Open-Ended Tasks Promote Creativity in Minecraft

Yue Fan[1], H. Chad Lane[1*] and Ömer Delialioğlu[2]
[1]Department of Educational Psychology, University of Illinois, Urbana-Champaign, USA // [2]Department of Computer Education and Instructional Technology, Middle East Technical University, Turkey //
yue.fan@liulishuo.com // hclane@illinois.edu // omerd@metu.edu.tr
[*]Corresponding author

ABSTRACT: Due in part to its flexibility and open design, the video game Minecraft has emerged as a popular tool for teaching and learning. Inspired by prior research showing the influence of problem-solving mindsets in physical settings, this study is an effort to understand the extent to which an open-ended task influences subsequent problem-solving behaviors in a virtual environment. Specifically, we investigate creativity and its relationship with task design in Minecraft by comparing a well-defined task group, instructed to follow step-by-step directions, with a group pursuing an open-ended task requiring a higher degree of agency. Creativity is assessed using two conventional approaches: the Alternative Uses Test (AUT) and the Consensual Assessment Technique (CAT). Judges were trained to evaluate using both methods and achieved sufficient agreement on a subset of the data prior to completing the full data set. Our results suggest that (1) participants who engaged in the open-ended task receive significantly higher CAT scores than those in the well-defined task group, and (2) among variables such as the level of skill/experience, interest in Minecraft, and materials (blocks) used in Minecraft, only game interest level has a significant influence on the CAT score.

Keywords: Creativity, Minecraft, Problem solving, Educational games, Computer-based learning environments

1. Introduction

Counter to early research that tended to focus on the potentially negative consequences of playing video games, the last decade has witnessed growing attention on the possible benefits of playing games, including investigations into learning, motivation, engagement, and creativity (Granic, 2014; Connolly et al., 2012). Research on the design and effectiveness of educational games has also grown dramatically suggesting that well-designed games can be effective in enhancing learning-related outcomes (De Freitas, 2018; Mayer, 2019). This body of work has laid a foundation for further study about how specific games and game genres may influence learners and be effectively integrated into educational programs.

Minecraft is one of the most popular video games in history with over 200M copies sold and 131M active monthly users (Watts, 2021). Minecraft is typically classified as a "sandbox" game, which means that players have a very high level of agency and freedom to pursue their own goals and explore/engage in creative activities in whatever ways they choose (Brand & Kinash, 2013). Studies on the impacts of sandbox games, and Minecraft in particular, are only now beginning to emerge. The focus of our work is on how Minecraft-based experiences may be deployed to promote creative thinking. The research reported here seeks to fill a gap in this literature and help educators design game-based learning activities to allow their students to explore their creativity and interests.

Not only is Minecraft popular, it has also been adopted by teachers and educators all over the world (Pusey & Pusey, 2015) due to its deep ties to Science, Technology, Engineering, and Math (STEM) learning (Lane & Yi, 2017; Short, 2012). One of the reasons for these direct links is because Minecraft can be viewed as a scaled-down simulation of the natural world and interactive representation of a wide range of STEM-relevant phenomena. Typical game activities involve exploring a range of different biomes, locating and collecting resources, interacting with animals and sea creatures, building large structures, farming, and much more. Given this rapidly growing interest, there is a pressing need to provide empirical support and evidence-based principles for designing content and leveraging the rich resources provided by Minecraft (Baek et al., 2020). The study reported in this paper focuses directly on a task that could easily serve as a learning activity (building a home), and so it has implications on how to design learning tasks that allow learners to have more freedom and ability to express themselves. Specifically, our findings suggest that less rigid structure is more likely to promote creativity in goal-driven learning activities in Minecraft.

In public dialogue, it is common to hear Minecraft described as a form of "digital Legos." Although intuitive and conceptually accurate since both activities use "blocks" as the standard unit of manipulation, the claim does not genuinely convey the full interactive capabilities of Minecraft. For example, Minecraft simulates a variety of real-world phenomena such as flowing water and plant/tree growth. It also allows for the construction of large,

complex machines with *Redstone*, Minecraft's version of electricity, enabling players to engage in automation of a range of science-relevant tools for farming, exploration, and building.

The study reported here represents a partial investigation of the accuracy of the common metaphor between Minecraft and Legos. Specifically, we report a replication of earlier work with Legos that explored the relationship between task openness and creativity (Moreau & Engeset, 2016). The key finding from this work was that open-ended tasks with Legos (e.g., "build a house") fostered greater creativity than well-defined, more narrowly defined tasks that do not allow significant choices to be made by a learner (e.g., "build a house exactly to specifications"). We sought to determine if these findings would hold up in a digital environment, thus suggesting that creativity emerges in similar ways in both tangible and virtual environments.

