CREATIVITY DIFFERENCES BETWEEN OPEN-ENDED AND WELL-DEFINED TASKS IN A VIRTUAL ENVIRONMENT

BY

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THESIS

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ABSTRACT

With recent growing attention to the potential benefits of educational games, Minecraft has emerged as a tool for students to learn multiple subjects and cognitive skills, including creative thinking. Recent studies on creativity have implications for the proper deployment of Minecraft-based instruction. For example, manipulation of different problem-solving spaces can induce different problem-solving mindsets (well-defined vs. open-ended). This work has shown that mindsets formed in an initial task would carry over and have significant influence in the subsequent problem-solving tasks.

The study reported here investigates creativity and its relationship between problem-solving mindsets and problem-solving spaces. It attempts to replicate previous research with Legos, but in Minecraft. Creativity is assessed using common approaches, including the alternative uses test (AUT) and the Consensual Assessment Technique (CAT).

The findings of this study suggest a partial replication in Minecraft of the original Lego study. Specifically, the study concludes (1) participants in an open-ended task receive significantly higher creativity scores than the well-defined problem-solving group, and that well-defined tasks diminish creative performance in a free-play task. (2) the presence of explicit instructions have no significant influence on the creativity score of the following free-play tasks. And (3) Among variables like the level of skill/experience, interest, and material used in Minecraft, only interest level proves to be significant to the creativity score in the free-play (open-ended) task.

Keywords: Minecraft, Creativity, problem-solving mindset, divergent thinking, Lego
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CHAPTER 1: INTRODUCTION

Over the last several decades, educational games have seen increasing attention from researchers and use in practice (Shabalina, 2015; Sharples, 2015). Counter to earlier research that tended to focus on the potentially negative consequences of playing video games, more recent research has suggested possible benefits of playing games, including improvements in motivation, engagement, problem solving, creativity, and more (Granic, 2014; Connolly, et al., 2012). This body of research has laid a foundation for further study about specific games and how they may influence learners.

Although there are many educational games, Minecraft stands out because of its accessibility, popularity and educational features. Not only is Minecraft one of the most popular entertainment games in history (second only to Tetris in terms of number of copies sold; (Peckhman, 2016), it has also been rapidly adopted by teachers and educators all over the world (Pusey & Pusey, 2015). Minecraft is typically classified as a sandbox game, which opens up gameplay substantially by encouraging player-selected goals and provides seemingly infinite opportunities to explore and engage in creative activities (Brand, J., & Kinash, S.,2013). However, studies on the impacts of sandbox games, and Minecraft in particular, are only now beginning to emerge. The focus of this thesis is on how Minecraft may promote creativity in a STEM learning context, a skill often included in characterizations of 21st century skills (P21, 2012). The research reported here seeks to fill a gap in this literature, and help educators more appropriately deploy sandbox games to allow their students to explore their creativity and interests.

With the increasing popularity of Minecraft, teachers and educational institutions have adopted Minecraft as an educational environment for teaching various disciplines and training
multiple skills (Lane & Yi, 2017; Short, 2012). One of the most emphasized, but least studied, applications of Minecraft is as a tool to promote creativity. As a sandbox game, Minecraft provides a high degree of freedom, which, when combined with learning content in classroom may foster students’ creativity in terms of problem solving and divergent thinking. The relationship between Minecraft play and creativity represents a relevant and important area for research in the educational game space.

In the popular media and public discourse, Minecraft is often described as a form of “digital Legos.” Although intuitive, to what extent this is true is unknown. Broadly, the study reported here investigates this question. Specifically, it reports a partial replication of earlier work with Legos that investigated the relationship between task openness and creativity. The key findings from this work was that open-ended tasks (e.g., “build your dream house”) foster greater creativity than well-defined, more narrowly defined tasks that do not allow significant choices to be made by a learner (e.g., a typical lab experiment in high school with precisely defined steps). The research questions addressed here focus on (1) to what extent the openness of a task in Minecraft has a significant impact on students’ creativity (especially with respect to divergent thinking); and (2) determining whether findings in the context of Lego problem solving hold up in the Minecraft environment.
CHAPTER 2: LITERATURE REVIEW

This chapter introduces relevant background knowledge in several related areas. The first part discusses the benefits of educational games, introduces Minecraft, its game play and how it is used for educational purposes. The second section explores creativity, its definition, composition, and the relationship with problem-solving mindset. Finally, the chapter summarizes the Lego study that serves as the counterpart for the study reported in this thesis and describes how it influenced the Minecraft experiment design used in this thesis.

Educational games

Educational games, as revealed by the name itself, are video games designed for educational purposes, such as cognitive learning, social and emotional development, and metacognition. A large proportion of earlier research on games emphasized the impact of video games due to perceived (and largely unsubstantiated) claims that they promoted “aggression, addiction, and depression” (Granic, 2014). Research has rapidly evolved since this time and weakened the stereotype when researchers recently paid more attention to the positive sides of video games and explored its psychological mechanisms and educational value. For example, because video games can be used as digital learning environments, students are allowed to explore methods, concepts, and skills rapidly and safely within an environment designed with specific learning components. (Malliarakis et al, 2015).

The benefits of educational games

Educational game research is vast, and the use of games for learning covers substantial ground (Blumberg, 2014; Ritterfeld, et al., 2009). Generally, learning that may happen in games
is often a result of the games mechanics, which, in educational games, often include a simulation environment that provides a context for exploration, experimentation, observation, and play (Pusey, 2015). Further, good game designs can be used to promote learning and engagement, such as increasing difficulty level, feelings of flow, goal orientation, and timely feedback (Gee, 2003; Oblinger, 2004). These designs often enhance the intrinsic motivation of a learner, inducing feelings of success and competence (Blanco-Herrera, 2015), and incorporate established techniques for challenge, fantasy, curiosity, control, and competition (Malone, 1980). Bodnar (2015) suggests that while educational games often encourage a trial-and-error approach to learning, they also give rapid feedback and guidance. James Paul Gee, a pioneer in educational games research and literacy researcher, has said that games “create a sense of shared purpose and identity, bridging gaps – like those that otherwise form between teachers and students – around age and technology awareness” (Gee, 2004).

Research has repeatedly shown that well-designed educational games can foster increased engagement, motivation, collaboration, communication, problem-solving, spatial skills, persistence, as well as gaining the academic achievement in discipline of math, language, science, history and P.E (Young, 2012; Shute, 2014; Gee, 2003; Erhel & Jamet, 2013; Papastergiou, 2009; Van Eck, 2006; Wouters, van Nimwegen, van Oostendorp, & van der Spek, 2013).

**Minecraft as an educational tool**

*What is Minecraft?*

Minecraft is a sandbox game that simulates the natural world. The game is made up of blocks of a wide range of types, which the reason it is often described as a virtual form of
LEGOs. The game was first released by Markus Person in 2009, then officially published in 2011 by Swedish company Mojang. By early 2018, it has become the “second best-selling video game of all time”, proved by over 144 million copies sold across all platforms (PC, console, mobile devices and VR)\(^1\). With millions of students playing the game all over the world, Minecraft is not only popular as an entertainment game, but has already been adopted in educational settings around the world, both for traditional classroom and informal learning (Pusey, 2015). Researchers have explored a range of uses of Minecraft as a learning tool, often considering it an affinity space that may bridge gaps between informal and formal learning, teachers and students (Brand, J., & Kinash, S., 2013).

The game play of Minecraft

The name “Minecraft” reveals the nature of playing game fairly directly. Consisting of two parts – i.e., mine and craft – typical play involves doing both. 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 a variety of complex things, like bridges, buildings, machines, and artifacts. These allow a player to survive (when in survival mode) and complete achievements in the game.

As mentioned, the basic unit for interaction in Minecraft is the block. Blocks in various textures (sand, grass, wood, metal, etc.), forms (block, stair, slab), colors, functions (filter, Redstone, TNT, etc.), are included. Based on the vast range of different blocks (Figure 2.1), players are able to build and create almost anything they can imagine.

