CHAPTER 7

Playing With Virtual Blocks: *Minecraft* as a Learning Environment for Practice and Research

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> *If we can discover a child's urgent needs and powers, and if we can supply an environment of materials, appliances, and resources—physical, social, and intellectual—to direct their adequate operation, we shall not have to think about interest. It will take care of itself—John Dewey (1913, pp. 95–96).*

INTRODUCTION: WHAT IS IN A "GAME?"

Whether it be over violence, addiction, or cognitive and social development, debates on the impact of video games have proven extraordinarily difficult to characterize. Confirmation biases and personal opinions seem to dominate public discourse, with video game play often spuriously implicated after mass shootings and violent attacks (Ferguson, 2016). Despite consistent attention being paid to the problems and consequences associated with video game play, researchers have also examined the possible positive aspects of video game play, which include benefits in motivational, emotional, cognitive, and social aspects of one's life (Granic, Lobel, & Engels, 2014). The explosion of games and game genres over the last several decades have even made it difficult to conclude that video games comprise a coherent category suitable for methodological inquiry. In a position statement addressing how video game study findings are reported, Bavelier et al. (2011) remarked that "One can no more say what the effects of video games are, than one can say what the effects of food are" (p. 763). Indeed, the highly novel designs and mechanics present in many modern games, especially those coming from the Indie (or "Independent") market, make them resistant to clear boundaries or categories. Thus, we argue that references to video game play may be less critical in reviewing their impacts than the kinds of experiences that they provide.

Cognitive Development in Digital Contexts
http://dx.doi.org/10.1016/B978-0-12-809481-5.00007-9

Video games provide engineered experience generators that seek to engage players emotionally, cognitively, and socially (Sylvester, 2013). Our position is that researchers who study the impact of game play should seek to link changes in knowledge or behavior to the kinds of manufactured experiences they provide. It is not enough for parents to blame video games for their children's behavior as much as it is unreasonable for a teacher to blame a child for using a cell phone in class. While acknowledging that the child might have stepped out of the set boundaries, we must recognize the *intentions* of the child while using the digital tool. Was the child acting out for attention, and games make him or her feel more adequate? Was the child using his or her cell phone to perform menial calculations in order to solve a much more elaborate math problem? When would it be appropriate for adults to intervene? Therefore, it is important for researchers, educators, and parents to develop an understanding of, for example, what kinds of situations arise within games, what decisions players make, and what sorts of interactions they have before making bold claims about their consequences. We further suggest unpacking the thinking and decision making required to play a given game and consider how players feel about the experiences they have in that environment.

In this chapter, we pursue these goals with a focus on the very popular and influential game, *Minecraft*. Because research that investigates *Minecraft* is nascent, we make no broad claims regarding its impacts or consequences of play; however, we do lay out an argument for why we believe *Minecraft* to be a unique educational game among its mainstream kin and why researchers and educators should consider it as potentially transformative for fostering learning and cognitive skills. Since Markus Persson released an early version of the game in 2009 (with the official release in 2011 through his Swedish company, Mojang), millions of children across the world have chosen to spend hundreds of thousands of cumulative years playing (Thompson, 2016). Given this situation, we believe that it is probably influencing how children think about the world around them including how it works and how we build on it. We view *Minecraft* as an ideal target for research on learning and development, to summarize the kinds of activities involved in playing, to describe how and why children play, and discuss how educators are already using it in schools and other contexts around the world. We present arguments for pursuing research on how *Minecraft* may foster science learning, promote collaboration and creativity, and be used as a vehicle for the development of interest.

Minecraft: An overview. Why is *Minecraft* so relevant for education and learning? What makes it appealing for educators and parents who may be unsure about their own family's video game playing policies? The simplest observation is that interactions in *Minecraft* involve a broad range of educationally relevant content. For example, in *Minecraft*, players routinely engage in activities that involve:

- exploring and investigating different biomes and climates that match those on Earth, including deserts, forests, jungles, and taigas;
- navigating in and around different types of terrain, such as hills, mountains, caverns, caves, and oceans;
- interacting with a wide variety of wildlife and agricultural content, including animals, fish, birds, wheat, grass, fruits, vegetables, and diverse fictional content;
- searching for, mining, collecting, and combining many different resources such as different kinds of wood, stone, metal, and dirt; and
- designing and building electrical circuits, switches, and complex machines that can sense and modify the world.

