And a recent study on media usage in the U.S. also reported that 67% of youth (ages 8 to 18) spent an average of 73 minutes daily playing video games, compared with only 38 minutes daily reading print materials (Rideout, Foehr, & Roberts, 2010). In 2013 only, Americans spent $21.53 billion on video game-related purchases (Entertainment Software Association, 2014).

How can video games cultivate creativity? Will Wright (2006), a renowned game designer, argues that video games are "dream machines" that have the ability to unleash human imagination. Wright explains that a game is a "possibility space" in which video games start at a well-defined state and end when a specific state is reached. How players reach a specific end is open-ended, and each player can navigate this possibility space by making continuous choices and actions.

Gee (2005) similarly describes how a well-designed game incorporates good learning principles that can support players' creativity. First, players are not mere consumers of the game but producers by making their own actions and choices. At a simple level, what players do and create in the game to progress through levels is a form of production. For example, in the popular "god" game called *Spore*, players create their own species and then the species evolve into more intelligent creatures and civilization. Some games, such as *LittleBigPlanet* or *Portal 2*, have built-in level editor functionality that allows players to modify the games and even create their own levels. Second, good games often encourage players to take risks, explore and try new things, and learn by failing. Failing is not a bad thing in games as it is in traditional education. In fact, failing is one way to get feedback about progress. Learning-by-failing can be found in many games, such as *World of Goo* (see Shute & Kim, 2011) where solving the goo-ball puzzles typically requires multiple trials, per puzzle. Third, video games are “pleasantly frustrating.” That is, tasks in a well-designed game are challenging but reside within a range of difficulty levels that gives players a great sense of accomplishment upon completing the task. For example, *Candy Crush Saga* presents levels with gradually increasing difficulties and scaffolds players at earlier levels. When players reach certain proficiency, then the game eventually removes the scaffolding.

Due to those affordances of video games to facilitate creative behaviors and risk-tasking, a few researchers investigated possible links between creativity and video games. For example, Hamlen (2009) investigated the relationship between self-reported time spent playing video games per week and performance on the Torrance Tests of Creativity Thinking (TTCT) in 4th and 5th graders. She reported that the number of hours of gameplay does not significantly predict TTCT performance controlling for gender and grade. In contrast, Jackson and colleagues (Jackson et al., 2012) investigated the relationship between gameplay time (i.e., participants’ response to *how often do you play videogames?)* and creativity using the TTCT, and they reported that playing video games is significantly associated with creativity.

Although investigating correlational relationships between video gameplay and creativity may be interesting, this line of research does not directly help educators and practitioners to use video games to foster creativity. First, those existing studies (e.g., Hamlen, 2009; Jackson et al., 2012) are based on the assumption that creativity is a “general” construct, and do not consider the possible interplay with or dependence on domains. Second, these studies do not clearly state how creativity is defined in their study (Plucker, Beghetto, & Dow, 2004). Third, how creativity is assessed in these studies is also problematic. That is, many studies view creativity as a unidimensional cognitive ability (e.g., divergent thinking) by using existing creativity tests (e.g., TTCT) that depend heavily on divergent thinking. Finally, these studies did not systematically review *how* specific aspects of creativity can be manifested in video games.

To support creativity using video games in the broader education community, we need to understand the affordances of video games in relation to the multidimensional aspects of creativity. That is, the first question we should ask is: What are some of the cognitive and noncognitive dimensions of creativity that are manifested in video games? In addition, attention needs to be paid to assessment methods that use creative behaviors and products that players create in and outside of video games (Plucker & Makel, 2010). Such behaviors and products are believed to be more valid indicators of creativity than commonly used self-report measures of creativity (McClelland, 1973; Shute, Ventura, & Kim, 2013).

The purpose of this chapter is twofold. First, we review the current literature of creativity and link the literature with the mechanics and features of popular games that foster players' creative endeavors, both inside (little "g") and outside (big "G") of games (Gee, 2003, 2008). Second, we describe a methodology called stealth assessment as a way to assess creativity in the context of games using examples from *Physics Playground* (Shute & Ventura, 2013).

Review of the Creativity and Games Literature

Multiple Dimensions of Creativity

According to Taylor (1988), there are more than 60 definitions of creativity, and there have been countless arguments over the accepted definition of creativity among psychologists (Amabile, 1983). Despite this lack of agreement, there are some common notions of creativity that run through the literature on creativity. First, creativity is generally defined as the ability to produce solutions or ideas that are both novel and effective (Lubart, 1994). Kaufman and Sternberg (2007) similarly have noted that most definitions of creativity consist of three components: novelty, quality, and relevance. That is, creative solutions are novel, of high quality, and appropriate to the given task, or some variant of the task.

Second, the majority of research on creativity (e.g., confluence approaches) suggests that there are multiple variables that need to converge for creativity to manifest (Amabile, 1983, 1996; Csikszentmihalyi, 1988; Sternberg & Lubart, 1992a, 1992b, 1996). For instance, Amabile (1983) emphasized the importance of social and environmental influences on creativity. She noted that creativity is best conceptualized not as a personality trait or a general ability, but instead as a *behavior* resulting from particular collections of personal characteristics, cognitive abilities, and social environments. Similarly, Sternberg and Lubart (1992b) explained that the different approaches to creativity can be viewed as a continuum between "less" contextualized approaches that focus on personal characteristics, and "more" contextualized approaches that include social-cultural variables that influence individuals' creativity. McCrae (1987) stressed that the ability to think creatively in conjunction with an inclination to do so (i.e., disposition) leads to creative productions.