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\(^1\) Minecraft Wikipedia: https://en.wikipedia.org/wiki/Minecraft
Figure 2.1 A selection of blocks available in the world of Minecraft

On a bigger scale, Minecraft also includes procedurally generated maps, influenced greatly by the makeup of Earth. Various different biomes with unique properties are generated, such as forests, taigas, swampland, extreme hills, desert, plains, ocean, and tundra. Those different items largely expanded the diversity of the game play and increased the player’s interest for further exploration.

To customize the game and create more variation, Minecraft can be played (1) either by individuals or in groups (via a network), (2) in survival or creative mode, and (3) with one more of tens of thousands of mods (modifications to the basic, vanilla game). Survival mode gives players limited resources and requires them to defend themselves from hostile mobs, like creepers and skeletons. Creative mode offers an unlimited supply of resources, no need for food or chance of injury, and also allows the player to fly freely around the world. In the study reported below, it was necessary to decide which mode and resources were needed to best replicate the LEGO study. Finally, mods created by the large amateur communities provide the player with additional experience and features to the game like animals, guns, planes (Lastowka, 2011).

Players can do almost whatever they want in the game. For example, in the survival mode, they can build any kind of shelter or house to protect from the threats, manage a farm or

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ranch for food, mine deep under the ground for precious resources, go fishing, fight against the monsters like Ender Dragon (or not). In creative mode players typically engage in very large projects, such as constructing buildings, complex machines (Figure 4), or even recreate actual or fictional places, like the Hogwarts in Harry Potter (Figure 5). One can easily see the potential for creative expression in Minecraft, and the motivation for this thesis.

![Figure 2.2 Automatic farming machine that produces wheat, potatoes, and carrots](image)

**Figure 2.2** Automatic farming machine that produces wheat, potatoes, and carrots

![Figure 2.3 The Real Hogwarts mod in Minecraft](image)

**Figure 2.3** The Real Hogwarts mod in Minecraft

*The benefits of Minecraft for education*

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The open world presented by Minecraft simulates many real-world phenomena, including terrain, weather, oceans, animals, and more. It 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. Minecraft clearly provides a framework for self-selected goals, an extreme sense of control, and contains all of the ingredients known to promote intrinsic motivation. (Tichon & Tornqvist, 2016)

One of the most prominent features of sandbox games are their openness and the high degree of freedom (Brand, 2013). Minecraft is nothing but choices: exploring the diverse landscapes and biomes, crafting various new blocks, the ability to personalize, playing single player or with multiple players, playing in survival or creative mode, and modding. This extreme level of choice provides an appropriate context for creativity.

The openness of Minecraft also goes hand in hand with the notion of autonomy. The nature of sandbox itself enables players to achieve goals alone or together. Unlike many other entertainment games that introduce complicated and intense combat, mission, and rewards systems, Minecraft builds on fundamentally simple mechanics and activities and removes the pressure of winning and leveling up. In Minecraft, sharing through social interaction, construction, exploration, collection, and combat happen at a player’s own pace (Lane & Yi, 2017).

The application of Minecraft for education

Minecraft is already in use as an educational tool serving in a variety of roles all over the world (Minecraft Teachers, 2015; Short, 2012). Minecraft has been used to teach different
subjects almost in every academic field, ranging from STEM, social science to humanity and art. Educators and researchers have demonstrated that Minecraft can be used for spatial skills and geometry (Förster, 2012), sustainable planning (West & Bleiberg, 2013), language and literacy (Bebbington, 2014; Martinez, 2014; Hanghj, et al, 2014), Digital Storytelling (Martinez, 2014), social skills (Petrov, 2014), informatics (Wagner, 2014), digital art (Martinez, 2014), project management (Saito et al, 2014), and chemistry (Hancl, 2013). It is certainly safe to say Minecraft is flexible and adaptable to different uses, and for the purposes of this thesis, if it can be shown to enhance creativity while engaging students in these various disciplines, reasons to use it would only increase.

**Creativity and Minecraft**

Analysis of Minecraft and related areas of research suggests that it can act as a learning environment for promoting engagement, problem-solving, collaboration, exploration, and creativity (Lane & Yi, 2017). Preliminary research has shown that the openness and basic play of Minecraft does have positive effects on students’ 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, 2012); In one case study that a teacher use Minecraft as the tool to let students create the machinima for demonstrate their learning. The students learned the concepts of characterization and create story plots in the English literature class through playing Minecraft. Although there are no quantitative findings about Minecraft and creativity, the study shows that Minecraft is used to be the inexperience tools for participants to express their creativity. And the openness of Minecraft allows for experiment with various conceptions of characterization and plot as well. (Cipollone, Schiffter, & Moffat, 2014).
Creativity

Creativity is frequently regarded as an essential criterion to measure intelligence and talent, and of particular relevance for 21st Century Learning (P21, 2015). This section provides a brief introduction to the creativity and related issues, including the assessment of creative thinking, and prior work exploring the relationship between Minecraft and creativity.

Definition

Defining creativity is not a straightforward endeavor. This thesis relies on an understanding of creativity that has garnered the most support from researchers, but acknowledges that it is certainly not, and may never be, a settled question. The definition of creativity used here is multidimensional (Kim, 2006). It includes two broad kinds of creativity: Big “C” (sociocultural definition) and little “c” (individualist definition) (Sawyer, 2012).

Big C can be defined as follows: “Creativity is 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” (Amabile, 1996, p.35). This means only those products that have social approval, the solutions to serious problems, or significant works generated by genius or famous people could be marked as “Big C” creative work. For example, the Mona Lisa painted by Leonardo da Vinci and the universal gravitation raised by Newton are creative works in this sense.

The counterpart of Big C is “little c”, which is defined producing “a new mental combination that is expressed in the world” (Sawyer, 2012, p.7). In this case, creativity is not limited to geniuses and famous 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 the 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 – many have done this before, and it is not as good as using a brush, but it achieves a similar goal and is a creative solution.

*Divergent thinking Convergent thinking*

There are at least two ways of thinking that contribute to creativity: divergent thinking and the convergent thinking. Divergent thinking involves experimentation to identify and develop multiple ideas, each of which could possibly become a solution (Cropley, 2006). In contrast, convergent thinking “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 and evaluation of those ideas, which relies on convergent thinking (Lubart, 2001).

Minecraft can be considered as a tool that inherently promotes divergent thinking for players given its (1) openness (2) constructive nature and (3) emphasis on collaboration. With respect to how Minecraft might promote divergent thinking, players repeatedly synthesize information to make decisions and try different tactics. In Minecraft, they are able to look at the whole picture with multiple dimensions with the help of comprehensive perspectives (up, down, left, right, inside, outside, etc.) and different senses (audio and visual). Players fully explore the virtual world with a broad range of possible interactions in Minecraft (Lane & Yi, 2017), experience the trial and error and learn from failure (Green, G. P., & Kaufman, J. C., 2015), which makes the divergent thinking possible.

The hundreds of combinations of blocks provide further fuel for the argument that it promotes divergent thinking. Lastowka (2012) 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), for example.

Playing collaboratively in a multiplayer mode could further boost divergent thinking. Research has shown that creativity occurs both in groups as well as in individual work (Sawyer, 2012). By communicating with others, people are able to simulate the different way of thinking, including use of imagination, perception, and reasoning. Such collective capabilities are crucial to creativity (Shabalina et al., 2015). Note that the study reported here did not seek to leverage collaborative creativity, however it does represent an important potential future direction of work in the search for evidence-based practices in the deployment of Minecraft for education.

**Creativity and Problem-solving mindset**

When thinking of using creativity to solve problems from daily life, it is necessary to mention the problem-solving mindset that would affect our creativity. According to research on problem-solving mindsets, cognitive activities that relate to problem solving, like creativity, will sustain over time and contexts (Moreau, 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, i.e., “how a solver represents, or structures a given problem” (Newell and Simon 1972; Stokes, 2007), it is possible to control the different types of mindset and see how it influences creativity.