Players have even reconstructed existing world wonders. Many of these works of engineering that can be found online (e.g., YouTube, dedicated servers) are virtual copies of actual structures such as the *Taj Mahal*, but many more can only exist virtually, such as *Westeros* from the television series *Game of Thrones* (see Fig. 1). To achieve such feats of engineering, players often work collaboratively by planning and coordinating their tasks. They assume roles (e.g., as resource collectors, planners, builders), work iteratively to refine and perfect their creations, and share their work with friends, family, and online communities.

The popularity of *Minecraft*. Since its release in 2009 and recent ascendance to the second most popular video game of all time (Peckham, 2016), *Minecraft* has achieved historic levels of use (see Table 1). Demographic data are difficult to gather given Mojang's privacy policies; however, one survey suggests that 20.59% (of the 100 M+ players) are less than 15 years of age.[1] With console and mobile app sales capturing more than 67% of total sales, the number of young players has grown since 2015: a recent analysis (Bryant & Levine, 2015) of mobile game play by children ages 6–14, found that 85% played at least several times a week, with almost half playing their favorite app every day. In the same age range, *Minecraft* tops the list of favorite apps for boys (with 16.3% indicating it as their favorite) and

[1] http://minecraft-seeds.net/blog/minecraft-player-demographics/.

Fig. 1 Minecraft recreations of the Taj Mahal (top) and Westeros (bottom; part of WesterosCraft.com, a mod devoted to the television show).

comes in third place for girls (with 8.5% indicating it as their favorite). For the youngest learners (ages 6–11), *Minecraft* finished in a clear first place again (over *Angry Birds*).

Given the massive size of the community, *Minecraft* has an enormous audience of players from many different age groups. Upon the release of touch-screen and mobile versions of the game, the number of younger players skyrocketed—this development is, in part, one of the motivations for investigating it as a unique learning tool. We contend that *Minecraft* is likely influencing these young learners, in terms of how they perceive the world and, relevant to national goals to improve students' achievement in STEM (science, technology, engineering, and math), how they learn science and math. With these data in mind, we describe below what it is like to play *Minecraft*, what players actually do when playing, and how they go about personalizing it for their own interests.

Table 1 How big is *Minecraft*?[a]

100,000,000+ players	19,000,000 PC downloads	54,000,000 units sold
241,000,000 logins per month (2011)	Purchased by Microsoft, $2.5B (2014)	2B+ hours played (Xbox alone)
18×10^{18} possible worlds	The Danish Geodata Agency built a 1:1 model of Denmark (1 T blocks) (2014)	"*Minecraft*" #2 YouTube search (2014)

[a] http://www.wired.com/2015/05/data-effect-minecraft/ Fallon, S. (May 27, 2015).

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Minecraft is a video game that is relatively intuitive to play and capable of supporting incredibly complex interactions and experiences. It is frequently characterized as a "sandbox" style game, whereby it prioritizes open play such that players can roam freely and pursue self-generated goals using any means that the game allows (Lastowka, 2012; West & Bleiberg, 2013). With its decidedly lower resolution graphics and open approach to content development, its success has come as a surprise to the commercial games industry. It is widely believed that one of the key factors behind its rapid ascent was Mojang's, the company behind *Minecraft*'s creation, early embracing of user generated content and user modification (a highly uncommon practice for game studios at the time). Although *Minecraft* has evolved substantially since its official release, the core mechanics, interactions, and basic game play modes have remained stable.