Among these factors that contribute to creativity, Guilford (1956) conceptualized creativity as involving four facets of divergent thinking— *flexibility* (the ability to produce ideas from various categories or classes), *fluency* (the ability to rapidly produce a large number of ideas), *originality* (the ability to produce ideas that are unique, novel, and uncommon), and *elaboration* (the ability to develop the details of an idea and carry it out). Flexibility has been recognized as an essential cognitive skill for creativity (Amabile, 1983) and is defined as the ability to generate a varied pool of ideas by switching among categories and using remote associations (Nijstad, De Dreu, Rietzschel, & Baas, 2010).

Openness to experience, one of the dimensions of the Big-Five factors, refers to a dispositional attribute that is characterized by an awareness of personal feelings and beliefs, receptivity to novel ideas, liberal values, intellectual curiosity, and fantasy (Berzonsky & Sullivan, 1992). Therefore, individuals with higher degrees of openness to experience are described as imaginative, sensitive to aesthetics, curious, independent thinkers, and/or amenable to new ideas, experiences, and unconventional views (Costa & McCrae, 1992). A long line of research has supported the strong association between openness to experience and creativity or some aspects of creativity (Costa & McCrae, 1992; McCrae, 1987). For example, McCrae (1987) reported a significant association ($r = .4$) between divergent thinking and openness to experience.

Willingness to take risks (i.e., risk propensity) can be defined as the extent to which an individual takes an action knowing there is uncertainty related to the potential pay-off of the action (Dewett, 2007). Risk-taking is associated with openness to change and new ideas (Madjar, Greenberg, & Chen, 2011) and willingness to take risks (and knowing the possibility of failing) has been recognized as an essential trait of eminent scientists and artists throughout history (Csikszentmihalyi, 1997; Sternberg & Lubart, 1996). Sternberg and Lubart (1992b) describe creative individuals as those who “buy low and sell high.” That is, creative individuals can come up with undervalued ideas at the moment, because they are very different from widely accepted ideas, but which, in fact, have great potential. Sternberg and Lubart (1992b) further argue that willingness to take risks is a prerequisite for growth and creativity because one needs to go beyond what is commonly accepted, and learn from various failings. Several studies have reported a positive association between willingness to take risks and creativity (Glover, 1977;

Glover & Sautter, 1977). For example, Glover and Sautter (1977) reported that willingness to take risks was significantly correlated with flexibility and originality. Willingness to take risks has also been studied in the context of organizational innovations for many years (e.g., Dewett, 2007; Kogan & Wallach, 1964; MacCrimmon & Wehrung, 1990). For example, Madjar et al. (2011) found that willingness to take risks is a significant contributor to individuals' creativity and innovation.

Developmental View of Creativity

In line with the view on the multidimensionality of creativity, the literature of creativity also emphasizes the importance of understanding developmental trajectories of creativity (Feldman, 1999). The developmental view of creativity is especially relevant for the education community as different levels of creativity may provide the basis for supporting students' *learning* of creativity in the classroom (Beghetto & Kaufman, 2007).

Gardener (1993) distinguished everyday creative activities by non-experts (i.e., little-c) from groundbreaking creative achievements by eminent scientists and geniuses (i.e., Big-C) in his study of seven renowned individuals, such as Albert Einstein. The recent model developed by Beghetto and Kaufman (Beghetto & Kaufman, 2007; Kaufman & Beghetto, 2009, 2013) further expands this distinction by including mini-c and pro-C, and proposed four levels of creativity—mini-c, little-c, Pro-C, and Big-C. Mini-c is defined as "*the novel and personally meaningful interpretation of experiences, actions, and events*" (Beghetto & Kaufman, 2007, p. 73). The mini-c idea is based on the dynamic and socio-cultural conception of creativity that everybody has creative potential that begins with an "internalization or appropriation of cultural tools and social interactions" (Moran & John-Steiner, 2003, p. 63). Pro-C, located between little-c and Big-C, represents effortful progression toward Big-C, and people who have expertise in creative domains fall into this category. One of the unique contributions of the Four C Model is that it allows us to think about how we can measure creativity beyond existing creativity assessment techniques.

Sources of Evidence for Creativity in Video Games

The current literature of creativity generally suggests that (a) creativity can be judged by the output of creative processes that is characterized by both novelty and relevance; (b) the creative process represents a confluence of factors including personality traits, attitudes, cognitive abilities, knowledge, and the environment, and (c) creativity is a socio-cultural developmental process that can be assessed at multiple levels. To support and assess people's creativity development in video games, therefore, one needs to consider those three aspects of creativity in relation to different sources of evidence that video games can afford.

As Gee (2003, 2008) convincingly argues, playing video games is a semiotic domain—an area or set of activities where people think, act, and hold particular values in certain ways. Similarly, to become creative in a semiotic domain, one first needs to learn how others behave or what are valued in the domain, and then later need to "buy low sell high" with their own unique contribution (Sternberg & Lubart, 1992a). Gee further differentiates little "g"—a game itself as software, from big "G"—a game and social interactions that take place outside of the game (e.g., online communities centered on the particular game). We propose that we should consider both sources of evidence (i.e., little "g" and Big "G") and levels of creativity development to support and assess creativity in and outside of video games (Figure 1).