Recent literature suggests three components are relevant for understanding a problem space: (1) the initial state (problem itself), followed by (2) the set of operators (rules and strategies) that are deployed in sequence to proceed from the initial state to (3) the goal state (the
solution) (Sternberg, 2009). Well-defined and ill-defined (open-ended) problem spaces can be loosely thought of as aligning with convergent thinking and divergent thinking. That is to say, divergent thinking is associated with open-ended problems, problems that are open to interpretation (ambiguous), and unclear/unspecified operators. Then, convergent thinking is related to well-defined problems, which require a clear and specific initial state and operational instructions to reach the single correct answer. Based on connection between problem-solving and creativity theory, experiments can be run to set up which kind of mindset best promotes students’ creativity and their ability to solve problems creatively.

**Lego study**

This section describes the Lego and creativity studies that inspired this thesis (Moreau & Engeset, 2016). In this work, researchers tried to answer the questions implied by the previous section with respect to problem solving mindsets. Researchers decomposed the problem-solving space to the initial state, the operator and the goal state, and controlled the degree of openness of the task with the well-defined vs. open-ended group, in order to investigate the influence of activated problem-solving mindset on the following tasks in terms of creativity. (Moreau & Engeset, 2016)

Three progressive experiments are reported, with the first two playing the key roles in influencing the work reported here in Minecraft. The first experiment compared the different mindsets (well-defined task vs. open-ended task vs. control) and their influence on a subsequent task (open-ended vs. well-defined). In the study, the Analogy Test and TTCT test in creativity were used. 136 undergraduate students participated. The findings showed that (1) a well-defined mindset (Lego kit with instruction, clear goal) diminishes performance on a subsequent open-
ended task (Lego bricks without instruction, unclear goal). While (2) an open-ended mindset decreases performance on a subsequent well-defined task but has little influence on performance in a subsequent open-ended (creative) task. They also collected data about other related factors that might related to the creativity, including the cognitive depletion (number of correct anagrams), affect (negative and positive), tolerance for ambiguity and sense of accomplishment, however, their effect on creativity is insignificant or marginal significant.

In the second Lego experiment, they used a $2 \times 2$ design (instructions: present vs. absent; and outcome: present vs. absent) and used the AUT assessment and index of enjoyment (Dahl and Moreau, 2007). According to the authors, (1) when participants were given a clear goal state in the first task (Lego kit with completed image for the goal) produced significantly less original ideas in the second task than those for whom the goal state in the first task was uncertain. (2) Having known set of operators (instruction present) in the first task did not significantly influence their creative performance on the second task. When the outcome of the task was presented (a clear goal state), a detrimental impact on creativity was observed. Other findings, but less relevant for the Minecraft study reported below, included an insignificant influence on the originality of creativity and task enjoyment. People tended to more enjoy the process of completing the task with specific instructions and unclear goal.

**Research questions**

In order to investigate to what extent the Lego study would translate to a Minecraft context, this study sought to replicate part of the design in Lego study and see (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 following an open-
ended task. And (2), whether the result of Lego study about problem-solving mindset and creativity could be reproduced in Minecraft. That is, whether step-by-step instructions are insignificant to creativity present in a second task.

This work is driven by three hypotheses:

H$_1$. *There is a positive relationship between open-ended problem-solving tasks and divergent thinking in Minecraft.* This means the creativity score would reflect a significant difference between well-defined tasks and open-ended tasks. People start with the open-ended tasks would have a better performance in the later free-play task than with well-defined tasks.

H$_2$. *Minecraft play and Lego are comparable in terms of their effect on creativity.* In other words, the experiment result of Lego will be replicable in Minecraft. That is to say the presence of a known set of operators (conveyed as instructions) has little influence on subsequent creative performance.

H$_3$. *The creativity score will have a significant positive relationship with the level of interest, skill/experience of the participants as well as the number of different types of material used to build the product.* Participants in high level of interest or skill/experience or material used would get significant higher creativity score (CAT and AUT) comparing to those in low level of skill/experience, interest or material.
CHAPTER 3: METHOD

The Minecraft study (reported here) combined the study 1 and study 2 of Lego study, where they both provide the open-ended and well-designed problem-solving mindset in the first task of playing Lego or Minecraft, then followed with the second task and test their creativity with the measurements like TTCT, AUT or CAT. Here, the experimental procedure is simplified by ignoring the measurements that have distant relationship to creativity, like assessing the enjoyment and focus on the relationship between problem-solving space (initial state, operators, goal state) and subsequent task performance in creativity score. Apart from that, the second task was modified such that all participants needed to accomplish the free-play task in 15 minutes and regarded the product they created as the source of evaluation their creativity level. In other words, we used AUT assessment like as in the Lego study, with another measurement added, the CAT, to verify the result.

Participants

To test these hypothesis, 48 undergraduate students from University of Illinois, Urbana-Champaign volunteered. 42 were determined to fit the requirement of having basic experience with Minecraft. After finishing the experiment, each student received a $10 Amazon gift card in return for their participation.

Study design and procedure

Each participant began with (1) a 4-minute survey, which included their demographic information, their interest in and experience with Minecraft. Next, participants (2) completed the first 15-minute problem-solving task in Minecraft, which was randomly assigned either well-
defined task (group 1) or open-ended task (group 2) with the material provided. Next, they completed (3) the AUT test (that asked for uses of a paperclip in 3 minutes), and ends with (4) a second 15 minute session of free play in Minecraft (to build anything at all). The whole experiment took roughly 40 minutes to complete. AUT responses help assess divergent thinking and screenshots and saved game maps of the product they created in Minecraft would be collected for CAT grading.

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<tr>
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<th>Step 1</th>
<th>Step 2</th>
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<td>15 min</td>
<td>3+15 min</td>
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<td>well-defined task</td>
<td>Survey</td>
<td>step-by step instruction</td>
<td>AUT (paperclip)</td>
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<td>“build the house” (with picture)</td>
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<td>open-ended task</td>
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<td>“build something”</td>
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**Table 3.1** Procedure of Minecraft study

**Instruments & Procedure**

Assessing creativity

Among a variety of creativity assessments, **consensual assessment technique (CAT)** (Amabile, 1982, 1983, 1996) and **Alternative Uses Test (AUT)** (Christensen, Guilford, Merrifield, & Wilson, 1960) are common choices for judging students’ levels of creativity. CAT falls in the category of “the judgement of creative product”, which is considered one of the best measurements of creativity in terms of reliability, discriminant validity, and nomological validity. The AUT assessment belongs to “the tests of divergent thinking”, which is correlated and possibly causally related to the creativity (Hocevar, 1989).
Survey

The survey consisted of 10 questions covering their frequency, history, preferences, motivation, skills, as well as their history with Minecraft.

Problem-solving task

For the problem-solving task, the participants were situated in the Minecraft environment with a basic landscape. They were provided with introductory information about Minecraft and asked to play around for a second and get used to the operation.

Then, participants were randomly assigned to either a well-designed task or an open-ended task. Participants in the well-defined task followed the step-by-step instructions and a clear order to “follow the step-by-step instruction, build the house with the bricks in the chest” with picture. The material used was exactly sufficient for the construction to the sample house (using 10 kinds of blocks).

Participants in the open-ended task were assigned an open-ended task, with no instructions but were given a picture of the desired result. They received an ambiguous order “build a house like the sample, with the bricks of your own choice”. A chest with varied materials (64 kinds of blocks) were provided for the participants to build products.
The Alternative Uses Test (AUT) is a divergent thinking test that measures the subject’s ability to come up with a wide range of solutions to a single problem in a fixed amount of time. To be specific, it asks participants to generate as many uses as possible for a common household object (Guilford, Merrifield, and Wilson 1958). In this study, participants were asked to “list the different uses of the paperclip as much as possible in three minutes”. The data were collected for assessing divergent thinking and three independent raters judged whether the answer is appropriate (whether it is reasonable), unusual (5% of the group mentioned) or unique (1% of the group mentioned) based on the example of AUT official manual, which makes it easier to make evaluation. The standard to decide whether the response is appropriate is presented to three judges in the, Agreement between the raters was calculated. The task performance would be assessed based on four aspects:
1. originality that statistically uncommon when compared to responses to the overall data set,
2. fluency that indicated by the quantity of the response
3. flexibility which means the number of different categories, and
4. elaboration that refers to the amount of detail (Guilford, 1967).

In this study, we implemented the fluency that measured by counting the amount of different appropriate uses written by the participants, and the originality which measured by the frequency of its occurrence across participants. Two judges independently computed these AUT scores. When judges disagree with each other, the score was determined by the third judge.

