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Seyedahmad Rahimi

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Going Beyond the Brick: Assessing and Supporting Creativity Using AI-Powered Digital Games

Seyedahmad Rahimi 

University of Florida

ABSTRACT

To support creativity, one should first assess it accurately. New techniques such as stealth assessment that use digital environments (e.g. digital games) can be used to assess and support creativity. In this paper, I discuss my passion for creativity and how my academic journey in creativity research started. Then, I discuss key studies and papers I wrote with my colleagues (including my Ph.D. dissertation). Specifically, I discuss the effectiveness of digital games on creativity, the effectiveness of creativity support tools in digital games, and the stealth assessment of creativity in a Physics game. Finally, I conclude with the future directions of my research in these areas and other areas such as the use of Artificial Intelligence (AI) in assessing and supporting creativity.

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Introduction

Throughout history creativity has been one of the crucial drivers that moves human civilizations forward (Hennessey & Amabile, 2010). For instance, the Partnership for 21st Century Learning (2019) included creativity as one of the essential skills for success in modern life. Moreover, the World Economic Forum (Gray, 2016) listed creativity as one of the most crucial skill that people need for success in the fourth industrial revolution. Creativity is important from an individual's perspective (i.e., a creative person can solve their daily problems and have more job opportunities) and a socioeconomic point of view (i.e., enhancing the quality of life in societies through scientific and life-changing discoveries and inventions). Living in an era where Artificial Intelligence (AI) is replacing many human jobs (Resnick, 2018), Instead of getting scared about AI and robots replacing us, we should change the way we think about work. For example, we can let machines do what they are good at (e.g., consistently being accurate at calculations and performing routine jobs) while we focus on what we are good at (e.g., being creative, empathetic, and caring for one another).

When I was in fourth grade, I had a painting teacher who told me "You are creative!" I took his message to my heart. When I was 20 years old, I was working in an advertisement company. I needed to think creatively for a living. I remember that I used to wake up with creative ideas for our projects and I would jot them down at the middle of the night. I was not aware, that I was going

through the creativity process: preparation, incubation, illumination, and verification (Wallas, 1926). Later, when I was getting my Ph.D. at the Florida State University, I was lucky to become familiar with an eminent scientist in the field of learning sciences and assessment, Dr. Valerie Shute. In 2018, Dr. Shute was invited, among other experts such as Dr. James Kaufman, to design a large-scale creativity assessment for the Programme of International Students Assessment (PISA) (PISA 2021 Creativity Assessment, 2021). As Dr. Shute's Ph.D. student, I was also invited to work on that project. Since then, I have been actively conducting research on creativity and will continue this journey wondering where it will take me in the future. Currently, I am an assistant professor of educational technology at the University of Florida. If I want to choose a mission for myself, I will say I am on a mission to design and develop tools that can help people learn better and deeper while they use and enhance their creativity. In this paper, I discuss my key creativity studies and conclude with my future research directions toward the mission I chose for myself. I start with a systematic review about the effects of video games on creativity.

Effects of video games on creativity

One primary question I have been investigating in the past five years, has been about the effects of video games on people's creativity. In a systematic review (Rahimi & Shute, 2021a), we investigate the effectiveness of video

games on creativity. Results showed that there are three main categories of studies when it comes to the effectiveness of video games on creativity: correlational, observational and perception, and experimental and quasi-experimental studies.

Results from the first category, the correlational studies, were mixed. Some studies reported no or negative correlation between playing video games and creativity (e.g., Hamlen, 2009, 2013); while other studies showed positive relationships between playing video games and creativity (e.g., Jackson et al., 2012). The second group of studies includes observational and perception studies where researchers selected some video games that they thought have high potential to improve people's creativity and observed how people interact with those games (e.g., Cipollone, Schifter, & Moffat, 2014; Hewett, 2016). These observational and perception studies provided some positive evidence in that regard. While the observational studies were heading to the right direction (i.e., investigating the high-potential video games), they still lacked the rigor needed to answer the effectiveness question: are video games effective in improving people's creativity. The third category of studies, experimental and quasi-experimental studies, compared various high-potential video games with other video games (e.g., *Minecraft*, *Portal 2*, *SimCity*) or control conditions (e.g., Blanco-Herrera, Gentile, & Rokkum, 2019; Checa-Romero & Gómez, 2018; Moffat, Crombie, & Shabalina, 2017). The findings of the studies in this category showed that some, not all, game genres such as sandbox games (e.g., *Minecraft*), puzzle games (e.g., *Portal 2*), and strategy games (e.g., *SimCity*) were shown to be suitable for supporting creativity.