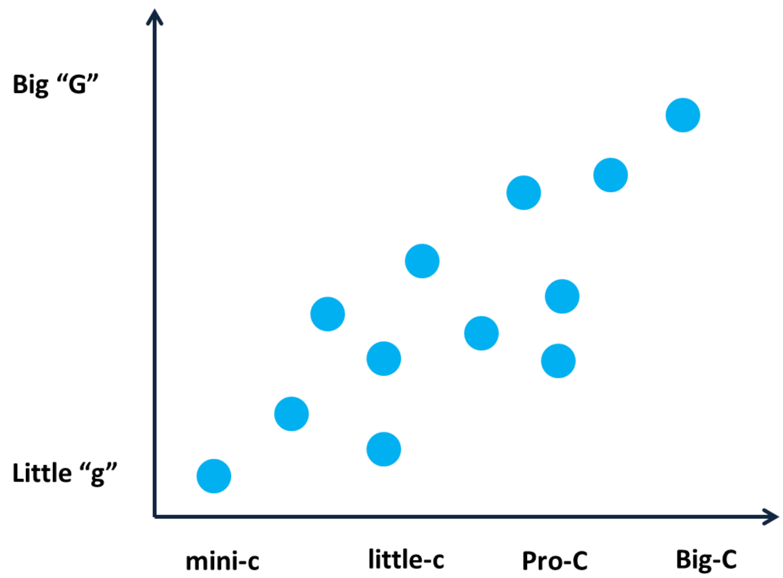


Figure 1. Two-dimensional approach to creativity assessment in games

Each blue dot in Figure 1 represents a unique source of evidence in the continuum of little "g" and Big "G". First, not all games can afford Big "G" as the majority of games remain close to the level of little "g" (e.g., *Candy Crush Saga*). Those games can be considered only for mini-c or little-c in a specific context (e.g., within particular levels). Games that are both at the levels of little "g" and Big "G" can provide a whole range of sources of evidence. For example, *LittleBigPlanet* (LBP) is a puzzle platform game in which the core game mechanic is to navigate the player's character, *Sackboy*, through multiple levels by avoiding hazards (e.g., spikes and fire) and enemies and earning as many score bubbles and item bubbles as possible without losing the character's life. This game offers three modes of gameplay: play, create, and share (Rafalow & Salen, 2014). As the game emphasizes user-generated content, players can earn extra items (by popping item bubbles) in the play mode that they can use later in the create mode. Therefore, LBP works as a semiotic domain in which players progress from mini-c within the game to little-c or Pro-C outside of the game as they further develop expertise.

Here is an illustration of how LBP can provide evidence for different levels of creativity. When a player initially starts playing the game, she only can manage to unlock levels using rather typical solutions. Later she can come up with very unusual solutions. Such behaviors (as they are still personal interpretations) can be considered as evidence of “mini c” in the little “g.” As the player becomes more fluent with the game, she can take screen captures of her creative solutions, and then post them on one of the many online communities related to the game (i.e., little “c” in the Big “G”). Furthermore, after months (or even years) of participating in the online community, she can develop advanced skills to produce creative and elaborate media art pieces around the game, and can become a well-known figure in the LBP community (i.e., Pro-C in the context of Big-G). In their ethnographic study of an LBP online community, for example, Rafalow and Salen (2014) described a user named “Sackdude” in the community who became a well-known figure as he had demonstrated high levels of technical skill and creativity required to create complex and interesting levels that are valued by the members of the LBP community.

Another game that can be considered using this framework is *Portal 2*. Portal 2 is a popular linear, first-person puzzle-platform video game developed and published by Valve Corporation. Players take a first-person role in the game and explore and interact with the environment. The goal of Portal 2 is to get to an exit door by using a series of tools. The primary game mechanic in Portal 2 is the portal gun, which is a device that can create inter-spatial portals between two flat planes. Puzzles must be solved by teleporting the player’s character and various objects using the portal gun. To solve the progressively more difficult challenges, players must figure out how to locate, obtain, and then combine various objects effectively to open doors and navigate through the environment to get to the exit door. In addition to resources in the game that can help in the quest, there are also various dangers to avoid-such as turrets (which shoot deadly lasers), and acid pools. All of these game elements can help (or hinder) the player from reaching the exit. As each level has one "correct" way of solving it, players don't have much freedom to be creative within levels. However, as players become more proficient with the game, they can create levels using the Puzzle Creator and further explore an online community called Steam Workshop in which they can share their levels or play other players' levels (i.e., Pro-C in the context of Big-G).

Creativity Assessment in Physics Playground

In the previous section, we reviewed the multidimensional aspects of creativity that can be cultivated inside and outside of video games. We further suggested that creativity should be assessed in the context of video games considering two dimensions: sources of evidence (i.e., little-g and Big-G) and levels of creativity development (i.e., mini-c to Big-C). In the following sections, we describe a methodology called stealth assessment and demonstrate how we designed creativity assessment in a game called Physics Playground.

Stealth Assessment

Stealth assessment refers to an approach that weaves assessments directly and invisibly into the fabric of any complex learning environment, particularly digital games (Shute, 2011; Shute, Ventura, Bauer, & Zapata-Rivera, 2009). During gameplay, players naturally produce rich sequences of actions as the products of continuous interactions with complex tasks. In stealth assessment, evidence needed to assess targeted skills is thus provided by the players' interactions with the game itself (i.e., the processes of play). 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 an activity—the norm in educational environments. Stealth assessment may be used to support learning and maintain flow, defined as a state of optimal experience, where a person is so engaged in the activity at hand that self-consciousness disappears, sense of time is lost, and the person engages in complex, goal-directed activity not for external rewards, but simply for the exhilaration of doing (Csikszentmihalyi, 1997).

New developments in psychometric techniques and cognitive theories have enabled the development of stealth assessment—emphasizing the nature of educational assessment as an evidentiary argument. The core element of stealth assessment is Evidence-Centered Design (Mislevy, Steinberg, & Almond, 2003). Evidence-centered design (ECD) is an assessment design framework that formalizes assessment arguments relative to claims about the learner and the evidence that supports those claims. ECD is flexible enough to reduce constraints of conventional assessment, and allows using continuous performances in complex and interactive environments. An overview of the ECD approach is described next.

ECD Models

The primary purpose of an assessment is to collect information that will enable the assessor to make inferences about students' competency states—what they know, believe, and can do, and to what degree. Accurate inferences of competency states support instructional decisions that can promote learning. ECD defines a framework that consists of three main models that work in concert.