For example, if a participant come up with 15 answers to the AUT assessment, 10 of them are judged as the appropriate answer, gain 10 points for fluency. Among those 10 answers, only 2 of them are “unusual” and 1 of them are “unique”, which means there are two answers that was mentioned less than three people (5% of the group), and one response that was mentioned only once among 48 participants, then the participant could earn $2 \times 1 + 2 = 4$ points for originality. And the AUT for this participant is to add the fluency and originality score together, that is $10 + 4 = 14$ points.

**CAT Assessment**

The consensual assessment technique (CAT) asks experts to rate the creativity of a collection of products by comparing them with one another individually and without outside guidance (Amabile, 1982). The CAT based on the definition of little “c” and the intuitive theory that the combined assessment of experts in certain field is the best measure of the creativity of a product. The product would be measured by more than three experts who was used their own
professional sense of what is creative in a domain (Baer, 2012). The CAT is examined to have fairly good inter-rater reliability, which is generally in the .80–.90 range (Whitney, & Amabile, 1998). The testing objects are quite fit in the range of the CAT, that are to judge the creativity of (a) students’ research designs or theories in science, (b) their artistic creations (Baer, 2009), which make it suitable for assessing the students’ in-game creation.

All participants were given the free-play problem-solving task in Minecraft at the end, with the result graded via the CAT assessment by experts. All the participants were log in the Minecraft and build anything they want with the material in the two chests (128 kinds of blocks) in 15 minutes. The products were evaluated by three experts in Minecraft. They made judgement 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).
CHAPTER 4: RESULT

Survey

Among 42 undergraduate students that participated the Minecraft study, 74% of participants were male, and 26% female. Two main categories were used for this analysis (1) the skill/experience level representing general video game experience and skill/familiarity with Minecraft, and (2) the interest level and motivation to play Minecraft. Unsurprisingly, skill/experience level had a high correlation to interest level (r=.70), which suggested the more they played Minecraft, the more they likely to engage and like playing the game.

The survey revealed that 55% of participants played Minecraft less than 3 years, 60% of them played less than once a month, although some of them played a lot when they were young. And participants are more familiar with basic operation like planting seeds and harvesting the crops (4.04/5), collecting/mining resources (4/5), crafting the tools (3.98/5), fighting the mobs (3.96), planning and designing buildings (3.79/5), but unfamiliar with advanced skills like using red stone (2.55/5), command blocks (2.35/5), and creating/maintaining a server (2.26/5).

In their skill/experience category, 40% of them had little difficulty with basic Minecraft operation and finished their designed product within 15 minutes. 36% of them have plenty of experience playing Minecraft, 24% of them could arguably be labeled as Minecraft “experts”. In terms of current appeal (likeness) of Minecraft than rate by 1-10, 19% of them gave a score under 6 points, 55% of them like Minecraft (7-8 points), 26% of them suggest highly interested in Minecraft that over 9 points. In terms of motivation for playing Minecraft, 93% of them think it’s “fun/ interesting”, 79% of them choose “play with friends”, which means Minecraft as a social tool and helps them collaborate with others, 48% of them state Minecraft is “easy”, and 19% of them choose “others are playing it”, which means peer pressure and external motivation
for playing the game. Other points that written by the participants includes “freedom” (14%), “create” (10%), “mods” (7%), “openness” (5%), “childhood gaming experience” (5%), “Redstone” (2%), “knowledgeable” (2%).

One comment from the survey highlight the close relationship between Minecraft and learning. A participant answered the motivation of playing Minecraft: “I've learned about chemistry, computer programming, gear ratios, nuclear reactors, and so much more with mods. I also started to develop an interest in EE when learning about red stone and using logic gates, which is partly why I'm in ECE now.” In this case, the influence of Minecraft not only rests on the virtual knowledge content it provides for students, but it becomes an engaging environment that promote their learning interests and even their academic development.

**H1: Well-defined mindset vs. Open-ended mindset on creativity performance**

To test if there is significant difference on creativity score between the two kinds of problem-solving mindsets discussed above, creativity score of both groups were assessed using the CAT and AUT. For the CAT assessment, scores were found to be normally distributed, thus meeting the requirement for a two-sample unequal variances t-test. AUT scores with 42 participants did not fit the normal distribution (p=0.04<0.05 in Shapiro-Wilk normality test), meaning hypothesis verification for the two groups required non-parametric testing, such as the Mann-Whitney U test (basing it on the continuity correction of the rank in group).

<table>
<thead>
<tr>
<th></th>
<th>well-defined task</th>
<th>open-ended task</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAT</td>
<td>M    SD   n</td>
<td>M     SD   n</td>
</tr>
<tr>
<td></td>
<td>5.06 1.58 22</td>
<td>6.05 1.42 20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>t  p    df</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.14* 0.038* 40</td>
</tr>
</tbody>
</table>

**Table 4.1** CAT score of well-defined task vs. open-ended task

Note: α=0.05. Three experts graded the products of all the participants (range 1-10) individually, and the CAT score for each individual was the mean of the three raters.
In the CAT × (well-defined vs. open-ended mindset), three raters evaluate the 42 participants’ creativity based on the screenshots of their products individually. The overall inter-rater reliability (irr=0.52) and the correlation between the three raters (R1, R2= 0.57; R1, R3=0.50; R2, R3=0.40) are acceptable based on the subjective nature of CAT grading. The t-test was conducted to assess the effects of well-defined task and open-ended task on participants’ CAT mean score among three judges. 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= 0.039 <0.05, Cohen’s d=0.66). That is to say, the main effect of the problem-solving mindset on CAT score was significant. The open-ended task gained significant higher CAT score than the well-defined task in the following creative free-play task.

<table>
<thead>
<tr>
<th>Tasks</th>
<th>N</th>
<th>Mean Rank</th>
<th>Sum of Ranks</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUT</td>
<td>22</td>
<td>24.18</td>
<td>532</td>
</tr>
<tr>
<td>1</td>
<td>20</td>
<td>18.55</td>
<td>351</td>
</tr>
<tr>
<td>Total</td>
<td>42</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4.2 AUT score of well-defined task vs. open-ended task (Mann-Whitney U test)

In the AUT × (well-defined vs. open-ended mindset), Mann-Whitney U test suggested an insignificant result that the well-defined group get higher mean (M=10.68) than the open-ended task (M=8.55), with U=161, W= 279, p-value = 0.14>0.05(insignificant). That is to say, 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, although the well-defined mindset suggested a higher score in average than the open-ended group. Additionally, the difference significant influence of the well-designed task and open-ended task on AUT and CAT score in is worth continued investigation.
**H2: Instruction present vs. instruction absent space on creativity performance**

In the Lego study, the creativity score was examined by the two indicators in AUT assessment, the fluency and originality, which could be compared with those data in Minecraft study. Both studies contained the 2 (instruction: present vs. absent) × (outcome: present) between-participants experiment that evaluated the participants’ divergent thinking with AUT assessment. After testing the Shapiro-Wilk normality test of fluency and originality, we found that the fluency is normally distributed (p=0.08>0.05, W=0.95) while the originality scores were not (p=0.001<0.05, W=0.90). Therefore, we tested the fluency with ANOVA and the originality with Mann-Whitney U test.

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluency</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>12.595</td>
<td>1</td>
<td>12.595</td>
<td>1.967</td>
<td>0.169</td>
</tr>
<tr>
<td>Within Groups</td>
<td>256.19</td>
<td>40</td>
<td>6.405</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>268.786</td>
<td>41</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 4.3** one-way ANOVA of the Fluency and problem-solving task

<table>
<thead>
<tr>
<th>task</th>
<th>N</th>
<th>Mean Rank</th>
<th>Sum of Ranks</th>
<th>Test Statistics b</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUT</td>
<td>1</td>
<td>21</td>
<td>25.24</td>
<td>142</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>21</td>
<td>17.76</td>
<td>299</td>
</tr>
<tr>
<td>Total</td>
<td>42</td>
<td></td>
<td>530</td>
<td>1.96215</td>
</tr>
</tbody>
</table>

**Table 4.4** Mann-Whitney U test of Originality and problem-solving task

When we look at the fluency in AUT assessment, both Lego and Minecraft study (F (1,40) = 2.07, p=0.17>0.05) suggested no significant effects on fluency. Incidentally, in the corresponding Lego study, instructions had no significant influence on originality (F (1, 132) = .19, n.s.). On the other hand, Mann-Whitney U test proves that the well-defined task (instruction present) has no significant higher influence on the originality in Minecraft
environment (p = 0.05, n.s., W=299). That is to say, the presence of instruction has no significant impact on the fluency and originality in the subsequent free-play tasks, which is consistent in Lego and Minecraft study.