This systematic review that we conducted revealed a gap: the games that have a high potential for improving creativity do not have a clear support system for creativity. Next, I discuss a study (my dissertation) that aimed to address this gap.

First inspire, then instruct to support students' creativity

According to Shneiderman (2007), enhancing people's creativity can be achieved by creating digital environments, such as digital games, that offer a range of supportive elements functioning as a cohesive system. These elements work together to boost human creativity. For example, Shneiderman proposes the use of inspirational supports (like showcasing examples of previous creative work) and instructional supports (such as providing step-by-step instructions for each stage of a creative pursuit) to improve humans' creativity. Through an experimental study (Rahimi, 2020; Rahimi & Shute, 2021b) with four conditions, I examined the effects of these two creative support systems (i.e., inspirational and instructional) on college students' creativity while creating game levels in *Physics Playground* (Shute, Almond, & Rahimi, 2019). *Physics Playground* is a 2-dimensional game (Figure 1) primarily for teaching Newtonian physics to 8th and 9th grade students. Players should target a red balloon using a green ball by drawing simple physics machines (i.e., lever, ramp, pendulum, and springboard).

Other than the gameplay mode, *Physics Playground* has a create mode (called level editor; Figure 2) where non-technical users can create game levels without the need to write any computer code. In this study, I focused on the level editor, developed a creativity assessment of student-made levels, and investigated two research questions – I focus on the second research question in the paper: *are the creativity-supports effective in improving college students' creativity? If they are effective, which creativity-support system is the most effective one?*

Using a pretest-posttest, experimental research design with four conditions, I recruited 114 college students from various ethnicities and colleges and

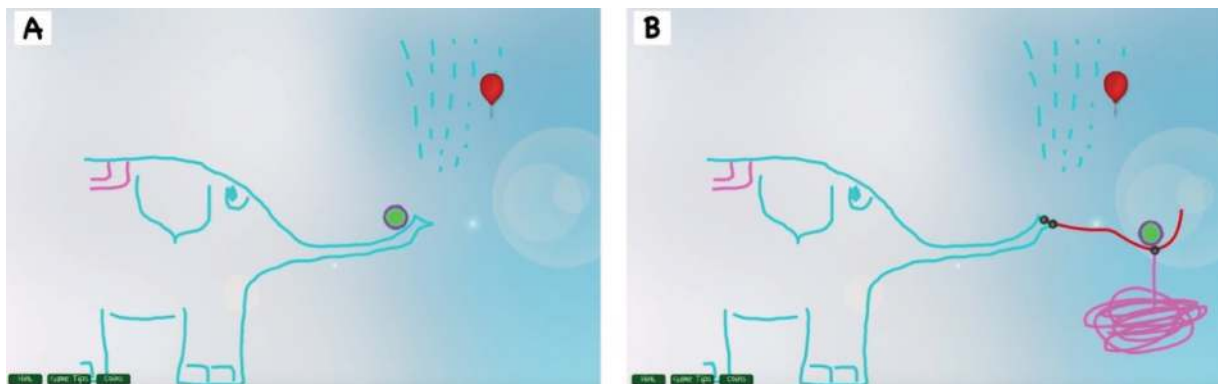


Figure 1. Trunk slide level in physics playground.



Figure 2. The modified version of PP's level editor for this study.

randomly assigned them into four conditions to create game levels: (1) *Inspirational* where the students created game levels only with inspiration supports (i.e., a website with example game levels, six randomly selected words that could spark ideas each time students wanted to start creating a new level, and a brainstorming spreadsheet); (2) *Instructional* where the students were instructed to design game levels in three steps: design as many levels as you can without paying attention to details; chose four of those levels, enhance and elaborate those four levels; (3) *Both* where the students designed game levels using both inspirational and instructional supports; and (4) *Control* where the student designed game levels with no creativity supports.