A world made out of blocks. Simply put, *Minecraft* is played in a world made entirely of blocks. The various blocks encountered in the game have different compositions and functions, such as variants of stone, wood, and metal. Even liquids, such as water and lava, are modeled as block units, although they adhere to natural laws such as gravity and flow. Prior to starting a single-player game, the terrain (i.e., a virtual world) must be generated. These digital worlds are huge as the exact cubic volume of a *Minecraft* world is 262 quadrillion by 144 trillion blocks (West & Bleiberg, 2013). The terrain generation algorithm produces remarkable (block-style) landscapes and includes features found in the natural world, such as varying biomes (e.g., desert, forest), caves, mountains, oceans, rivers, and lakes (Fig. 2 shows two typical screenshots). No two *Minecraft* worlds are exactly alike, and the generation algorithm can be adjusted to meet entertainment or educational needs (such as favoring more deserts or oceans).

Two primary modes of play: Survival and creative. In stark contrast to a majority of commercial games, *Minecraft* does not include an active narrative or set game play objectives. Nor is there is a direct way to "win" or obvious ways to "level up," although some elements of experience points are used (e.g., items acquired during gameplay can be enhanced through "enchanting,"

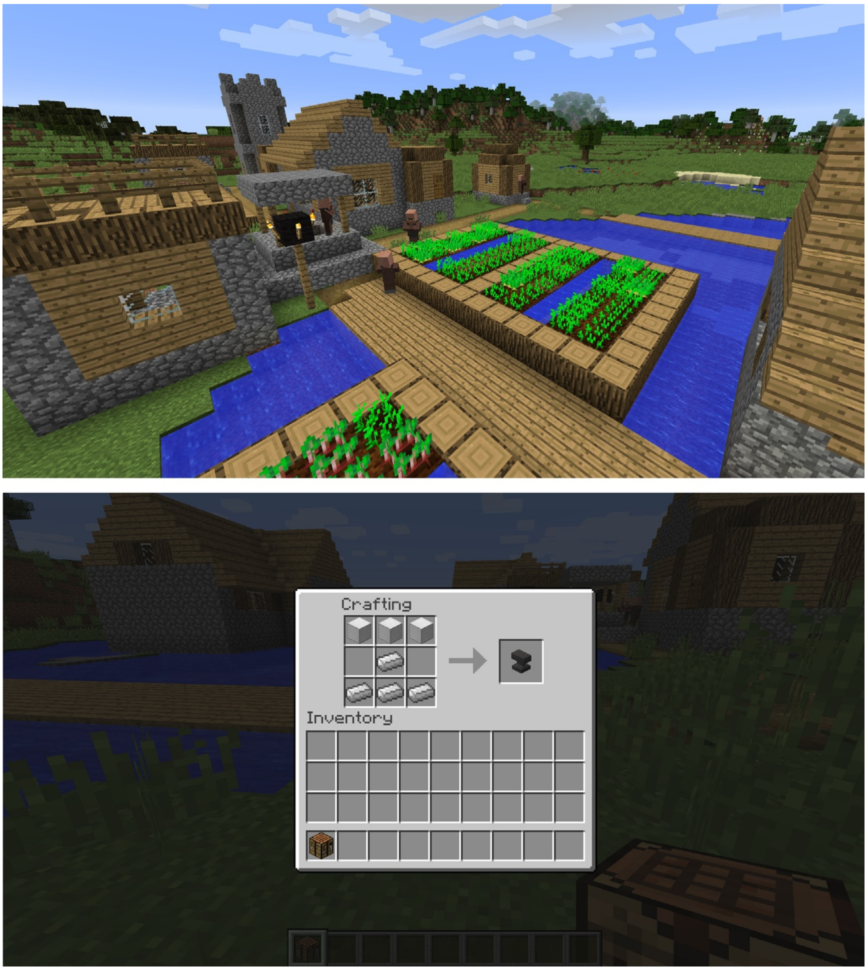

Fig. 2 Typical Minecraft interactions. The top screenshot shows an automatically generated village and farm, while the bottom screenshot shows a crafting screen, where the player can create new items (e.g., an anvil) from more basic components (e.g., iron ingots).

which is only possible after enough experience points have been earned). Although recent versions of *Minecraft* provide five different modes of play, the two most commonly used modes are survival mode, whereby the player must actively seek resources and forge tools to survive, while monsters spawn randomly during the night. The purpose of this mode is to survive by collecting, building, crafting, and defending. The creative mode grants the player invincibility, an unlimited supply of blocks and resources, the ability to fly, and places no active restriction on the player's imagination. Specifically, in this mode, players are gifted the power to create and destroy as they find necessary, goals are entirely self-generated, and the game introduces no obstacles to play. The creative mode is common for play-like activities, such as riding roller coasters, creating video recordings, exploring another player's world, interacting with and crafting their own modified objects.