<table>
<thead>
<tr>
<th>Outcome: Present</th>
<th>Instructions: Present</th>
<th>Instruction: Absent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lego</td>
<td>Fluency: 5.59 (1.96)</td>
<td>Fluency: 5.29 (2.39)</td>
</tr>
<tr>
<td></td>
<td>Originality: 1.21 (1.27)</td>
<td>Originality: 1.32 (1.79)</td>
</tr>
<tr>
<td>Minecraft</td>
<td>Fluency: 7.48 (2.80)</td>
<td>Fluency: 6.38 (2.22)</td>
</tr>
<tr>
<td></td>
<td>Originality: 3.05 (2.18)</td>
<td>Originality: 1.86 (2.08)</td>
</tr>
</tbody>
</table>

**Table 4.5** The comparison between Lego and Minecraft study in the AUT score and problem-solving space

Notes: In AUT task, the fluency indicates the number of different uses that participant generated, and the originality refers to the novelty of the response. The grading procedure was followed the instruction by Guilford (1967). Values are means, with standard deviations in parentheses. The table compared the fluency and originality score of the experiment (instruction: resent vs. absent) × outcome present between Minecraft and Lego study.

If we have a close look at the details like means and standard deviations. Both Lego and Minecraft study suggest that instruction present group (well-defined problem-solving mindset) got higher fluency and originality score in average. (see Table 4.5 above) In other words, given the specific instruction in the first task, although insignificant, but have higher AUT score in average in the following free-play task than those who don’t have instruction.

<table>
<thead>
<tr>
<th></th>
<th>fluency</th>
<th>originality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lego</td>
<td>Mean: 5.79</td>
<td>Mean: 1.14</td>
</tr>
<tr>
<td></td>
<td>SD: 2.71</td>
<td>SD: N/A</td>
</tr>
<tr>
<td></td>
<td>Range: 7~17</td>
<td>Range: 0~10</td>
</tr>
<tr>
<td>Minecraft</td>
<td>Mean: 6.93</td>
<td>Mean: 2.45</td>
</tr>
<tr>
<td></td>
<td>SD: 2.56</td>
<td>SD: 2.19</td>
</tr>
<tr>
<td></td>
<td>Range: 2~12</td>
<td>Range: 0~9</td>
</tr>
</tbody>
</table>

**Table 4.6** The comparison between Lego and Minecraft study in AUT assessment

We can see in the Table 4.6 that, in the Lego study, the fluency, indicates the amount of qualified response to the uses of the paperclip, has the mean of 5.79, ranging from 2-17, with standard deviation of 2.71. While in Minecraft study, the fluency has the mean of 6.93, ranging from 2-12 and sd = 2.56, with less range, higher mean and lower standard deviations. For the
originality, the Minecraft study got better performance (M=2.45, range: 0-9, sd=2.19) than those in Lego study (M = 1.41, range: 0–10).

To sum up, although the range of Lego study is larger than Minecraft, participants in Minecraft study suggests higher fluency and originality in general than the Lego study. In other words, the participants in Lego study could get high AUT score while the Minecraft study excels in the group performance.

**H₃: The relationship between variables and creativity score**

Apart from the comparison between Minecraft and Lego study in H₁ and H₂, we consider three variables that might have effects on the creativity score, i.e., (1) the skill/experience level, (2) the interest level and (3) the different types of blocks used in game. All the data were quantified and divided into high and low level in two categories, i.e., the skill/experience and interest of Minecraft. To test the H₃ if there are any relationship between the variables and their creativity score, the t-test were conducted to three groups of comparison. i.e., CAT× (low skill/experience level vs. high skill/experience level), CAT× (low interest level vs. high interest level), and CAT× (low material level vs. high material level).

<table>
<thead>
<tr>
<th>CAT score of different level of skill/experience, interest and material</th>
<th></th>
<th></th>
<th>t</th>
<th>p</th>
<th>df</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>low level</td>
<td></td>
<td>high level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skill</td>
<td>M</td>
<td>SD</td>
<td>n</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td></td>
<td>4.91</td>
<td>1.87</td>
<td>17</td>
<td>5.95</td>
<td>1.18</td>
</tr>
<tr>
<td>Interest</td>
<td>5.08</td>
<td>1.63</td>
<td>22</td>
<td>6.02</td>
<td>1.38</td>
</tr>
<tr>
<td>Material</td>
<td>5.21</td>
<td>1.69</td>
<td>19</td>
<td>5.79</td>
<td>1.45</td>
</tr>
</tbody>
</table>

**Table 4.7** CAT score of different level of skill/experience, interest and material

Note: α=0.05. Each participant was labeled with high or low level of skill/experience, interest and material individually.

It’s obvious in the Table 4.7 that those who have low level of skill/experience got lower CAT score (M=4.91) than those who are of high level of skill/experience (M = 5.95; t = -2.03,
p = 0.05 (insignificant)). The same with the different types of blocks used in building the product also suggest a higher CAT score in high level of material (M=5.79, t=-1.19, p=0.24>0.05 (insignificant)) than those in low level of material (M=5.21). For the test of interest level, which got Mean of 5.08 for low level group and M=6.02, t=-2.01, p=0.049 (significant) for high level group, Cohen’s d=0.62 (medium).

The result turns out that only the participants with higher interest would have a marginal significant effect on CAT score. For the level of skill/experience and material used, there is an insignificant difference in CAT score between high and low level of skill/experience and material, although the mean of high level group of skill and material suggest higher CAT mean than those in low level groups. Those findings prove that the variables like skill/experience of playing Minecraft, using more diverse material to build the artifacts have no significant influence on CAT score.

<table>
<thead>
<tr>
<th>AUT score of different level of skill/experience, interest and material</th>
<th>low level</th>
<th>high level</th>
<th>t</th>
<th>p</th>
<th>df</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skill</td>
<td>M=9.47</td>
<td>M=9.80</td>
<td>-0.23</td>
<td>0.818</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td>SD=4.09</td>
<td>SD=5.11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>n=17</td>
<td>n=25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interest</td>
<td>M=8.27</td>
<td>M=11.20</td>
<td>2.10*</td>
<td>0.042*</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>SD=4.17</td>
<td>SD=4.82</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>n=22</td>
<td>n=20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material</td>
<td>M=9.68</td>
<td>M=9.65</td>
<td>0.02</td>
<td>0.982</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>SD=4.27</td>
<td>SD=5.08</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>n=19</td>
<td>n=23</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4.8 AUT score of different level of skill/experience, interest and material

Note: α=0.05

Correspondingly, we did the same t-test for each of variables in AUT test. Both the skill/experience (M\textsubscript{low}=9.47, M\textsubscript{high}=9.80, t=-0.23, p=0.82>0.05 (insignificant)) and the material level (M\textsubscript{low}=9.68, M\textsubscript{high}=9.65, t=0.02, p=0.98>0.05 (insignificant)) have insignificant difference in turns of AUT score of the next free-play task. While the interest level has significant influence on the AUT test, with M\textsubscript{low}=8.27, M\textsubscript{high}=11.2, t=-2.10, p=0.04<0.05 (significant), Cohen’s
d=0.65 (medium), which means participants who have high level of interest on Minecraft would have significant higher AUT score in the following free-play task.