To externally assess students' creativity, two isomorphic tests of creativity were created: (1) *verbal*: Alternative Uses test (Wallach & Kogan, 1965); (2) *figural*: inspired by the Torrance Test of Creative Thinking (TTCT; Torrance, 1977), I created two items (e.g., complete empty shapes and used three ordinary shapes and create a meaningful object/story). The two test forms were counterbalanced for the pretest and the posttest to count for the order effect. Each test item was scored for fluency, flexibility, originality, and elaboration. I used the congenital assessment of creativity (Amabile, 1982) to assess student-made levels' creativity (the four scores were averaged) (see Rahimi, 2020 for the full description of the scoring process).

Results showed that students in the four conditions did not show a significant difference on any of the external assessments of creativity. However, the only significant

difference among the four conditions was for figural flexibility. Examining the effects of the creativity supports on the creativity of the game levels created by the students showed an overall significant effect of the condition controlling for the overall figural creativity score as a covariate. Students in the Inspirational condition designed significantly more creative levels than students in the Instructional condition and the No Supports condition controlling for their pretest overall figural creativity. There was no significant difference between the Both and Inspirational conditions. Similarly, there was no significant difference between the creativity scores of the four most creative levels of the Instructional condition and the No Supports condition. Overall, the results from the in-game measure of creativity indicate that most of the creativity shown in students' game levels come from the inspirational supports. Moreover, Students in the Instructional condition created significantly more levels than students in the Inspirational condition controlling for their pretest figural fluency.

In sum, with cautious in generalizing the results, in similar environments it may be better to first inspire and then instruct to enhance people's creativity rather than providing one of the supports or no supports. The main reasons for the effectiveness of the Both condition may include (1) more chance for practice being creative Creativity, like a muscle, can be trained, exercised, and strengthened by practice (Richards, 2010); (2) familiarity with the possibilities and going beyond them by having access to example levels. Theories of creativity have pointed out that to be creative, one must know what has been done to be able to go beyond it (Csikszentmihalyi, 1997); (3)

reduced cognitive load because of the instructional supports – cognitive load is detrimental to creativity (Shneiderman, 2007); and (4) boost in students' affective state. According to Amabile's (Amabile, 1982) research, progress can positively affect their affective state, which likely led to more creativity. Lack of all or some of these reasons could have led to the other conditions' ineffectiveness. Next, I discuss a study that used stealth assessment to objectively assess students' creativity without human judgment.

Stealth assessment of creativity in physics playground

Stealth assessment (Shute, 2011) uses technology-rich environments (e.g., digital games, virtual reality, or other digital simulations) as vehicles for assessing and fostering learner's various competencies (*unobservables*). As shown in Figure 3, as learners play or interact with the digital learning environment (e.g., a digital game), the system continuously captures interaction data in logfiles. Then, the stealth assessment system identifies data that show evidence for the learner's competencies (*observables*). A statistical modeling approach then

accumulates the evidence in real-time into a learner model. The evidence accumulation process can be accomplished by using a simple count of observable frequencies, or by more sophisticated statistical modeling, e.g., Bayesian network modeling.

Stealth assessment uses the evidence-centered design framework of assessment (ECD; Almond, Steinberg, & Mislevy, 2002). ECD includes four core models (Figure 4): (1) the *Competency Model* (CM) which defines the competency of interest and its sub-facets (*unobservables*), their relationships to each other; (2) the *Evidence Model* (EM) which identifies appropriate indicators (*observables*) in the game (i.e., establishing the rules of evidence) that provide evidence for the CM variables via statistical linkages (i.e., the statistical model); (3) the *Task Model* (TM) involves the creation of various task types that can elicit the evidence needed for the evidence model; and (4) the *Assembly Model* (AM) which allows researchers to arrange various tasks together with various difficulty levels, sufficient per competency.