As with Moreau and Engeset (2016), we investigate (1) whether there are creativity differences between open-ended tasks and well-defined tasks, i.e., whether a well-designed problem-solving mindset would produce lower creativity scores in a subsequent free-play task. And (2) whether interest, skill/experience of the participants as well as the number of different types of blocks used to build would affect creativity scores of the participants. We pursue the following two research questions:

- To what extent does the use of open-ended tasks in Minecraft influence a player's creativity?
- Does creativity have a significant relationship with level of interest, skill/experience, and the number of different types of blocks used to build (when given the choice to use as many as desired)?

In the remainder of this article, we first describe Minecraft in more detail, arguing that it qualifies as an authentic learning environment then describe our partial replication of the Moreau and Engeset (2016) study. We conclude with a discussion of the findings and implications on practice.

2. Minecraft as an authentic learning environment

Minecraft is fundamentally a world made up of blocks (earning it the Lego analogy) that come in a wide range of types (see Figure 1). These blocks can easily be manipulated (e.g., created, destroyed) and have vastly different properties and functions. Some blocks are solid, harder or softer, transparent or opaque, "sticky", or even a liquid. The name *Minecraft* reveals the nature of playing: typically one collects materials (as blocks) and then combines those in ways to create new tools and resources. In turn, the results unlock new capabilities and enable more advanced forms of play. Players collect resources in the world by *mining* (often with a tool, such as a pickaxe), and then learn to *craft* new items that further enable building of more complex artifacts, such as bridges, buildings, machines, and farms.

Figure 1. A selection of blocks available in Minecraft each with unique properties and conditions for use

To customize the game, Minecraft can be played (1) either by individuals or in groups, (2) locally or on a server, and (3) with the use of "mods" (modifications to the basic game). Players can play in *survival* mode, which requires resource collection, some combat, and the creation of structures to protect oneself from enemies. In *creative* mode, on the other hand, the player has an unlimited supply of resources, no need for food, no chance of injury, and the ability to fly freely around the world. In the study reported below, a hybrid mode was used that

enabled free play, but with no combat or chance of taking damage. In our study, a limited set of blocks were provided to best estimate the Lego study in which a fixed set of LEGOs were provided to participants prior to beginning the task (Moreau & Engeset, 2016).

Minecraft provides practically unlimited opportunities to manipulate and customize their in-game experience. Intuitively, it is not difficult to link the openness of this and other sandbox games to potential benefits in creative thinking and self-determination. By definition, sandbox games promote intrinsic motivation by providing a context for self-generated goals and natural autonomy (Tichon & Tornqvist, 2016). One of the most prominent features of sandbox games are their openness and the ability to explore vast computer-generated spaces however a player desires (Brand & Kinash, 2013). Minecraft exemplifies these freedoms: exploring the diverse landscapes and biomes, crafting various new blocks, customizing one's living space, collaborating and coordinating with friends, "modding" to add unique features, and more. This extreme level of choice provides an ideal context for creative problem solving and expression.

Minecraft can also be viewed as an *authentic learning environment* in the sense that it shares many of the same characteristics of the natural world (e.g., weather, terrain, different biomes, living creatures, caves, mountains, flowing water) and enables many of the same activities that humans engage in (e.g., exploring, building, collaboration, resource collection, construction of machines with moving parts). Considering Herrington & Oliver's (2000) framework for authentic learning environments, Minecraft faithfully reproduces many real-world settings, provides opportunities to engage in realistic activities (e.g., building complex structures), provides easy access to expert content (e.g., through mods or content built in world), the ability to take on multiple roles (e.g., surveyor, designer, or builder), and includes direct support for collaboration through a shared workspace and chat (p. 4-6). The claim that Minecraft includes sufficient complexity to be considered a realistic learning environment is also supported by its growing use as a testbed for real-world problems. For example, Project MALMO at Microsoft uses Minecraft for the development of machine learning models in robotics (Johnson et al., 2016). In addition, Facebook created *CraftAssist,* a tool for studying human-agent collaboration around complex joint tasks and capture of natural language interactions (Jayannavar et al., 2020). In sum, Minecraft, while not originally designed as a simulation tool, provides a wide range of features and capabilities that enable it to recreate problem solving contexts that can resemble key aspects of the natural world.

3. Creativity, Legos, and Minecraft

In this section, we clarify our definition of creativity and provide background necessary for our study.

3.1. Big C vs. Little c Creativity

Research on creativity tends to address two broad categories of creativity: Big "C" (sociocultural definition) and little "c" (individualist definition) (Sawyer, 2012). Big "C" refers to "the generation of a product that is judged to be novel and also to be appropriate, useful, or valuable by a suitably knowledgeable social group" (Sawyer, 2012, p.8). This means those products with widespread social approval, solutions to societal problems, or significant works generated by famous artists or musicians are frequently cited as examples. For example, the Mona Lisa painted by Leonardo da Vinci and universal gravitation as articulated by Newton both qualify.