When comparing the CAT and AUT assessment together and see if the variables other than the problem-solving mindset that could have influence on participants’ creativity, we can conclude from the Table 4.7 and Table 4.8 that both skill/experience level and the material level do not have significant influence on their creativity while there is a significant difference between high level of interest and low level of interest in terms of AUT and CAT assessment.
CHAPTER 5: DISCUSSION

Creativity has now seen a consistent focus from researchers now for over 50 years (Sawyer, 2012), with much of it looking at how to enhance creative thinking. Since creativity required for problem-solving would form the mindset that have long lasting effects on people’s thinking and behavior (Smith 1994), the method of this thesis emphasizes problem-solving mindsets used in a priming task (well-defined or open-ended) and its impact and influence on a following creative activity. We argue that participants who given the well-defined problem-solving task would form the well-defined mindset that influence their way of thinking creatively, which is different from the performance of participants with the open-ended mindset. The previous study showed that (1) well-defined mindsets hinder the creativity performance on a following open-ended task (Lego study 1) and (2) given step-by-step instruction have little influence on the divergent thinking of the subsequent creative task. (Lego study 2). And results of Minecraft study partially replicate earlier work with Legos, suggesting that open-ended tasks lead to higher levels of creative on subsequent performance.

In this study, two hypotheses were raised corresponding to the two conclusions in the Lego study. The intent of these hypotheses was to investigate whether, and to what extent, the findings would hold up in Minecraft. If so, it would lend credence to the often-made suggestion that Minecraft is a “digital form” of Legos.

According to the results of the t-test we accept the hypothesis of H1. The result of CAT assessment indicates that there is a significant difference between well-defined task and open-ended task, and the mean of the open-ended task is higher than the well-defined one. However, the significantly higher CAT scores for open-ended mindset, which is disproved by the insignificant higher AUT score for the well-defined mindset. Suppose the creativity difference
does exists between the well-defined mindset and open-ended mindset, there should have same tendency among various assessments. While in this case, we can see both TTCT and CAT suggest the significant higher creativity score in the open-ended mindset, which confronted by the insignificant, higher creativity score of the well-defined task in AUT assessment. This could be explained to the different assessments, the significant result from Lego study 1 is measured by TTCT, with the index of Originality, Abstractness and Elaboration, which is different from the CAT and AUT measurements in Minecraft environment. And for the AUT assessment that was used in Lego study 2, although it was designed to compare the creativity difference between instruction (present vs. absent) and outcome (present vs. absent), it suggested the same higher AUT score of the well-defined mindset than the open-ended mindset, which consisted with the findings in Minecraft environment. 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.

We can accept the $H_2$ since Lego and Minecraft study reach the agreement that there is no difference between the instruction present or absent, according to the two indicators, fluency and originality of AUT, which means given a clear instruction dose not closely related to lower creativity level in the subsequent problem-solving task.

Based on the comparison between Lego and Minecraft study about the two hypotheses, we can conclude that the result of Lego study is comparable and able to reproduce in the Minecraft environment. The result suggests that considering Minecraft a virtual form of Lego is a reasonable metaphor to use.

Besides the two hypophyses that verify the Lego study, the Minecraft study also explored the relationship between other variables like the different levels of skill/experience, interest and
material. The H3 was rejected because the level of skill/experience and material got insignificant result of both CAT and AUT test. Although most of them have nothing to do with the creativity score, the data did show significant difference of the creativity score between the low interest level and the high interest level, which indicates that participants who have high interest in Minecraft, are likely gain more creativity score than those who have low interest in Minecraft.

**Implication**

The results of this study could be relevant to how instructors choose to use Minecraft. For example, when possible, more open-ended tasks might be best. Students might enjoy it more (than being on rails) and there may be downstream consequences on their creative thinking. Minecraft provides many STEM-relevant opportunities, and thus the chance to explore creativity in a STEM context could be highly appealing to educators.

Also, 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 prefer open-ended. The relationship between these two, learning, and creativity could be a good next study.

Another idea is to extend the comparison between Lego and Minecraft (digital version of Lego) and their effects on creativity. Although conclusions cannot be reached by comparing the AUT scores of the Legos and Minecraft studies, it is interesting to note that students in the Minecraft study had higher AUT scores (Table 4.6). Based on the comparison between tangible vs. digital Lego, it would be valuable to pursue mutual and cumulative impacts on each of them and see if there any potential significant differences between their influence on creativity. For example, the Lego may be specialized in the reality-based interaction (Horn & Jacob, 2007),
which makes it more easily to transfer the knowledge and be accepted by students. While the Minecraft may have the advantage of the infinite material, hundreds of combinations, and the advanced functions in STEM field by using the Redstone and Command blocks, which enable unlimited fun, exploration and expression of their creativity.

**Limitations**

For CAT assessment, comparing to the range of inter-rater reliability (irr=0.8~0.9) for CAT test in general, the Minecraft CAT (irr=.52) is relatively low, this may result from the inconsistent standard for the screenshot for judgment. Some inconsistency was present in how the data was presented to raters, which could easily be corrected in a second analysis of the data. It also could because of the incomprehensive judgment of the game artifacts, raters only do the grading based on the two-dimensional screenshots while some creative consideration could more expressively presented by logging to the game file and evaluate in the three-dimensional dynamic way. And the inconsistent skill/experience and interest level of the participants also affect their creative performance in Minecraft environment. Some creative participants cannot fully present their creativity due to their limited skill to use Minecraft as a tool, which is also be a reason for the low correlation between CAT and AUT assessment.

The biggest drawback of the Minecraft research lies in the AUT assessment. Participants are not given the standard for answering the question, like the example of the appropriate answer in AUT manual, which makes them generate a bunch of invalid responses and largely effected the reliability and validity of the AUT result. One of the most obvious evidence is the answer to the AUT test is not conform to the normal distribution.
Another question results from the participants. Participants in this study are the undergraduate students in University of Illinois, which indicates a relatively high intelligent group. Based on the structure of Intellect from Guilford (1971), the divergent thinking level of the participants are closely associated with their intelligent level, and thus, the result could be selective in the group. What’s more, 74% of male and more than half of them are major in STEM field, and other majors include education, business/ economics, and art/design. Since we have little idea about the connection between different disciplines and their creativity performance, and the judging standard in their areas may diverse, we can only say that the Minecraft study is valid in this certain group, which may have bias comparing to the creativity level in population.
REFERENCES


# APPENDIX A: IRB APPROVAL

## University of Illinois at Urbana–Champaign

## Institutional Review Board Office
528 East Green Street, Suite 203, MC-419
Champaign, IL 61820
E-mail: irb@illinois.edu 
Web: www.irb.illinois.edu

# IRB Application for Exemption

Application for Review of Research Involving Human Subjects

All forms must be completed, signed by the RPI, and submitted by FAX, Email, or single-sided hard copy.
Please type responses; handwritten forms will not be accepted.
Please, no staples!

- Initial Submission
- Revised IRB-1, date of revised IRB-1

1. RESPONSIBLE PROJECT INVESTIGATOR (RPI) The RPI must be a nonvisiting member of UIUC faculty or staff who will serve as project supervisor at UIUC. For other research team members [including those from other institutions], please complete the Research Team Attachment and provide with the completed application. Include all persons who will be 1) directly responsible for the project’s design or implementation, 2) recruitment, 3) obtain informed consent, 4) involved in data collection, data analysis, or follow-up.

<table>
<thead>
<tr>
<th>Last Name: Lane</th>
<th>First Name: H Chad</th>
<th>Academic Degree(s): PhD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dept. or Unit:</td>
<td>Office Address:</td>
<td>Mail Code: 708</td>
</tr>
<tr>
<td>Educational Psychology</td>
<td>226B Education Building</td>
<td></td>
</tr>
<tr>
<td>Street Address:</td>
<td>City: Champaign</td>
<td>State: IL</td>
</tr>
<tr>
<td>1310 S Sixth St</td>
<td>Zip Code: 61820</td>
<td></td>
</tr>
<tr>
<td>Phone: 217-333-2245</td>
<td>Fax: n/a</td>
<td>E-mail: <a href="mailto:hclane@illinois.edu">hclane@illinois.edu</a></td>
</tr>
</tbody>
</table>

- UIUC Status: Nonvisiting member of (Mark One) ☒ Faculty ☐ Academic Professional Staff
- CITI Training, Date of Completion, 3/10/2015
- Additional training, Date of Completion 1, Research with children: 4/26/2015

2. PROJECT TITLE

Creativity Differences Between Open-ended and Well-defined Tasks in a Virtual Environment

3. Please review the six [6] categories of exemption listed below and indicate the category or categories that apply to your research. [Note: Exempts do not apply for prisoners, or for research that specifically targets persons who are cognitively impaired or persons who are economically or educationally disadvantaged.]