We used stealth assessment to assess creativity in *Physics Playground* (to see a full report on this study please see Shute & Rahimi, 2021). In this study, we asked four research questions – I focus on the validity question

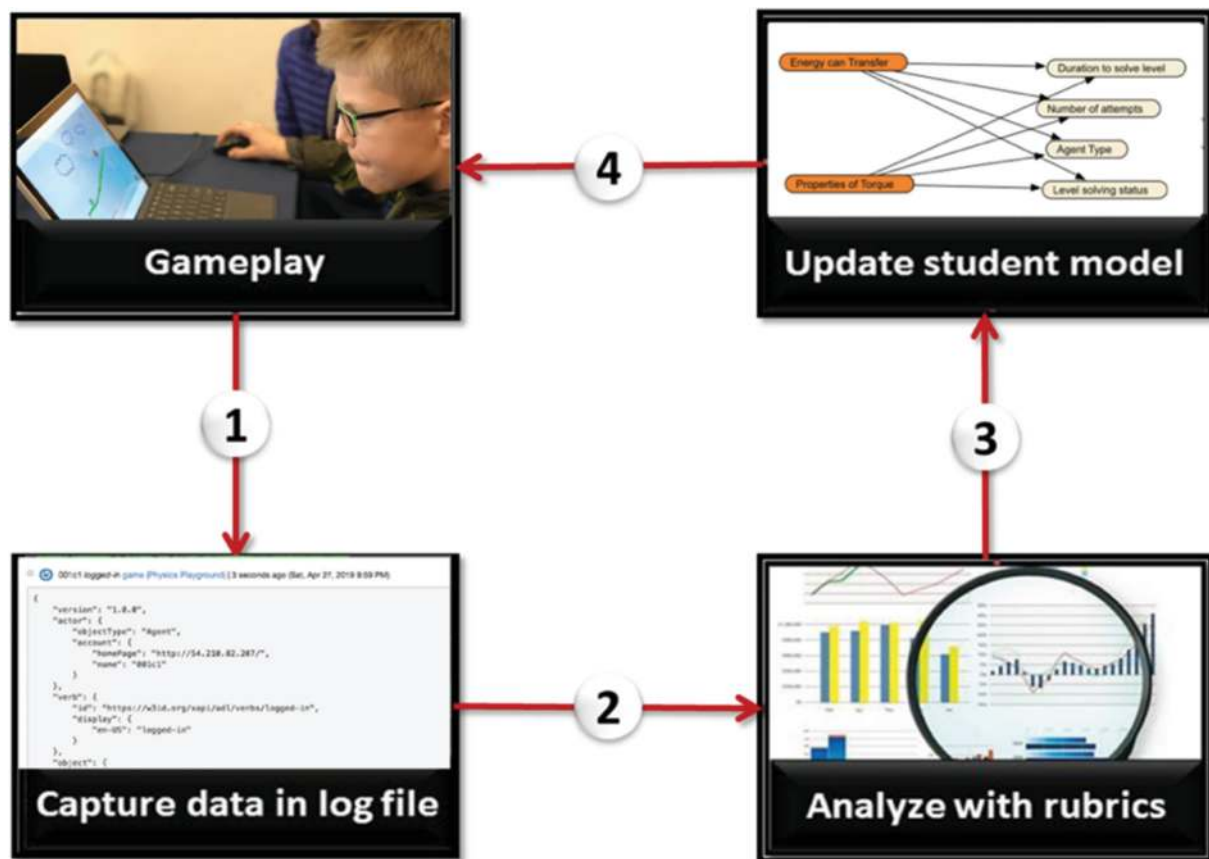


Figure 3. Stealth assessment process.