Little "c," on the other hand, is defined as producing "a new mental combination that is expressed in the world" (Sawyer, 2012, p. 7). In this case, creativity is not limited to validation by a large group of people, but extends to all people who are solving everyday problems. Everyone exhibits little "c" creativity to some capacity since daily life involves the combination of elements to create new products or to solve simple problems in a novel way. There is no restriction that others have not used the same solution. For example, someone who has toothpaste, but no toothbrush might brush their teeth with their finger, it achieves a similar goal and is a creative solution. Although we focus on little "c" creativity in our study, one can certainly not rule out the potential for big "C" creativity to be possible in Minecraft. Indeed, massive undertakings are not uncommon in the game that take years of effort, specialized skills, and collaboration (Peckham, 2013).

3.2. Divergent thinking and convergent thinking

Research has identified at least two ways of thinking that contribute to creativity: divergent and convergent thinking. Divergent thinking expands a problem solution space and involves experimentation to identify and

develop multiple ideas, each of which could possibly become a solution. In contrast, convergent thinking prunes a problem-solving space and "emphasizes speed, accuracy, and logic" in pursuit of "the single best (or correct) answer to a clearly defined question" (Cropley, 2006). Creativity can be regarded as a cyclic process of ideation (i.e., the formation of ideas) that relies on divergent thinking to expand a set of potential solutions followed by evaluation of those ideas to identify the best options, which relies on convergent thinking (Lubart, 2001).

Minecraft can be considered as a tool that inherently promotes divergent thinking for players given its openness emphasis on building, and high degree of collaboration. During regular game play, players repeatedly synthesize information to make decisions and implement different approaches for building and coordinating activities. It is simple (and natural) to look at projects from multiple dimensions (top-down, inside, outside, etc.) and in different natural settings. Players fully explore the virtual world with a broad range of possible interactions in Minecraft, employ trial and error, and learn from failure (Green & Kaufman, 2015), which suggests divergent thinking is implicitly encouraged. The virtually limitless sets of combinations of virtual blocks provide further fuel for the argument. Lastowka (2011) explains that "Minecraft is rooted in the free exchange of creativity and users' creations." In creative mode, players construct buildings, tools, machines solely for the purpose of creative expression (Garrelts, 2014).

Research has shown that creativity can be boosted during group work and via interactions between creators (Sawyer, 2012). This is similarly compatible with Minecraft since playing collaboratively in a multiplayer mode is one of the most common ways to play. By communicating with others, people engage in different ways of thinking, including use of imagination, perception, and reasoning. Such collective capabilities are crucial to creativity (Shabalina et al., 2015). Note that while the study reported here did not investigate collaborative creativity, the collaborative affordances of Minecraft suggest important future directions of research.

3.3. Creativity and the problem-solving mindset

In the context of using creativity to solve problems from daily life, the *problem-solving mindset* has a close relationship with our creativity. According to research on problem-solving mindsets, cognitive activities that relate to problem solving will sustain over time and contexts (Moreau & Engeset, 2016). The problem-solving mindset refers to a phenomenon that people's behavior or thinking processes in one case can influence their ideas and performances in later, unrelated tasks. Since the formation of mindset is largely affected by the problem space in which the learner works, it is possible to manipulate perceptions of a problem space and see how those differences influence creativity.

Research has revealed three key components that are relevant for understanding a problem space: (1) the initial state (problem itself), (2) the set of operators (rules and strategies) that enable one to proceed from the initial state to (3) a goal state (the solution) (Davidson & Sternberg, 2003). According to Kitchener (1983, p. 223) *well-defined* problems are those "for which there are absolutely correct and knowable solutions," while *ill-defined* problems are those "for which there are conflicting assumptions, evidence, and opinion which may lead to different solutions." Well-defined and ill-defined problem spaces can be loosely thought of as aligning with convergent thinking and divergent thinking. Divergent thinking is most closely associated with open-ended problems where solutions are open to interpretation and may have unclear/unspecified operators. Convergent thinking, on the other hand, is more closely related to well-defined problems in the sense that a clear and specific initial state is given and an operational path to reach a correct answer exists in the problem space. Based on connection between problem solving and creativity theory, experiments can be run to set up which kind of mindset best promotes learner creativity and their ability to solve problems creatively.