- ☒ 1. Research conducted in established or commonly accepted educational settings, involving normal educational practices, such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
- ☐ 2. Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation.
- ☐ 3. Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office, or (ii) federal statute(s) requires(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.

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Additional CITI modules may be required depending on subject populations or types of research. These include: (i) research enrolling children; (ii) research enrolling prisoners; (iii) FDA regulated research; (iv) data collected via the internet; (v) research conducted in public elementary/secondary schools; and, (vi) researchers conducted in international sites

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University of Illinois at Urbana-Champaign
Institutional Review Board
Approved March 6, 2018
IRB # 17618

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4. Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available or if the information is recorded by the investigator in such a manner that subjects cannot be identified, directly or through identifiers linked to the subjects. [Note: to be eligible for this exemption, all data, documents, records or specimens must exist prior to IRB review and must have been collected for purposes other than the proposed research. To qualify for an exemption in this category, the proposed research must be strictly retrospective.]

5. Research and demonstration projects which are conducted by or subject to the approval of department or agency heads. The program must deliver a public benefit or service (e.g., Social Security Act or Older American Act). Such research or demonstration projects must be conducted pursuant to specific federal statutory authority; there must be no statutory requirement that the project be reviewed by an Institutional Review Board and the project must not involve significant physical invasions or intrusions upon the privacy of participants.

6. Taste and food quality evaluation and consumer acceptance studies, (1) if wholesome foods without additives are consumed or (2) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the Food and Drug Administration (FDA) or approved by the Environmental Protection Agency (EPA) or the Food Safety and Inspection Service of the U.S. Department of Agriculture (USDA).

If the proposed research does not qualify in any of these categories, please complete the IRB-1 application found at: www.irb.uiuc.edu

4. Research Summary: Please summarize, in lay language, the objectives and significance of the research.

With the increasing popularity of Minecraft, teachers and educational institutions are using Minecraft as an educational tool for teaching various disciplines and training multiple skills. One of the most eminent application is using Minecraft to promote students’ creativity. This study tries to replicate the LEGO study in Minecraft environment, to see if the experiment result of Lego could reproduce in the Minecraft environment. Secondly it investigated the relationship between the openness of Minecraft task and its effects on students’ creativity, especially in divergent thinking. The finding of this study may beneficial to the educational game design and increase students creativity.

5. Participants: Describe who will participate in the research and how they will be recruited.

The target group of the study is the undergraduate student, with basic experience with Minecraft in the University of Illinois at Urbana Champaign. The participants will be asked to complete an online survey about your Minecraft playing habits and demographic information. They will receive a one-time virtual $10 Amazon gift card upon completion of survey AND two 15 minutes Minecraft playing. The prescreening should take 7 minutes. The problemsolving tasks in Minecraft should take 30 minutes, the AUT assessment would take 3 minutes. The participants will receive the Amazon gift card payment from email by the end of April.

6. Research Procedure: Specifically describe what the participants will do and where the activities will take place. Outline the approximate dates and durations for specific activities, including the total number of treatments, visits, or meetings required and the total time commitment. Please include a copy of each of your measures as attachments.

The participants are being asked to be a subject in a research study about creativity and Minecraft. They will be asked a series of 10 questions about your demographic information and Minecraft habits in 6-7 minutes. The target group would go on and take two problem-solving tasks playing Minecraft, each of them take 15 minutes. And they would take AUT assessment for 3 minutes. Each of those visits will take about 40 minutes in total.
The participants are the undergraduate students at the University of Illinois at Urbana-Champaign with basic knowledge about the operation of Minecraft. This research will be performed at the University of Illinois at Urbana Champaign. More details can be found in the full proposal document.

Related file
Yue Fan_survey_question
Yue Fan_problem-solving task_design
7. Data Collection: Please explain how confidentiality will be maintained during and after data collection. If applicable, address confidentiality of data collected via e-mail, web interfaces, computer servers and other networked information.

All data collected in this study will be fully confidential. In many cases, we will audio and digital data of interaction with the software. All such collection will be carefully explained in informed consent scripts (assuming assent). These will be provided before any studies are conducted.

Computers used in the studies will log interactions with the system, including actions, timestamps, and events in the software. No information about the player will be collected. Free-text input will be possible given how Minecraft functions. Players will use research accounts rather than their personal Minecraft accounts. The researchers will take notes during the observation and interview with each participant and will prepare a written summary afterward. Any potentially identifying information will be excluded from the written summary.

All notes and survey or test forms will be stored in folders on site with the researchers and in our presence at all times. Data will be transported securely, being stored by usual means within the sites in question. When the data is analyzed and converted to digital form, the resulting files will be kept in password protected folders on the personal machines of researchers. All researchers on the team will have access.

8. Consent Process: Describe when and where voluntary consent will be obtained, how often, by whom, and from whom. Attach copies of all consent and assent forms.

The researcher will explain the goal and procedures of the study to the participant through email and offer them a ‘fact sheet’ about the research study. Participants may then sign up for a time slot to meet the researcher for a face-to-face experiment. Upon arrival, the researcher will reiterate the goal and procedures of the study verbally and attain a written signature of consent from the participant if they choose to proceed with the study.

9. Dissemination of Results: What is (are) the proposed form(s) of dissemination (e.g., journal article, thesis, academic paper, conference presentation, sharing with the industry or profession, etc.)?

Results will be shared with the informal learning and education communities. Some results may be disseminated through journal articles, conference presentations, and/or a dissertation publication. We will also publish findings on the project website.

10. Individually Identifiable Information: Will any individually identifiable information, including images of subjects, be published, shared, or otherwise disseminated?

☐ No
☐ Yes
11. Funding Information:

Is your research funded or is there a pending funding decision?

☐ No
☒ Yes

If yes, please indicate the funding agency: NSF

Please provide a copy of the funding proposal.

I am attaching the full proposal.

12. Expected Completion Date: December, 2020

INVESTIGATOR ASSURANCES:

I certify that the project described above, to the best of my knowledge, qualifies as an exempt study. I agree that any changes to the project will be submitted to the Institutional Review Board for review prior to implementation. I realize that some changes may alter the exempt status of this project. The original signature of the RPI is required before this application may be processed (scanned or faxed signatures are acceptable).

2/26/2018

Responsible Project Investigator

Date

This section is for IRB Office Use Only

UIUC IRB Protocol No

Exempt under 45 CFR §46.101(b) ☐ (1) ☐ (2) ☐ (3) ☐ (4) ☐ (5) ☐ (6)

Reviewed by: ____________________________
APPENDIX B: INSTRUCTION TO MINECRAFT TASK

Instruction - first task

Please follow the instruction below to finish the tasks. You have 15 minutes to use Minecraft creating an artifact.

The screenshot for your creation is needed for evaluation. Please use F2/F2+Fn to save and send the screenshot to the email address: vuefan2@illinois.edu from the following address.

- %appdata%\.minecraft\screenshots (Windows)
- ~/Library/Application Support/minecraft/screenshots (OS X)

Before you take the task, please read this guidance to walk you through the Minecraft setting.