At the start of a typical survival game, the player learns that she can gain wood by chopping at a tree barehanded. With wood, she can then make wooden planks and sticks through a process known as *crafting*. Four wood planks can be combined to create a *crafting table* (Fig. 2), which enables players to create more complicated tools and objects, such as an anvil as shown in the figure. Duncan (2011) explains that once the initial learning curve is mastered, the player learns how to create an even stronger axe, to construct tracks and mine carts to move ore, to make torches to light dark caves, and to recombine building blocks (stone, iron, glass) into fortresses that defend against nocturnal monsters (survival mode only). If the player gathers all the proper materials, it is possible to build working electrical circuits or coal-powered engines that function similarly to their real-life counterparts (West & Bleiberg, 2013). The pattern of collect, build, and improve repeats throughout the game, thus, enabling new tools and resources to be constructed.

The creative mode in *Minecraft* is vastly different. Players have access to an unlimited supply of the complete slate of, for example, blocks, tools, creatures, and objects. With no threats and no chance of harm from falling (your character is actually hurt when you fall too far in survival mode), players in creative mode normally build and engage in deeply elaborate and creative projects, such as recreating the Taj Mahal (shown in Fig. 1, which would have no real practical value in survival mode). Other key differences in creative mode include the ability to fly (which enables the player to view their work from a top view and explore terrains more quickly), ability to spawn creatures, such as chickens and polar bears (as many as desired), and to exert complete control over the environment, including rain and sunlight (via *Minecraft's* command line). The creative mode ultimately provides a construction and experimental playground where players can learn how to build in *Minecraft*, work on elaborate structures and inventions, and show off their work to peers and the world. Later, we discuss links between *Minecraft* and the development of creativity.

Customization and personalization. A common explanation given for *Minecraft's* remarkable success is that it is highly customizable as players create their own environment through design and construction of their own buildings, structures, and caves during normal game interactions and use a variety of external tools to make more substantive changes to the game. The three aspects of customization and personalization we address here are avatar design, world editing, and "modding" (i.e., game modification).

Avatars and skins. The "skin" of a character refers to the avatar's appearance, which is the representation of the player in the game. "Steve" (see Fig. 3) is the default character in *Minecraft* who has become a YouTube celebrity and the "face" of *Minecraft* on promotional materials. The simplest form of personalization entails adjusting or replacing the Steve skin to something more appealing to that player. Numerous Internet tools allow players to create their own skins from scratch (e.g., NovaSkin), or download existing avatars inspired, perhaps, by other interests (e.g., Darth Vader). Generally, avatar creation and selection can act as a window into a learner's identity and self-perceptions (Kafai, Fields, & Cook, 2010), and *Minecraft* is

Fig. 3 Steve, the default character in *Minecraft*, surrounded by a variety of animals and a "Creeper" (the four-legged creature to the right of Steve).

very similar to other games in this regard. For example, a player can create an avatar that, for example, sits in similarity or in opposition to their real-life persona. As with changing skins, players can also load "texture packs," which simply change the surface appearances of blocks, clouds, and other objects in the game.

Playing God: Map editors and modding. Other forms of customization of *Minecraft* are more sophisticated and involve making changes that involve use of external tools (i.e., that are not part of "Vanilla" *Minecraft*). Stepping back briefly to the early years of *Minecraft* development, one of the most noteworthy decisions that emerged was the decision to grant tremendous power to the player community to change the game in fundamental ways. This decision was atypical for game studios around 2009, but is now generally regarded as one of the most profound contributors to *Minecraft's* success. We describe two such forms of customization in the remainder of this section: map editor tools and game "mods" (or modifications).