3.4. How Minecraft and Legos are believed to promote Creativity

Substantial evidence has emerged supporting the connection between creativity and game design (Green & Kaufman, 2015). For example, in a study of almost 500 children, videogame play was found to be related to multiple dimensions of creativity, whereas other information technology use was not (Jackson et al., 2012). In terms of supporting creativity, Melián Díaz et al. (2020) found increases in divergent creativity after presenting teachers in training a Minecraft task to "build the home of your dreams" using a different measure of creativity than the study presented here. Preliminary research has also shown that the openness and basic play of Minecraft has positive effects on learner creativity. "To play Minecraft is to use the game as a creative tool. Minecraft requires players to be creative, even if that creativity is limited to designing a crude shelter or tunneling the layout of a mine" (Lastowka, 2011). Despite these promising preliminary findings, we are aware of no rigorous research demonstrating causal links between Minecraft play and creativity. With its high level of customization,

block types, and specialized tools, Minecraft enables high levels of expressivity which suggests it is an ideal environment for promoting creative thinking. Further, the openness of Minecraft allows for experimentation with various conceptions of narrative and characterizations of plot lines, further aligning it with conditions that known to promote creative production (Cipollone et al., 2014).

The Lego and creativity studies conducted by Moreau and Engeset (2016) were the inspiration for our study. This research used Legos and sought to confirm the notion of problem-solving mindsets described in section 3.3. Researchers decomposed the problem-solving space to the initial state, operator and goal state. The degree of openness was manipulated in order to investigate the influence of activated problem-solving mindsets on subsequent creative tasks. Three experiments are reported in their article, with the first experiment forming the basis for our Minecraft replication. This study compared three different mindsets (well-defined vs. open-ended vs. control) and their influence on a subsequent task (open-ended vs. well-defined). The findings showed that a well-defined mindset (instructions with clear goal) diminishes performance on a subsequent open-ended task (no instruction, or goal). Our study follows the same design.

4. Methods

4.1. Research design and variables

Participants were randomly placed into the experimental or comparison group upon arrival. The independent variable was the task design (open-ended or well-defined problem-solving task) while dependent variables were (1) a conventional creativity measure, the Alternative Uses Test (AUT) and (2) a free-play building task in Minecraft for use with the Consensual Assessment Technique (CAT). Here, the experimental procedure was simplified by ignoring the measurements that have a distant relationship to creativity, such as enjoyment which was included in the Lego study (Moreau & Engeset, 2016). Our experiment focused on the relationship between problem-solving space (initial state, operators, goal state) and subsequent task performance. Further, participants were given 15 minutes in their free play (second task), which was the product assessed in the CAT (dependent measure of creative expression). To best mirror the Lego study, participants were given a fixed set of Minecraft blocks from which draw in this free-play task. In summary, we used AUT assessment as in the Lego study (Moreau & Engeset, 2016) with an additional measurement added, the CAT, to capture creativity in different ways.

4.2. Participants and characteristics

The participants of the study were 42 undergraduate students from a university in the midwestern section of the United States who fit the requirement of having basic experience with Minecraft (i.e., they played Minecraft before and at least knew basic operation of playing the game). We administered a survey to gather basic demographic information and to capture the Minecraft playing characteristics of the participants. Among those participants, 74% of participants were male and 26% were female. Two main categories of questions were included in the survey (1) the skill/experience level with video games generally as well as specific Minecraft experience, and (2) the interest level and motivation to play Minecraft. Unsurprisingly, skill/experience level had a high correlation to interest level ($r = .70$), meaning simply that people who liked the game played it more often.

Table 1. Participant familiarity with common Minecraft activities

Activity	Rating
Collecting/mining resources	4.69
Farming (planning, harvesting crops)	4.31
Crafting tools; using crafting tables	4.29
Planning, designing, and building	4.00
Redstone (i.e., electricity, machines)	2.64
Command blocks	2.36
Creating/maintaining a Minecraft server	2.26

Note. Rating ranges from 1 (low familiarity) to 5 (high familiarity).

All participants had some prior exposure to Minecraft which ranged from over 10 years of experience to less than a month. 38% still played at least once a month and the remaining 62% had not played recently (within a month). Table 1 shows participant ratings of their experience with several common Minecraft activities, revealing high familiarity with many (mining, farming, building) but less exposure to advanced play (Redstone,

command blocks). Only basic skills were required to fully participate in the study. Finally, self-reports on the appeal of Minecraft using a scale of 1-10 (10 = high), 19% gave a score under 6 points, 52% liked Minecraft (7-8 points), 28% expressed high interest with a rating of 9 or 10. In sum, these data indicate participants in the experiment exhibited sufficient knowledge of Minecraft and most found it to be an enjoyable way to spend time.