Basic operation in Minecraft

<table>
<thead>
<tr>
<th>Function</th>
<th>Key operation</th>
<th>Function</th>
<th>Key operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Move</td>
<td>WASD</td>
<td>Fly/jump</td>
<td>Space</td>
</tr>
<tr>
<td>Direction</td>
<td>Mouse</td>
<td>Choose bricks</td>
<td>#1–#9</td>
</tr>
<tr>
<td>Use item/place block</td>
<td>Right click</td>
<td>Screenshots</td>
<td>F2/Fn+F2</td>
</tr>
<tr>
<td>Attack/destroy</td>
<td>Left click</td>
<td>Open/Close Inventory</td>
<td>E</td>
</tr>
</tbody>
</table>

Material needed for the task

<table>
<thead>
<tr>
<th>Name</th>
<th>Oak wood</th>
<th>Oak wood plank</th>
<th>Stone brick</th>
<th>Stone brick stair</th>
<th>Oak wood stair</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graph</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
<td><img src="image5.png" alt="Image" /></td>
</tr>
<tr>
<td>Name</td>
<td>Glass</td>
<td>Oak fence</td>
<td>Oak door</td>
<td>Oak leaves</td>
<td>Stone brick slab</td>
</tr>
<tr>
<td>Graph</td>
<td><img src="image6.png" alt="Image" /></td>
<td><img src="image7.png" alt="Image" /></td>
<td><img src="image8.png" alt="Image" /></td>
<td><img src="image9.png" alt="Image" /></td>
<td><img src="image10.png" alt="Image" /></td>
</tr>
</tbody>
</table>
Using Minecraft to build the house like the instruction bellowed.

**Step 1 build the pillar**

Using oak wood to set up the pillar of the building, with 5 blocks in width, 7 blocks in length, and 3 blocks in height.

**Step 2 build the wall**

1. Leave three empty blocks for windows in the middle in length and cover the other part with oak wood planks.

2. Leave one empty block in the middle of the width and cover the other part with oak wood planks.
3. Add two pillars at either side of the front part of the house.

4. Add a block in the middle to leave space for the doorway.

Step 3 build the roof

1. Add a rows of oak wood planks along the top two layers and two rows again horizontal to those just placed.

2. Leaving the front with a three-block gap.

3. Add a stone block at the top point of the house and stone stars along both sides of the roof.

4. Add stairs so that leaves an overhang and add slabs along the top layer of the roof.
5. Add stairs underneath.

Step 4 make decoration

1. Add wood diagonal to the house.

2. Add two blocks of fences on top of those woods.

3. Place grass in between those wooden blocks.

4. Fill in the windows and the door.

5. Add two stairs in the front door.

Congratulations!
You’ve finished the task!
Final goal

Front

Back

Front door

Side face

Using Minecraft to build a house with the bricks of your own choice.
APPENDIX C: SURVEY

1. You are invited to participate in a research study on creativity and Minecraft. This study is conducted by H. Chad Lane, Associate Professor of Educational Psychology from the University of Illinois Urbana Champaign.

You will be asked to complete an online survey about your Minecraft playing habits and demographic information. You will receive a one-time $10 Amazon gift card upon completion of 7 minutes survey, 3 minutes AUT assessment AND two 15 minutes Minecraft playing. You will receive your payment by email at the end of April 2018.

Your decision to participate or decline participation in this study is completely voluntary and you have the right to terminate your participation at any time without penalty. You may skip any questions you do not wish to answer. If you do not wish to complete this survey just close your browser.

Although your participation in this research may not benefit you personally, it will help us understand the relationship between the openness of the game and its’ influence on creativity. There are no risks to individuals participating in this survey beyond those that exist in daily life. Your decision to participate, decline, or withdraw from participation will have no effect on your current status or future relations with the University of Illinois.

Faculty, students, and staff who may see your information will maintain confidentiality to the extent of laws and university policies. Personal identifiers will not be published or presented.

If you have questions about this project, you may contact H. Chad Lane, 217-333-2245, hclane@illinois.edu. If you have any questions about your rights as a participant in this study or any concerns or complaints, please contact the University of Illinois Office for the Protection of Research Subjects at 217-333-2670 or via email at irb@illinois.edu.

Please print a copy of this consent form for your records, if you so desire.

☐ I have read and understood the above consent form, I certify that I am 18 years old or older and, by clicking the submit button to enter the survey, I indicate my willingness voluntarily take part in the study.
2. Please enter participant number (that you got from the experimenter)

3. What's your age?
   - Below 18
   - 18
   - 19
   - 20
   - 21
   - Above 21

4. What's your gender?
   - Male
   - Female
   - Prefer not to answer

5. How long did you play Minecraft?
   - Less than 1 year
   - 1-2 years
   - 2-3 years
   - 3-5 years
   - 5-10 years
   - More than 10 years

6. How often do you play Minecraft?
   - Less than once a month
   - Once a month - once a week
   - One - three times a week
   - Almost every day
7. How much do you like Minecraft?

<table>
<thead>
<tr>
<th>0 - Not at all</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10 - A great deal</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
</tr>
</tbody>
</table>

8. Why do you like Minecraft? (multiple choice)
- It’s fun.
- It’s free.
- It’s easy.
- I could play it with my friends.
- Others are playing the game.
- Other (please specify) [ ]

9. How do you familiar with the following activities in Minecraft?

<table>
<thead>
<tr>
<th>Activity</th>
<th>Unfamiliar</th>
<th>Somewhat familiar</th>
<th>So-so</th>
<th>Pretty familiar</th>
<th>Very familiar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exploring the maps/mods</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crafting the tools</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planting seeds and harvesting the crops</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planning and designing buildings</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Building automatic machines/systems</td>
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<tr>
<td>Collecting/mining resources</td>
<td></td>
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</tr>
<tr>
<td>Fighting the mobs</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Using command blocks</td>
<td></td>
<td></td>
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<tr>
<td>Building the red stone circuits</td>
<td></td>
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<tr>
<td>Spawning/breeding animals</td>
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</tr>
<tr>
<td>Creating/maintaining a server</td>
<td></td>
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<tr>
<td>Other (please specify)</td>
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</tr>
</tbody>
</table>

Other (please specify)
10. How much do you know about Minecraft? (multiple choice)

☐ I am still new at it.

☐ I have nailed down the basics.

☐ I can do quite a lot in the game. I look up the wiki/forums/web sites/videos about Minecraft.

☐ I consider myself an expert and use advanced features regularly.

☐ All my friends ask me Minecraft questions (that I can answer). I use mods, set up servers, and more.

☐ I play it alone and do whatever I want, without any tutorials or related information.

☐ I play it with my friends and discuss how to play the game.

☐ Other (please specify)

☐

11. Please leave your email address.

☐
APPENDIX D: SCREENSHOTS FOR CAT ASSESSMENT

A decorated building

A Redstone music box

A fountain surrounded by roller-coaster
# APPENDIX E: SCREENSHOT FOR AUT ASSESSMENT

<table>
<thead>
<tr>
<th>fluency</th>
<th>originality</th>
<th>AUT</th>
<th>List the uses for a paper clip as much as possible</th>
<th>use 1</th>
<th>use 2</th>
<th>use 3</th>
<th>use 4</th>
<th>use 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>1</td>
<td>5</td>
<td>clip paper together</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>clip chip/snack bags</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>unbend to use as a long piece</td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>unbend and loop to make a keychain</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>5</td>
<td>13</td>
<td>wire</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>2</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>fold it into a square</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>use it as a key to open a lock</td>
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<tr>
<td></td>
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<td></td>
<td>use its head to open a package</td>
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<td></td>
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<td></td>
<td>write letter with ink</td>
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<td></td>
</tr>
<tr>
<td>9</td>
<td>2</td>
<td>11</td>
<td>hold papers together</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>poke holes in things</td>
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<td></td>
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<td>earrings</td>
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<td></td>
<td>pick locks</td>
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<td>hold pants together</td>
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<td></td>
<td></td>
<td>to hold together papers</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td>to mark a spot in a packer/bot to force open a disk drive</td>
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<td></td>
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<td>to press a reset button</td>
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<td></td>
<td></td>
<td></td>
<td>to clean under your nails</td>
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<tr>
<td>12</td>
<td>4</td>
<td>16</td>
<td>hold paper</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>conduct electricity</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>tie things with wire</td>
<td></td>
<td></td>
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<td></td>
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<td>shape into poke tool</td>
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<td></td>
<td></td>
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<td>needle</td>
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<td>holding together papers</td>
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<td></td>
<td>holding together open bags of chips or eatables</td>
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<td>2</td>
<td>1</td>
<td>3</td>
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<td></td>
<td></td>
<td></td>
<td>Clip paper</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bathroom door lock key (pouf) Improvised nail (when small) Railing/pipe in Paper Model/Scrap</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>5</td>
<td>13</td>
<td>lock pick</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>holding papers</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>electrical wiring</td>
<td></td>
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