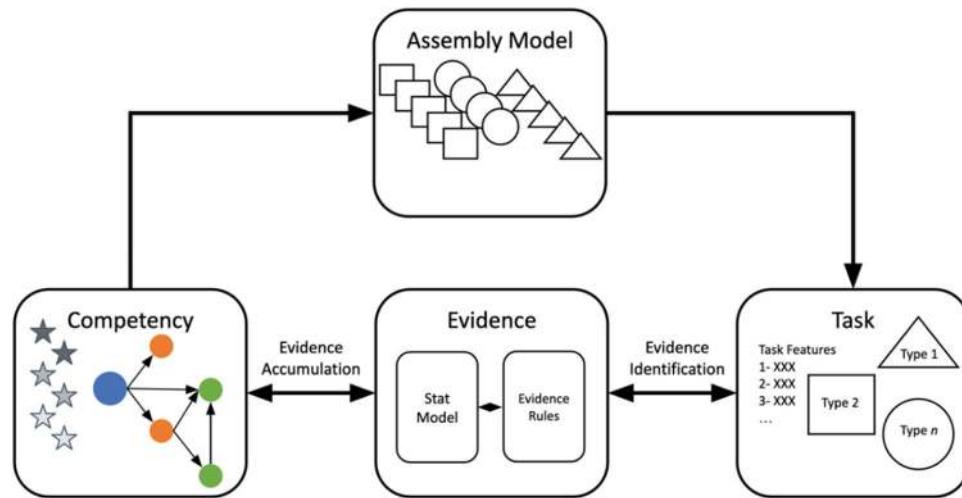


Figure 4. ECD models.

in this paper: *Is our stealth assessment estimate of creativity valid* (i.e., does the stealth assessment estimates of students' creativity correlate with the external measures of creativity)? First, we conducted a literature review to define our competency model of creativity in the context of *PP*. In this study, we included fluency, flexibility, and originality as the sub-facets of gameplay creativity, shown in Figure 5. We also identified appropriate EM variables (i.e., observables) as indicators in *Physics Playground* per sub-facet.

After establishing the relevant observables for each of the three facets of creativity, we created a Bayesian network (BN) to estimate students' creativity in *Physics Playground* (see Figure 6). The BN automatically calculates the low, medium, and high probability estimates

for fluency, flexibility, originality, and finally for overall creativity, per student.

We found significant correlations between our stealth assessment of creativity and the Alternative Uses test showing evidence for the convergent validity of this assessment. In fact, such validation studies should be carried out before using the stealth assessment estimates for real-time changes to the game environment. Using stealth assessment estimates to improve learners' creativity in real-time is one of the future directions I am taking our research (see Rafner et al., 2021 for a systematic review on the use of game-based environments with stealth assessment to assess creativity). Next, I discuss the future directions of my research related to creativity.

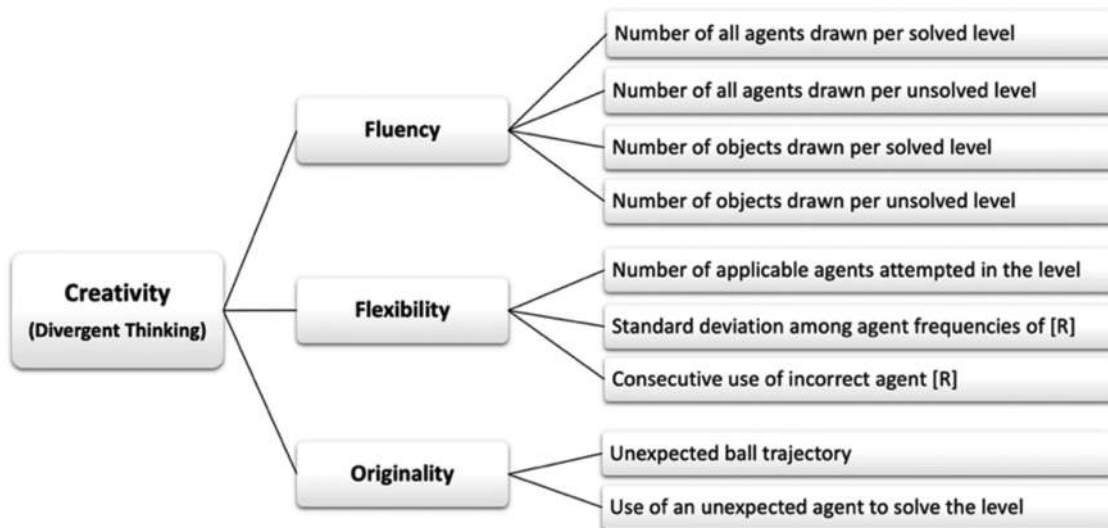


Figure 5. CM of creativity with evidence model variables (indicators) on the right. Note. *R indicates reverse coding (for negative evidence).