4.3. Procedure

The research procedure that participants were guided through took roughly 40 minutes to complete (Figure 2). Upon arriving, participants completed a 4-minute survey, which included their demographic information, and their interest in and experience with Minecraft (results presented in section 4.2). Participants were then situated in the Minecraft environment with a basic landscape and provided with a reminder of how to play if needed. They were then invited to move around in-game and acquaint themselves with workspace for a few minutes. Participants then completed a 15-minute problem-solving task in Minecraft that was either well-defined (group 1) or open-ended (group 2), assigned randomly. All participants were provided a collection of resources from which to build in the game (in chests). The well-defined task group was given printed instructions and a clear direction to "follow the step-by step instruction, build the house with the bricks in the chest" with pictures. The resources provided precisely what was needed to construct the sample house (see Figure 3).

Figure 2. Procedure of the Minecraft creativity study

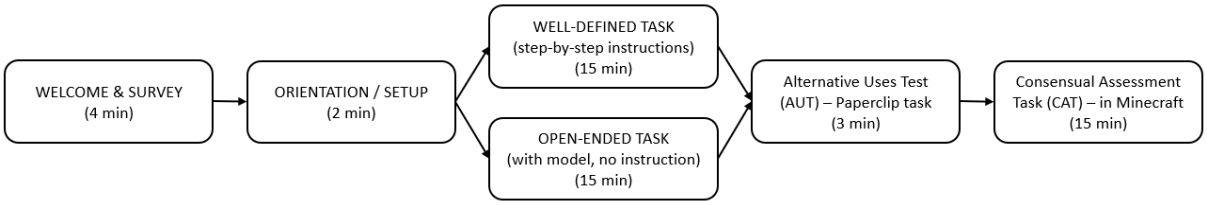

Figure 3. Model house used in the well-defined task group

Front Back

Front door Side face

Participants in the open-ended condition were also given a picture of a house, but with the general directive to "build a house like the sample, with the blocks of your own choice." A chest with varied materials (64 kinds of blocks) were provided for the participants to build in a wide range of styles and to a larger scale. No further guidance was provided.

Upon completion of the task, all participants first completed the Alternative Uses Test (AUT) that asked for as many uses of a paperclip can be generated in 3 minutes. Finally, participants were invited to return to Minecraft

for a 15-minute session of free play in Minecraft with instructions to build anything they wanted in full creative mode (no limit on blocks that were made available). The product of this session was used for our Consensual Assessment Test (CAT). Screenshots and saved game maps of the product they created in Minecraft was collected for CAT scoring.

4.4. Data collection instruments and analysis

The initial survey consisted of 10 questions covering their frequency, history, preferences, motivation, skills, as well as their history with Minecraft. The results of the survey were summarized in section 4.2.

The Alternative Uses Test (AUT) (Guilford, 1967) and Consensual Assessment Technique (CAT) (Amabile, 1982) are two of the most common choices for judging levels of creativity. The AUT assessment seeks to capture divergent thinking and has repeatedly been shown to correlate with additional measures of creativity (Hocevar & Bachelor, 1989). The CAT assessment seeks to measure creativity as expressed through a product or artifact and is considered one of the best measurements of creativity in terms of reliability, discriminant validity, and nomological validity. Multiple experts are needed to rate the creativity of a collection of products by comparing them with one another individually and without outside guidance (Amabile, 1982). This test focuses on little "c" creativity and builds on the intuitive theory that the combined assessment of experts in certain field is the best measure of the creativity of a product. The product of a CAT is usually scored by at least three experts who use their own professional sense of what is creative in a domain (Kaufman & Baer, 2012). The testing objects used in prior CAT assessments have covered a wide range of artifacts, including engineering and artistic creations (Baer & McKool, 2009), which make it suitable for assessing open-play Minecraft products.

We used three expert Minecraft players as judges who were not involved in the research project. They evaluated the 42 participants' free-play Minecraft products (i.e., "build anything") without awareness of which condition a participant was assigned to. The overall inter-rater reliability was acceptable between the three (irr = 0.52), with the correlation between the three raters (R1, R2 = 0.57; R1, R3 = 0.50; R2, R3 = 0.40) similarly acceptable based on the subjective nature of CAT grading. A *t*-test was then used to assess the effects of well-defined task and open-ended task on participants' CAT mean score among three judges.

The AUT asks participants to generate as many uses as possible for a common household object. In this study, participants were asked to "list the different uses of a paperclip as much as possible in three minutes." We used two of Guilford's (1967) dimensions that most directly reflect divergent creativity: (1) *originality*, which refers to a statistically uncommon answer when compared to the overall data set, and (2) *fluency*, indicated by the quantity of appropriate responses given. Three independent raters judged whether each answer was appropriate (reasonable), unusual (5% of the group mentioned) or unique (1% of the group mentioned). Following the AUT official manual (Wilson et al., 1954), we required at least 2 of the 3 judges to indicate that an answer was appropriate in order to include it in the measurement.