The ECD framework allows/requires an assessor to: (a) define the claims to be made about students' competencies, (b) establish what constitutes valid evidence of the claim, and (c) determine the nature and form of tasks that will elicit that evidence. These three actions map directly onto the three main models of ECD shown in Figure 2.

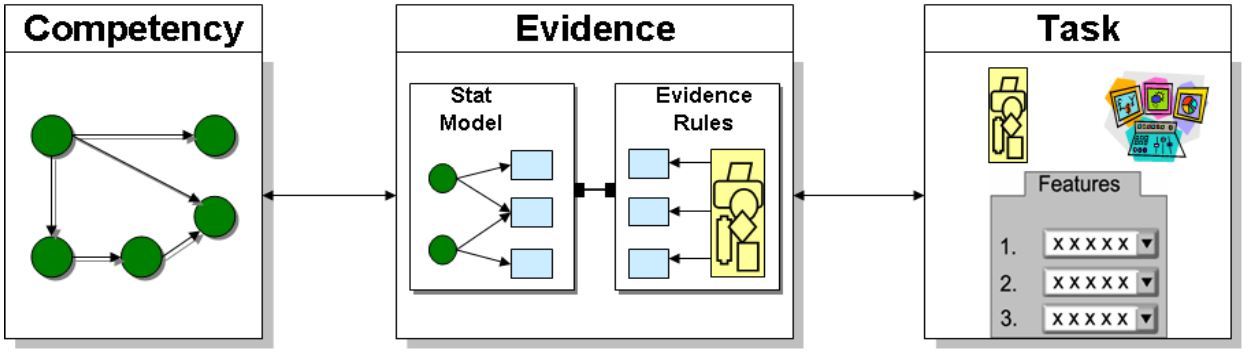


Figure 2. Three main models of an evidence-centered assessment design (adapted from Mislevy, Almond, & Lukas, 2003)

A good assessment has to elicit behavior that bears evidence about key competencies, and it must also provide principled interpretations of that evidence in terms that suit the purpose of the assessment. Working out these variables, models, and their interrelationships is a way to answer a series of questions posed by Messick (1994) that get at the very heart of assessment design:

- What collection of knowledge, skills, and other attributes should be assessed? (Competency Model). This can also be phrased as: What do you want to say about the person at the end of the assessment? Variables in the competency model (CM) are usually called "nodes" and describe the set of person variables on which inferences are to be based. The term "student model" is used to denote a student-instantiated version of the CM—like a profile or report card, only at a more refined grain size. Values in the student model express the assessor's current belief about a student's level on each variable within the CM.
- What behaviors or performances should reveal those constructs? (Evidence Model). An evidence model expresses how the student's interactions with, and responses to a given problem constitute evidence about competency model variables. The evidence model (EM) attempts to answer two questions: (a) What behaviors or performances reveal

targeted competencies; and (b) What's the connection between those behaviors and the CM variable(s)? Basically, an evidence model lays out the argument about why and how the observations in a given task situation (i.e., student performance data) constitute evidence about CM variables.

- What tasks should elicit those behaviors that comprise the evidence? (Task Model). A task model (TM) provides a framework for characterizing and constructing situations with which a student will interact to provide evidence about targeted aspects of knowledge or skill related to competencies. These situations are described in terms of: (a) the presentation format (e.g., directions, stimuli), (b) the specific work or response products (e.g., answers, work samples), and (c) other variables used to describe key features of tasks (e.g., knowledge type, difficulty level). Thus, task specifications establish what the student will be asked to do, what kinds of responses are permitted, what types of formats are available, and other considerations, such as whether the student will be timed, allowed to use tools (e.g., calculators, dictionaries), and so forth. Multiple task models can be employed in a given assessment. Tasks are the most obvious part of an assessment, and their main purpose is to elicit evidence (which is observable) about competencies (which are unobservable).

In short, the ECD approach provides a framework for developing assessment tasks that are explicitly linked to claims about student competencies via an evidentiary chain (e.g., valid arguments that serve to connect task performance to competency estimates), and are thus valid for their intended purposes.

Stealth Assessment of Creativity in Physics Playground

Physics Playground (PP) is a computer-based game designed to assess and support students' nonverbal understanding of physics principles, commonly referred to as qualitative or conceptual physics. 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 how the physical world operates and how physical objects interact.

PP is characterized by an implicit representation of Newton's three laws of motion including concepts such as balance, mass, gravity, and conservation of energy and momentum (Shute, Ventura, & Kim, 2013). These physics principles are operationalized by the use of simple machine-like devices called *agents of force and motion* including ramps, levers, pendulums, and springboards to move a green ball to the red balloon on the screen.

Many of the levels in PP can be solved by various solutions, using more than one agent. Thus PP allows players to be creative and produce interesting mechanical devices that the designers of the game did not expect. Furthermore, players often attempt multiple times to achieve the "awesomest" solution. To assess these creative behaviors in the game, we identified three creativity competency model variables—fluency, flexibility, and originality, and identified in-game observables that provide evidence for those variables (i.e., evidence model variables). Table 1 summarizes the creativity competency and evidence model variables in PP.