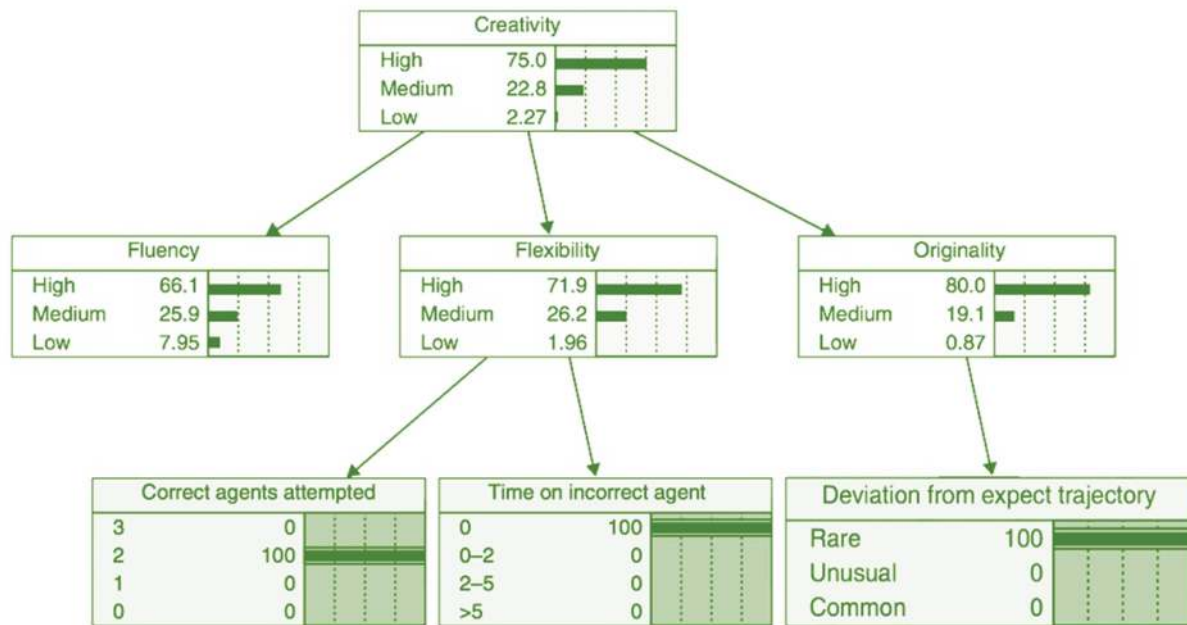


Figure 6. Creativity BN with its child nodes and example indicators for one game level.

Future directions

As a learning scientist and a creativity researcher, my future work generally falls into two overlapping categories: (1) assessment and improvement of creativity using technology-rich environments and innovative assessment method; and (2) integrating creativity in game-based learning to promote deep learning.

Assessment and improvement of creativity

Regarding the assessment of creativity, I will continue to apply the stealth assessment technique in assessing creativity in different domains and learning environments. For instance, currently, I am working on a validation study to validate a stealth assessment of creativity in a digital computer science and music remixing learning environment called *EarSketch* (Magerko et al., 2016). In this environment, high school students write JavaScript code, remix existing pieces of music and sound effects, and create music. Using a consensual assessment technique (Amabile, 1982), I am examining the convergent validity of the stealth assessment of creativity in *EarSketch*. Once validated, this stealth assessment can be used in real-time to diagnostically identify students' level of creativity at a sub-facet level and provide personalized creativity supports and enhance the creativity of their music.