To complete data analysis, two judges independently completed their AUT scoring, with a third judge used to break ties when they arose. To derive a score, participants received one point for each appropriate response (fluency). From all appropriate responses, then, 1 point was awarded for each "unusual" answer and 2 points for each "unique" answer. For example, if a participant generated 15 answers to the AUT assessment and 10 of them are judged as appropriate, they are assigned 10 points for fluency. If among those 10 answers, only 2 of them are "unusual" and 1 "unique." If those two answers that are mentioned by less than three people (5% of the group) and one response mentioned only once among 48 participants, then the participant could earn $2\times1+2=4$ points for originality. The AUT score for this participant is to add the fluency and originality scores to get 14.

Finally, for the free play "build anything" task in Minecraft, the result was graded via the CAT assessment by experts. Three experts made their judgments about the product creativity with score (range: 1-10), independently based on their own criterion (no standardized judging criterion, a common design choice in creativity research).

5. Results

5.1. RQ1: The relation between task type and creativity

To test if there was a significant difference on creativity score between the two kinds of problem-solving tasks discussed above, the creativity score of both groups using the CAT and AUT were considered. For the CAT

assessment, scores were found to be normally distributed, thus meeting the requirement for a two-sample unequal variances *t*-test (see Table 2). AUT scores with 42 participants did not fit the normal distribution ($p = .04 < .05$ in Shapiro-Wilk normality test), meaning hypothesis verification for the two groups required a non-parametric test. For this, we used Mann-Whitney U test basing it on the continuity correction of the rank in group.

Table 2. CAT scores for well-defined vs. open-ended tasks

Task	*M*	*SD*	*n*	*t*-test	*df*	*p*
Well-defined task	5.06	1.58	22	2.14*	40	.038*
Open-ended task	6.07	1.42	20			

Note. *$p < .05$.

Since participants in the well-defined condition received a lower creativity score ($M = 5.06$) than those in the open-ended condition ($M = 6.05$; $t = -2.14$, $p = .038 < .05$, Cohen's $d = 0.66$), the main effect of the problem-solving task on CAT score was significant. The open-ended task produced significantly higher CAT scores than the well-defined task in the final "build anything" free-play task.

The AUT × (well-defined vs. open-ended task), Mann-Whitney U test suggested no effect was detected. The well-defined group scored higher ($M = 10.68$) than the open-ended task ($M = 8.55$), with $U = 161$, $W = 371$, although this was not significant ($p = 0.136$). Thus, there is no significant difference between well-defined mindset and the open-ended mindset in their AUT performance of the following free-play problem-solving task.

5.2. RQ2: The relationship of level of interest, skill/experience of the participants, and the number of different types of materials used with creativity

Apart from creativity difference between the well-defined problem-solving task and the open-ended task in Minecraft, we consider three variables that might have effects on the creativity score: (1) skill/experience level with Minecraft, (2) interest level in the game, and (3) the different types of blocks used in the open task. All the data were quantified and divided into high and low level in two categories: skill/experience and interest in Minecraft. To test if there are any relationship between the variables and their creativity score, a *t*-test was used with three groups of comparison: CAT × (low skill/experience level vs. high skill/experience level), CAT × (low interest level vs. high interest level), and CAT × (low block use vs. high block use).

Table 3. CAT scores for skill in Minecraft, interest in Minecraft, and for overall number of different blocks used.

	Low level			High level			*t*	*p*	*df*
	M	*SD*	*n*	*M*	*SD*	*n*			
Skill	4.91	1.87	17	5.95	1.18	25	2.03	.051	25
Interest	5.08	1.63	22	6.02	1.38	20	-2.01*	.049*	40
Blocks	5.21	1.69	19	5.79	1.45	23	1.19	.239	36

Note. *$p < .05$. The CAT (Consensual Assessment Technique) is a subjective judgment by domain experts on the level of creativity present in an artifact.

This analysis (Table 3) showed first, that those who have low level of skill/experience had a lower CAT score ($M = 4.91$) than those who are of high level of skill/experience ($M = 5.95$; $t = -2.03$, $p = .051$, marginally significant). For the test of interest level, the high-interest group (M = 6.02) had a significantly higher CAT score than the low-interest group ($M = 5.08$, $t = -2.01$, $p = .049$), with Cohen's $d = 0.62$ (medium). Lastly, in terms of the number of different blocks used in free play, no significant difference was found between those with a high level of block use ($M = 5.79$, $t = -1.19$, $p = .24 > .05$) than those with low counts ($M = 5.21$).

Correspondingly, we did the same t-test for each of the variables using the AUT scores (Table 4). Neither skill/experience ($M_{low} = 9.47$, $M_{high} = 9.80$, $t = -0.23$, $p = .82 > .05$) nor blocks used ($M_{low} = 9.68$, $M_{high} = 9.65$, $t = 0.02$, $p = .98 > .05$) were statistically significant. However, interest level (in Minecraft) was significant for the AUT test ($M_{low} = 8.27$, $M_{high} = 11.2$, $t = -2.10$, $p = .04 < .05$) with a medium effect size (Cohen's $d = 0.65$). Thus, participants who have high level of interest on Minecraft also had significantly higher AUT scores.