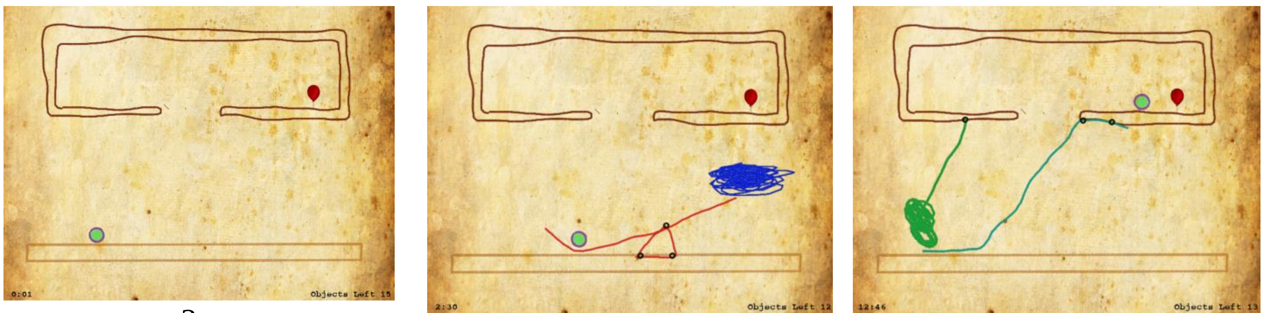
Table 1.
Competency and Evidence Model Variables for Creativity Assessment in PP

CM variables	EM variables
Fluency	Number of agents used in a problem Number of drawn objects per solved problem Number of drawn objects per unsolved problem
Flexibility	Number of correct agents attempted in the problem Standard deviation among frequencies of agent use [per session] [R] Consecutive use of incorrect agent [R]
Originality	Difference between ball trajectory in a solution from the expected trajectory

*R indicates negative evidence

Here is an illustration of how these variables work to assess players' creativity in the context of PP. Figure 3a is how a level called *Attic* looks when the level starts. The most common solution among PP players (and expected by the designers) involved drawing and using a lever to propel the ball to the balloon (shown in Figure 3b). Any trajectory of the ball that deviates from the trajectory shown in Figure 3b can provide evidence for originality as it is very likely to be a rare (thus unique) solution. Only a few players (out of 100s) created solutions similar to Figure 3c using both a pendulum (to add force to the ball) and a ramp (to guide the ball to the balloon). Such a solution provides positive evidence for both fluency and originality in PP. That is, while most players used only one agent (e.g., lever), this solution requires two agents, providing evidence for *fluency—Number of agents used in a problem*. Moreover, as the trajectory of the ball in this solution deviates from the common solution, it provides evidence for *originality—Difference between ball trajectory in a solution from the expected trajectory*.

These indicators, as evidence of little-c in the context of little-g, can be identified and scored during gameplay. For example, in PP, the game engine tracks the trajectories of the players' ball in a successful solution (i.e., the set of X, Y coordinates), and saves them out as series of vector values in the log file. Those vector values are then can be compared to the most common trajectory, and large differences between trajectories are thus evidence for originality.

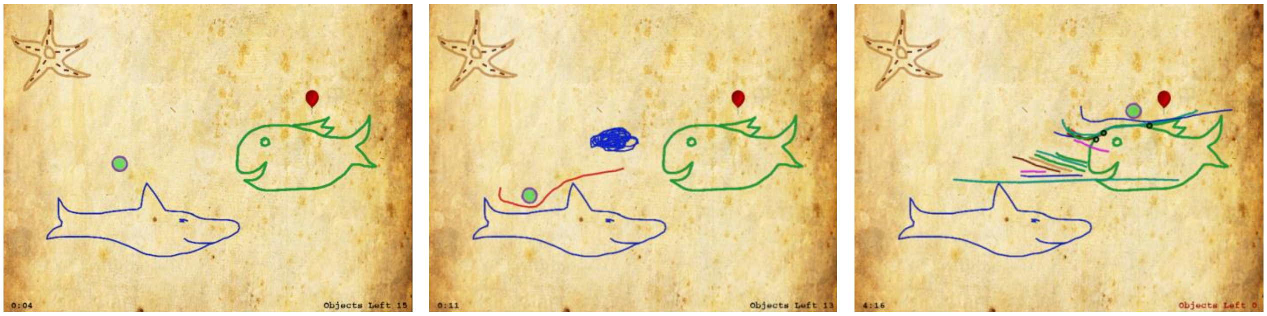


3a. 3b. 3c.

Figure 3. The Attic level and two possible solutions

Establishing these evidence model variables (i.e., in-game indicators) and scoring rules to decide *when* those indicators provide evidence for creativity can be tricky depending on the nature of a given level or game. Furthermore, as "gaming the system" is not always viewed negatively in the gaming context, differentiating creative solutions from solutions that exploit the features of the game is critical (Kuecklich, 2004). As the very definition of creativity emphasizes both *novelty* and *relevance,* therefore, in-game behaviors that are not appropriate in terms of the rules and mechanics of the game should not be considered as evidence for creativity.

For instance, Figure 4a is a level called *Shark.* As the level starts, the ball lands on top of the blue shark on the left of the screen, and players are expected to create a lever (as shown in Figure 4b) and drop a weight, to move the ball to the balloon. Some of the players, however, figured out that if they quickly draw lines under the ball to stop it from falling on the shark, they can solve this level without using agents of motion (shown in Figure 4c). Although the trajectory of the ball shown in Figure 4c deviates from the one in Figure 4b, such a solution does not provide evidence for *originality* as this solution violates the rules of the game.



4a. 4b. 4c.

Figure 4. The Shark level and two possible solutions

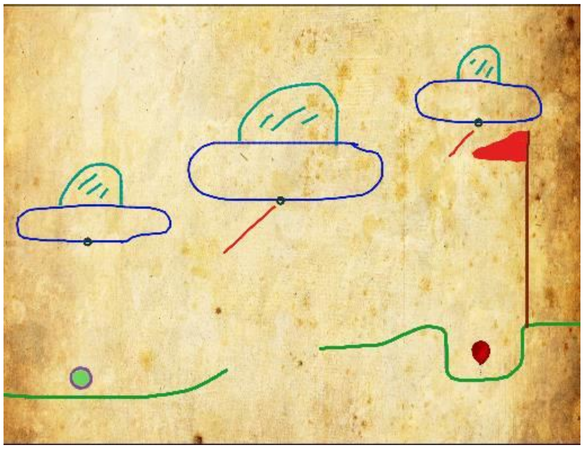
The examples above show how we identified evidence for “little c” in the “little g” of PP. That is, such assessment uses in-game behaviors specific to the levels of the game. Another source of evidence for creativity that we identified in PP is the levels created by players. We should note that, although using user-created levels for creativity assessment is not completely “stealth” as it requires holistic scoring by human-raters, it can be considered as assessment of “little c” or even “Pro C” in the “Big G.”