Another venue for assessment of creativity that I will work on is leveraging the power of AI to improve the accuracy of stealth assessments of creativity. Stealth

assessment is a top-down approach. That is, using ECD we first start by operationalizing the construct we are trying to assess (e.g., creativity) and then we will design a digital environment that can help elicit the evidence we need for assessing that construct. Such top-down methods may be improved if combined with bottom-up approaches such as Machine Learning (ML). ML can identify new patterns, not captured in stealth assessment evidence models, that are relevant to the assessment of creativity in the log data. Using ECD, we create digital environments (e.g., *Physics Playground* or *EarSketch*) eliciting evidence for creativity. Once those digital environments are used by a target audience, unsupervised ML techniques can find patterns and indicators (observables) linked to creative performance in user log data. These newly discovered observables may enhance stealth assessment models' accuracy.

I will also explore additional AI applications in creativity assessment. AI-powered Natural Language Processing (NLP) algorithms can analyze written or spoken language to detect creativity, assessing novelty, unique language use, and originality. In a recent study (Rahimi, Walker, Lin-Lipsmeyer, & Shin, 2023) in the *Creativity Research Journal*, we used NLP to classify sentences in Minecraft videos, identifying subfacets of creativity based on a rubric (Rahimi, 2020). -one of the most popular sandbox video games. We identified a collection of videos on YouTube describing high quality, creative building structures created by *Minecraft* players. Then, we extracted the narrations of those videos and trained an NLP model to identify the correct

code for each sentence. For example, the sentence “Wow, I have never seen such building before” could be coded both as evidence for surprise and originality. NLP techniques have advanced with Large Language Models (LLMs) such as GPT-4, learning patterns, grammar, and semantics from vast text data. These AI tools can enhance creativity assessment in written or spoken tasks.

Similarly, for assessing creativity in other domains such as drawing, AI-powered image and video analysis techniques can be used. AI models can evaluate visual creativity by analyzing images or videos. Generative models like GANs (Generative Adversarial Networks) can generate new, creative visual content, and AI can compare the submitted images or videos to assess their originality. In general, the ever-increasing computational power of AI systems with deep learning, neuronal networks techniques can make it possible for these systems to compare a creative product with a huge number of similar products and identify the level of novelty in the product at hand.

AI systems can also be used for enhancing and supporting human’s creativity as well. Instead of replacing humans with AI-powered machines, we should use AI to augment humans’ intelligence (Warr, Mishra, Henriksen, & Woo, 2023). In other words, instead of Artificial Intelligence or AI, I am more interested in Intelligence Augmentation or IA. This argument holds for creativity as well. Instead of using generative AI (e.g., Chat GPT or Dall.E 2) to create products for us, we can use such systems as creativity supports and augment our creativity—i.e., creativity augmentation. Having said that, I am not against having AI-powered systems create things for us. However, I am more interested in human-AI partnership for creativity which may open new doors for how creative we can be.

Finally, combining an accurate assessment of creativity, using the top-down and bottom-up approaches, and providing the right creativity supports, I will pursue a line of research for designing and developing digital environments (e.g., digital games) that can accurately assess and improve people’s creativity. Such environments benefit from AI-powered, stealth assessment of creativity, and can deliver appropriate creativity supports to people when they need help. For instance, if the assessment model identifies that a user lacks flexibility in their ideas, the system can nudge the user toward thinking about new categories of ideas. Or if they need inspiration, the system can showcase a variety of similar work. I believe such games can enhance local creativity (e.g., being creative related to what a person is doing such as playing a game) and general creativity (e.g., creative thinking skills that can

be transferred to other domains and situations in life). Next, I discuss a new line of research I am working on to use creativity to improve students’ learning of a subject matter.

Integrating creativity in game-based learning environments

Game-based learning (GBL) offers a fun mechanism for engaging with defined learning outcomes and goals (Plass, Mayer, & Homer, 2020). The situated and interactive nature of digital games can promote active and effective learning (Gee, 2005) and increase the time people spend engaging with the embedded learning content (Coller & Scott, 2009). GBL with efficient problem solving improves engagement and learning, however, I hypothesize that *creative* game-based learning (CGBL) can further improve engagement and learning. I define CGBL as learning any concepts (e.g., Newtonian physics) by playing any games that is designed with that concept and creative thinking in mind. To be successful in CGBL, students need to think creatively and solve game problems or conduct specific tasks in novel ways. Such games provide many affordances that permit people to show or even possibly improve their creativity and improve their learning at the same time. Those affordances can be in (1) creative gameplay (e.g., solving a game level using multiple solutions); and (2) creative game content production (e.g., designing new game levels) (Bowman, Kowert, & Ferguson, 2015; Gee, 2005). In CGBL, creativity helps learning and learning helps creativity. My future research will focus on developing a CGBL design framework for designing educational games that use creativity to deepen learning. I hypothesize that CGBL works better than GBL games in terms of improving learning outcomes for the following reasons.