To summarize, when comparing the CAT and AUT assessment together to see if variables other than task condition had influence on participants' creativity, neither skill/experience level nor number of different blocks used had significant influence. However, a high level of interest in Minecraft is associated with higher AUT and CAT scores, perhaps suggesting that more creative people are naturally drawn to Minecraft to begin with.

Table 4. AUT scores for skill in Minecraft, interest in Minecraft, and for overall number of different blocks used

	Low level			High level			*t*	*p*	*df*
	M	*SD*	*n*	*M*	*SD*	*n*			
Skill	9.47	4.09	17	9.80	5.11	25	-0.23	.818	39
Interest	8.27	4.17	22	11.20	4.82	20	-2.10*	.042*	38
Material	9.68	4.27	19	9.65	5.08	23	0.02	.982	40

Note. $^{*}p < .05$. The AUT (Alternative Uses Test) is a common assessment of creative thinking that asks participants to imagine as many different applications or uses of an object that they can generate (e.g., a paperclip in our case).

6. Discussion

Our analysis of CAT (Consensual Assessment Technique) scores, used to assess Minecraft products created during a subsequent task, produced a statistically significant difference in creativity present in favor of the open-ended condition. The significantly higher CAT scores for the open-ended task supports the idea that open-ended tasks promote creativity in Minecraft more so than well-defined tasks do. However, this was not replicated for the external creativity test, the AUT, where we found no significant difference between the two conditions.

One possible reason is that we chose to use of a simpler assessment of divergent thinking than the original Lego study. In particular, the significant result from Moreau and Engeset's (2016) Lego study 1 is measured by a version of Torrence Test of Creative Thinking (Kim, 2006), a more complex assessment than the one used in our study. Lego study 2 was designed to compare the creativity difference between instruction (present vs. absent) and outcome (present vs. absent). In this study, the researchers found a higher AUT score resulted from well-defined mindset than the open-ended mindset, which was not contradicted in our study (our well-defined group did have a higher mean AUT score, but it was not significant). Another potential explanation is that the AUT is simply too far of a transfer test as it has nothing to do with Minecraft, Legos, or construction activities. The results suggest many avenues for future research, such as using the Torrence test after Minecraft play, or even modifying the AUT to focus on Minecraft-related content (e.g., many Minecraft objects can be used in novel, unintended ways such as using pressure plates as shelves, or stair pieces as chairs at a table).

Based on the comparison between Lego and Minecraft studies related to research question 1 (Do open-ended tasks promote creativity?), we can conclude that the key result from the Lego study (Moreau & Engeset, 2016) is comparable and that the finding holds up in Minecraft. This suggests that considering Minecraft a virtual form of Legos is a reasonable metaphor. This is perhaps not surprising due to the fundamental similarities between the two experiences – both are block-based and present very similar interaction mechanics. If anything, Minecraft may have potential to promote creativity in ways that go beyond Legos simply because of additional features that are present in Minecraft but not Legos. For example, Redstone enables the construction of machines, switches, lights, and moving parts. Further, in Minecraft it is possible in incorporate simulated plants and animals, and work in the context of a simulated natural world (e.g., with mountains, streams, lakes, and more). Of course, the fundamental strength of Legos is that it is physical, which has been consistently been shown to have a variety of benefits over purely virtual interfaces (Schneider et al., 2010). Moving forward, it will be important to investigate the ways in which physicality can be leveraged and hybrid learning environments can be used to reap benefits from both. It is promising, for example, to see Minecraft being used to allow learners to explore the use of 3D printers in design tasks (Niemeyer & Gerber, 2015).

In terms of theoretical perspectives on the study, we view our results as supportive of the important role of the design of problem-solving tasks in creativity research and education. Generally, the intervention likely qualifies as a version of *creativity priming*, in that it seeks to establish cognitive and affective conditions that influence future behavior (Sassenberg et al., 2017). Additionally, we found that prior interest in Minecraft contributed to a higher level of creativity present in both the AUT and CAT assessments. Prior research has demonstrated consistent associations between advanced interest and the accumulation of knowledge (Hidi & Renninger, 2006). If one infers from our survey results that greater interest in Minecraft is associated with greater knowledge of the game, our study further supports the established idea that creativity is bolstered by prior knowledge (e.g., Ward, 1994). Specifically, knowledge of and experience with the game of Minecraft seemed to enable greater levels of creative expression in our subsequent open-ended task.