To use user-created levels for creativity assessment, we identified features of levels that are aligned with the dimensions of creativity. Table 2 describes relevant creativity dimensions and specific scoring rules used to make holistic judgment about user-created levels.

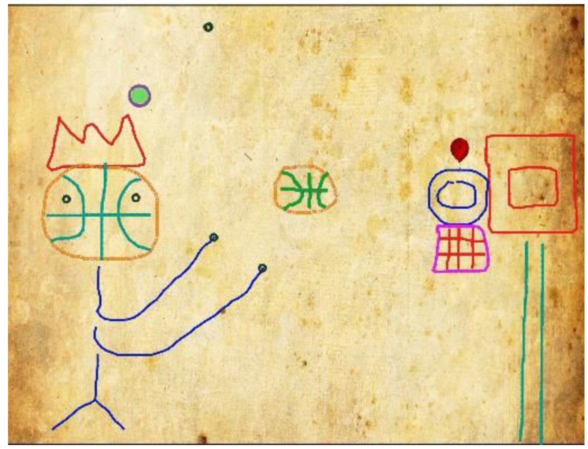
Table 2.
Scoring Rubrics for Player-Created Levels in Physics Playground

Categories	Scoring rules
Relevance	*Can it be solved?* (This is a screening criteria) ○ If unsolvable, then don't score other variables → assign 0 ○ If solvable? → assign 1
Elaboration	*How difficult is it?* (Possible scores: 0, 1, 2, 3, and 4) ○ Balloon is located above ball ○ Any agent other than ramp is required ○ Obstacles to remove/avoid are present ○ Ball is falling out of the problem space
Originality	*Is it original relative to existing problems?* (Possible scores: 0, 1, and 2) ○ Almost identical → assign 0 ○ Has some similarities → assign 1 ○ Very dissimilar → assign 2
Aesthetics	*Is it aesthetically pleasing?* (Possible scores: 0, 1, and 2) ○ Aesthetically unappealing with poor visual elements → assign 0 ○ Plain with completed visual elements → assign 1 ○ Very pleasant with well thought-out visual elements → assign 2
Humor	*Is it humorous* (i.e., Does it make you smile)? (Possible scores: 0, 1, and 2) ○ Not humorous at all → assign 0 ○ Somewhat humorous → assign 1 ○ Very humorous → assign 2

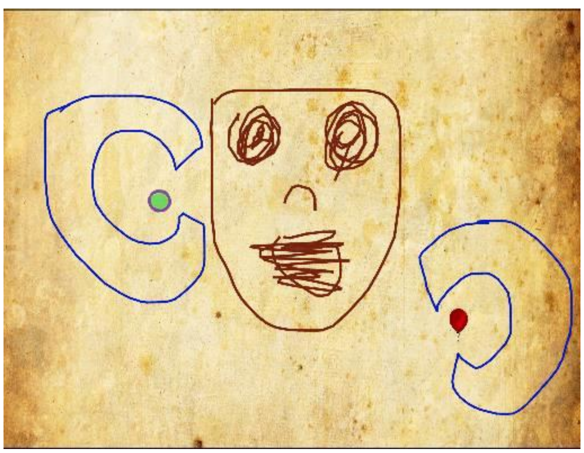
Based on the scoring rules described in Table 2, the maximum creativity score that a level can receive is 11. Figure 5 includes some of the player-created levels and associated scores based on the scoring rules.



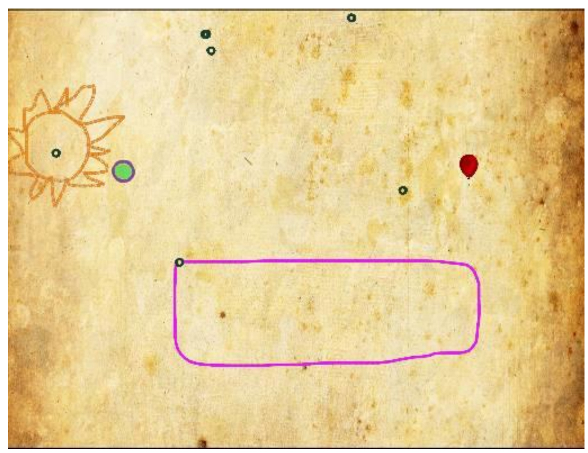
"Derp Invasion" (9/11)



"Hoop City"(8/11)



"Monkey" (0/11)



"Sunny" (3/11)

Figure 5. Examples of player-created levels and associated scores

"Derp Invasion" is judged to be a fairly creative level as it a medium difficulty level (3/4) that is solvable (1/1), very different from the existing levels (2/2), aesthetically pleasing (2/2), and somewhat humorous (1/2). Although "Hoop City" received the same scores for most categories, it scored lower than "Derp Invasion" as it is an easy problem (this can be solved by simply drawing a ramp over the basketball). Although "Monkey" could be a fairly creative level, it scored 0 as it is not solvable (the ball is stuck in the left ear of the monkey, and it is impossible to get it out). “Sunny” scored 0 at the originality category as there is a level called “Sunny” in the game and looks the same as well.

Discussion

Playing video games has become a customary and important part of everyday life for today’s youth, and the broader education community has been exploring affordances of video games to support various competencies that are valuable for success in the 21st Century. In this chapter, we discussed how video games can support creativity development both inside and outside of video games, and described our approach to assess creativity in Physics Playground. We based our discussions on the current literature which views creativity as multidimensional and developmental.