First, through creative gameplay students can practice and enhance their divergent and convergent thinking skills that are key elements of creative thinking (Guilford, 1956). These two complementary modes of thinking refer to divergently generating many ideas and convergently selecting the best ideas (Barbot & Tinio, 2015). They help students broaden their thinking, evaluate options, and refine solutions (Guilford, 1956). Flexibility, one dimension of divergent thinking, refers to the ability to generate ideas from different categories or perspectives (e.g., finding alternative solutions to a problem) (Abdulla Alabbasi, Hafsyhan, Runco, & AlSaleh, 2021; Forthmann, Holling, Çelik, Storme, & Lubart, 2017). Similarly, cognitive flexibility theory (CFT) suggests that deep learning requires learners to engage with new content from multiple perspectives

and in flexible ways of thinking (Spiro, 1988). Therefore, learning environments that encourage learners to think flexibly (e.g., games based on CGBL) may improve learning.

Second, through creativity in generating game content (e.g., game level design), again, students can find new perspectives in learning (CFT and divergent thinking are relevant here); instead of solving a problem, they need to pose or design a problem. Since game level design is usually highly open ended, and students can design their levels in any way they want (e.g., they can bring in their own culture, stories, interests), students' internal motivation can increase as stated by the self-determination theory (SDT; Black & Deci, 2000). SDT posits that intrinsic motivation and learning outcomes are enhanced when three basic psychological needs are met: competence, autonomy, and relatedness. If a game environment allows students to share the game levels they created, their intrinsic motivation can be enhanced supported by the relatedness component of SDT. Intrinsic motivation is crucial for creativity (Amabile, 2012), and engagement (Black & Deci, 2000); engagement is crucial for learning (Emerson, Cloude, Azevedo, & Lester, 2020). If CGBL involves game level design, these needs will be fulfilled by allowing learners to acquire and demonstrate skills (competence), express their own narratives (autonomy), and share their created game levels with others (relatedness). Additionally, creative game level design can be used as means to help those students who do not identify as "gamers" (e.g., girls and African Americans) to get started with a fun, creative activity and later engage with gameplay activities as well. Therefore, CGBL can enhance the participation of students from the historically marginalized communities.

Currently, I am redesigning *Physics Playground*, which is based on efficient problem solving, to develop *Physics Playground 2* which will be based on CGBL. The new game design features promote divergent thinking skills. Additionally, students will engage in game level design activities using the game level editor, which offers creativity and physics support (Rahimi, 2020; Rahimi & Shute, 2021b). *Physics Playground 2* will pioneer the integration of stealth assessment and cultivation of both creativity and physics understanding of middle school students in an educational game. I will test my hypothesis after *Physics Playground 2* is built: CGBL is more effective than GBL in improving students' learning outcomes.

Conclusion

As I mentioned in the introduction, I am on a mission to design and develop tools that can help people learn better and deeper while they use and enhance their creativity. What I discussed in this paper shows what

I have been working on so far and what I will be doing in the future to accomplish my mission. We have come a long way from Guilford's presidential address at the American Psychological Association (APA) in 1950 (Guilford, 1950) encouraging psychologists to pay more attention to creativity. With the new advances in learning sciences, creativity research, psychometrics, and technology, a rich future related to how we understand, assess, and improve people's creativity is on the horizon. While staying open to new experiences in my research agenda related to creativity and learning sciences, I hope I can contribute to the field of creativity research in novel and valuable ways.

Disclosure statement

No potential conflict of interest was reported by the author.

ORCID

Seyedahmad Rahimi  <http://orcid.org/0000-0001-9266-758X>

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