Creativity has been a consistent focus from researchers for over 50 years (Sawyer, 2012), with much of this work looking at how to enhance creative thinking. Our work investigated the role of a priming task (well-defined or open-ended) and its impact on subsequent creative activities. In this study, two research questions were raised

that were inspired by a prior Lego study (Moreau & Engeset, 2016). The intent was to investigate whether and to what extent, the findings would hold up in Minecraft – that is, do open-ended tasks produce higher levels of creativity in future tasks? If so, it would lend credence to the often-made suggestion that Minecraft is a "digital form" of Legos. Our findings suggest that in-game creativity was enhanced, however that this creativity did not extend to a general, non-Minecraft activity. Further research should investigate both the duration and nature of this finding, and look more deeply into how to design learning-related tasks in the game. Given Minecraft's continued growing popularity and use in education, we anticipate a consistent and growing need for further empirical research with the game.

6.1. Implications and future directions of research

The results of this study could be relevant to how instructors choose to use Minecraft. When it is possible to provide less structure in a task, using less specific guidelines and rules may have downstream benefits. Learners might enjoy it more (as was the case in the Lego study) and there may be additional opportunities to leverage creative thinking in subsequent tasks as learners grow more accustomed to receiving less guidance. Also, as discussed, Minecraft provides many STEM-relevant opportunities for learning and thus the chance to explore creativity in a STEM context could be highly appealing to educators. The potential to increase its authenticity and relate it to real-world phenomena needs continued investigation. For example, researchers are now using Minecraft as a tool for engaging children in Urban Planning and to communicate their vision for the cities they live in (Andrade et al., 2020). Combining architectural and civil engineering goals in a Minecraft-based curriculum could set seeds for a new generation of creative cities and innovative solutions to sustainability and environmental challenges.

Potential links between aptitude and creativity are worthy of further research – learners with lower aptitude tend to benefit more from closed tasks, whereas high aptitude learners are comfortable with open-ended learning challenges. Unpacking the relationship between these two, learning, and creativity could have benefits. Further, investigation of learning paths that gradually reduce guidance and scaffolding (Reiser & Tabak, 2014) such that open-endedness is presented gradually, and perhaps made available to learners who may never choose such tasks without such support.

Another possible avenue is to extend the comparison between Lego and Minecraft and their effects on creativity. It would be valuable to pursue mutual and cumulative impacts on each and see if there any potential significant differences between their influence on creativity. For example, a Lego-based approach may be specialized in a tangible interaction (Horn & Jacob, 2007), which makes it more easily to transfer the knowledge and be accepted by students. While Minecraft may have the advantage of constructions with more interactivity and of much greater scale. Advanced functions in Minecraft may deepen links to STEM fields, such as with Redstone and "Command" blocks, which link coding/computing into the game directly.

6.2. Limitations

The current study has several limitations that should be considered. The first is the acceptable but less than desired inter-rater reliability for the CAT assessment (kappa = 0.52). This may have been a result of how the data was captured (screenshots of the game), or our decision to not pursue a common metric for judges for evaluating the products of the participants. Also, based on the structure of Intellect from Guilford and Hoepfner (1971), divergent thinking levels of participants are closely associated with their intelligent level, which was not accounted for in our study. Thus, the result could be selective in the group of participants in this study. Another important limitation of our intervention is a short duration (40 minutes) bringing the generalizability and stability of our results into question (we note, however, that our model study from Moreau and Engeset (2016) consisted of roughly the same length of time). Finally, we note that we chose to not use a pre-post test design, which limits the ability for the study to suggest a causal connection between condition and creativity scores. It is indeed possible that creative people simply score highly in both environments. It is a methodological challenge to do a creativity post-test due to inherent testing effects (that is, the test itself may activate creative thinking). A more complicated future study could perhaps give creativity pre-tests far in advance to the intervention to minimize this kind of effect.

7. Conclusion

From programming, to sales, to STEM careers of all kinds, the ability solve problems creatively is seen as critical for success in the modern world (Sawyer, 2012). The question of how to design learning interventions in ways that simultaneously engage learners and promote creative thinking is critical in order to meet this growing demand. Our work addresses the tension that arises between well-defined tasks versus those that are more open-ended and suggests that providing opportunities with less guidance and more loosely structured learning activities may have downstream benefits in terms of promoting creative thinking. This study showed a basic replication in Minecraft of prior work using Legos suggesting that a digital environment may be similarly as effective to promote creativity. It also showed that prior interest in Minecraft contributed to heightened levels of creativity in a subsequent task. Future work should investigate leveraging the power of both virtual and physical environments as well as the design of more flexible plans for learners with variable levels of comfort with open-ended work.

Acknowledgement

Ömer Delialioğlu was supported by the Fulbright Visiting Scholar Program by the Turkish Fulbright Commission for the enrolment in this research.

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