To optimize affordances of video games for creativity development and assessment, there are several challenges that the community of creativity researchers need to address. First, we first need to rethink how we operationalize and validate assessment. As the creativity manifested around a game is considered to be specific to the domain (or the game), the conventional way of validating new assessments is by investigating correlations with existing measures, but that may not be the most reasonable method for creativity assessment in video games. Second, game, instructional, and assessment designers need to further investigate and establish particular design principles that are conducive to cultivating creativity.

Finally, well-designed games are challenging yet highly engaging. Such games often inspire players’ imagination beyond the game, which provides opportunities to support all levels of creativity. Gamers actively seek out interesting and difficult problems, and strive for not just a solution, but the awesomest one. Thus we need to further explore ways to foster players’ creativity as an essential aspect of gameplay, which can lead to creative behaviors in other areas. We additionally propose that games can be used to assess different levels of creativity, and educators and game designers should consider assessment design methods such as stealth assessment and ECD to identify sources of evidence for creativity inside and outside of games.

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References

Amabile, T. M. (1983). The social psychology of creativity: A componential conceptualization. *Journal of Personality and Social Psychology, 45*(2), 357–376. doi: 10.1037/0022-3514.45.2.357

Amabile, T. M. (1996). *Creativity in context: Update to "The social psychology of creativity."* Boulder, CO: Westview Press.

Autor, D. H., Levy, F., & Murnane, R. J. (2003). The skill content of recent technological change: An empirical exploration. *The Quarterly Journal of Economics, 118*(4), 1279–1333. doi: 10.1162/003355303322552801

Beghetto, R. A., & Kaufman, J. C. (2007). Toward a broader conception of creativity: A case for" mini-c" creativity. *Psychology of Aesthetics, Creativity, and the Arts, 1*(2), 73–79.

Berzonsky, M. D., & Sullivan, C. (1992). Social-cognitive aspects of identity style. *Journal of Adolescent Research*, *7*(2), 140–155. doi: 10.1177/074355489272002

Bybee, R. W., & Fuchs, B. (2006). Preparing the 21st Century workforce: A new reform in science and technology education. *Journal of Research in Science Teaching, 43*(4), 349–352. doi: 10.1002/tea.20147

Casner-Lotto, J., & Barrington, L. (2006). *Are they really ready to work? Employers' perspectives on the basic knowledge and applied skills of new entrants to the 21st Century US workforce*. New York, NY: The Conference Board. Retrieved from http://www.p21.org/storage/documents/FINAL_REPORT_PDF09-29-06.pdf

Costa Jr, P. T., & McCrae, R. R. (1992). Four ways five factors are basic. *Personality and Individual differences*, *13*(6), 653–665.

Csikszentmihalyi, M. (1988). Society, culture, and person: A systems view of creativity. In R. J. Sternberg (Ed.), *The nature of creativity: Contemporary psychological perspectives* (pp. 325–339). New York, NY: Cambridge University Press.

Csikszentmihalyi, M. (1997). *Creativity: Flow and the psychology of discovery and invention*. New York, NY: Harper perennial.

Dewett, T. (2007). Linking intrinsic motivation, risk taking, and employee creativity in an R&D environment. *R&D Management*, *37*(3), 197–208. doi: 10.1111/j.1467-9310.2007.00469.x

Entertainment Software Association. (2014). *Essential facts about the computer and video game indusry*. Retreived from http://www.theesa.com/facts/pdfs/ESA_EF_2014.pdf

Feldman, D. H. (1999). The development of creativity. In R. J. Sternberg (Ed.), *Handbook of creativity* (pp. 169–186). New York, NY: Cambridge University Press.

Florida, R. L. (2002). *The rise of the creative class: and how it's transforming work, leisure, community and everyday life*. Cambridge, MA: Basic Civitas Books.

Friedman, T. L. (2005). *The world if flat: A brief history of the twenty-first Century*. New York, NY: Farrar, Straus and Giroux.

Gardner, H. (1993). *Creating minds: An anatomy of creativity seen through the lives of Freud, Einstein, Picasso, Stravinsky, Eliot, Graham, and Gandhi*. New York, NY: Basic books.

Gee, J. P. (2003). What video games have to teach us about learning and literacy. *Computers in Entertainment (CIE)-Theoretical and Practical Computer Applications in Entertainment, 1*(1), 20–24.

Gee, J. P. (2005). Good video games and good learning. *Phi Kappa Phi Forum, 85*(2), 33–37. doi: citeulike-article-id:3137216

Gee, J. P. (2008). Learning and games. In K. Salen (Ed.), *The ecology of games: Connecting youth, games, and learning* (pp. 21–40). Cambridge, MA: MIT Press.

Glover, J. A. (1977). Risky shift and creativity. *Social Behavior and Personality: An International Journal, 5*(2), 317–320.

Glover, J. A., & Sautter, F. (1977). Relation of four components of creativity to risk-taking preferences. *Psychological Reports, 41*(1), 227–230.

Guilford, J. P. (1956). The structure of intellect. *Psychological Bulletin, 53*(4), 267–293. doi: 10.1037/h0040755

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

Hargreaves, A. (2003). *Teaching in the knowledge society: Education in the age of insecurity*. New York, NY: Teachers College Press.

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. doi:10.1016/j.chb.2011.10.006

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. doi: 10.1037/a0013688

Kaufman, J. C., & Beghetto, R. A. (2013). Do people recognize the four Cs? Examining layperson conceptions of creativity. *Psychology of Aesthetics, Creativity, and the Arts, 7*(3), 229–236.

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

Kuecklich, J. (2004). *Other playings–cheating in computer games.* Papre presented at the Other Players Conference, Copenhagen, Denmark. Reterived from http://www.computingscience.nl/docs/vakken/vw/literature/03.kuecklich.pdf

Levy, F., & Murnane, R. J. (2004). *The new division of labor: how computers are creating the next job market*. Princeton, NJ: Princeton University Press.

Lubart, T. I. (1994). Creativity. In R. J. Sternberg (Ed.), *Thinking and problem solving* (pp. 289–332). New York, NY: Academic Press.

Madjar, N., Greenberg, E., & Chen, Z. (2011). Factors for radical creativity, incremental creativity, and routine, noncreative performance. *Journal of Applied Psychology*, *96*(4), 730–743. doi: 10.1037/a0022416

McClelland, D. C. (1973). Testing for competence rather than for intelligence. *American Psychologist*, *28*(1), 1–14.

McCrae, R. R. (1987). Creativity, divergent thinking, and openness to experience. *Journal of Personality and Social Psychology, 52*(6), 1258–1265. doi: 10.1037/0022-3514.52.6.1258

Messick, S. (1994). The Interplay of Evidence and Consequences in the Validation of Performance Assessments. *Educational Researcher, 23*(2), 13–23. doi: 10.3102/0013189x023002013

Mislevy, R. J., Almond, R. G., & Lukas, J. F. (2003). *A brief introduction to evidence-centered design* (ETS Research Report RR-03-16). Princeton, NJ: Educational Testing Service. Retreived from http://www.ets.org/Media/Research/pdf/RR-03-16.pdf.

Mislevy, R. J., Steinberg, L. S., & Almond, R. G. (2003). Focus article: On the structure of educational assessments. *Measurement: Interdisciplinary research and perspectives, 1*(1), 3–62.

Moran, S., & John-Steiner, V. (2003). Creativity in the making:Vygotsky's contemporary contribution to the dialectic of development and creativity. In R. K. Sawyer, V. John-Steiner, S. Moran, R. J. Sternberg, D. H. Feldman, & J. Nakamura (Eds.), *Creativity and development* (pp. 61–90). New York, NY: Oxford University Press.

Nijstad, B. A., De Dreu, C. K., Rietzschel, E. F., & Baas, M. (2010). The dual pathway to creativity model: Creative ideation as a function of flexibility and persistence. *European Review of Social Psychology, 21*(1), 34–77.

Partnership for 21st Century Skills. (2007). Beyond the three Rs: Voter attitudes toward 21st Century skills. Retreived from http://www.p21.org/storage/documents/P21_pollreport_singlepg.pdf

Plucker, J. A., Beghetto, R. A., & Dow, G. T. (2004). Why isn't creativity more important to educational psychologists? Potentials, pitfalls, and future directions in creativity research. *Educational Psychologist, 39*(2), 83–96. doi: 10.1207/s15326985ep3902_1

Plucker, J. A., & Makel, M. C. (2010). Assessment of creativity. In J. C. Kaufman & R. J. Sternberg (Eds.), *The Cambridge handbook of creativity* (pp. 48–73). New York, NY: Cambridge University Press.

Rafalow, M. H., & Salen, K. (2014). *Welcome to sackboy planet: Connected learning among LittleBigPlanet 2 players*. Retreived from http://dmlhub.net/publications/welcome-sackboy-planet-connected-learning-among-littlebigplanet-2-players

Resnick, M. (2007). Sowing the seeds for a more creative society. *Learning and Leading with Technology*, *35*(4), 18–22.

Rideout, V. J., Foehr, U. G., & Roberts, D. F. (2010). *Generation M2: Media in the lives of 8-to 18-year-olds*. Retreived from http://kff.org/other/event/generation-m2-media-in-the-lives-of/

Sawyer, R. K. (2006). Educating for innovation. *Thinking Skills and Creativity, 1*(1), 41–48. doi: 10.1016/j.tsc.2005.08.001

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

Shute, V. J., & Kim, Y. J. (2011). Does playing the World of Goo facilitate learning? In D. Y. Dai (Ed.), *Design research on learning and thinking in educational settings: Enhancing intellectual growth and functioning* (pp. 359–387). New York, NY: Routledge Books.

Shute, V. J., & Ventura, M. (2013). *Measuring and supporting learning in games: Stealth assessment*. Cambridge, MA: The MIT Press.

Shute, V. J., Ventura, M., & Kim, Y. J. (2013). Assessment and learning of informal physics in Newton's Playground. *The Journal of Educational Research, 106*(6), 423–430. doi: 10.1080/00220671.2013.832970

Shute, V. J., Ventura, M., Bauer, M., & Zapata-Rivera, D. (2009). Melding the power of serious games and embedded assessment to monitor and foster learning. In U. Ritterfeld, M. J. Cody & P. Vorderer (Eds.), *The Social Science of Serious Games: Theories and Applications.* (pp. 295–321). Philadelphia, PA: Routledge/LEA.

Sternberg, R. J., & Lubart, T. I. (1992a). Creativity: Its nature and assessment. *School Psychology International*, *13*(3), 243–253. doi: 10.1177/0143034392133004

Sternberg, R. J., & Lubart, T. I. (1992b). Buy low and sell high: An investment approach to creativity. *Current Directions in Psychological Science, 1*(1), 1–5.

Sternberg, R. J., & Lubart, T. I. (1996). Investing in creativity. *American Psychologist*, *51*(7), 677–688. doi: 10.1037/0003-066x.51.7.677

Symonds, W. C., Schwartz, R. B., & Ferguson, R. (2011). *Pathways to prosperity: Meeting the challenge of preparing young Americans for the 21st Century*. Cambridge, MA: Harvard Graduate School of Education.

Taylor, C. W. (1988). Various approaches to and definitions of creativity. In R. J. Sternberg (Ed.), *The nature of creativity: Contemporary psychological perspectives* (pp. 99–121). New York, NY: Cambridge University Press.

Wright, W. (2006). Dream machines. *Wired Magazine*, *14*(4), 110–112.