With more than 1.8×10^{19} possible maps, *Minecraft* is capable of providing an essentially endless number of possible worlds to explore. The number of possible worlds is a topic of debate as it also depends on which version of *Minecraft* is used. Different kinds of blocks tend to become available in more recent releases. Normally, players begin with a random map and can provide a seed number, which can be used to guarantee replication of individual maps when the seed is reused (each generated world requires a random number "seed" which is used to guide terrain decisions, such as topographical features and biomes). If, however, a user wishes to have maps with specific features or characteristics, the *Minecraft* user community has produced a wide range of tools that allow players to create their own maps easily without programming. These tools, often called *map editors,* allow players to readily make broad-sweeping changes to worlds. They work much like a typical paint or publishing tool, with the exception that they are used to define a three-dimensional (3D) space through sculpting and manipulation of surface features of a map (e.g., mountains, basins, valleys, trees, sand, creatures), bodies of water (e.g., rivers, lakes, oceans), and underground structures (e.g., caves, lava). Different tools allow editing in both third person view (top down) and first person (similar to playing the game). Authored maps are easily loaded from inside *Minecraft* and played like any other map.

The most significant and powerful changes to *Minecraft* involve changing the code that controls the game, a process known as *modding* (i.e., "modifying"). The possibility for the player community to create and share new versions of *Minecraft* reflecting their own ideas has likely contributed greatly to its success. *Mods* (the product of modding) can be found on most imaginable topics and span the science and technology gamut. A large number of mods simply change the look and feel of *Minecraft*, add content, and provide new capabilities such as combining multiple tools into one (to save inventory space) or jumping higher than the programmed default. However, many others leverage the powerful simulation components of *Minecraft*. A few of these mods that are highly relevant to science learning include

- *Galacticraft:* Allows players to travel through the solar system, design and travel spaceships, explore planets and moons, experience different environments and gravities, use life-support technologies, and engage with friends in space races and other competitions.
- *ComputerCraft:* provides programmable turtles, essentially small robots, for automation of many game tasks, networking simulation, command-line interfaces, and more computing simulations.
- *Climate Control:* allows players to control environmental behaviors, including ocean sizes, biome frequencies, and other weather/environmental factors.
- *Agricraft:* provides a more detailed and complex agricultural system for *Minecraft*, including more crops, hybrid crops (mixing breeds), and irrigation tools.

Using mods is relatively simple whereby a user first needs a "mod loader," which is a separate program that helps players find new mods and manages the activation of the ones desired at any given time (many people play *Minecraft* with several mods active at once, and change frequently). Once loaded, a new game is started from within the chosen loader (documentation is typically provided when using the new resources from a mod may not be obvious). Notably, these mods are created by the community. Comparable to how *Wikipedia* grew and is now sustained, mods depend on user-generated content and donated time. The enormous range of mods available to the world represents a significant resource, for players seeking new kinds of experiences and educators who wish to focus on specific topics. So how can educators and researchers leverage these tools? How can *Minecraft* be applied in educational settings and used to answer questions about cognitive development and learning? The remainder of the chapter focuses on these questions.

MINECRAFT AS AN ENVIRONMENT FOR TEACHING AND LEARNING

Because *Minecraft* is essentially a simulation of the natural world and boasts high levels of popularity among children, educators around the world are rapidly embracing it for educational uses (Thompson, 2016). In this section, we describe several examples of how it can be used to promote learning and how teachers have leveraged these capabilities in the classroom.

Science and engineering in Minecraft. *Minecraft's* strong links to science topics imply that it is worthwhile to ask to what extent it might act as a proxy for the study of and experimentation with simple phenomena from the natural sciences, such as those performed in middle- or high-school science classes. Short (2012), a high-school science teacher who uses *Minecraft* extensively, identifies several techniques for teaching ecology, mathematics, and physics. He highlights students' ability to explore different biomes and identify the conditions in each biome that impact sustainable life (e.g., access to water, temperature). As an example, Short describes *Minecraft*'s "smelting" feature, whereby a player can combine game objects in a furnace to create a new resource. The process has a rather direct mapping into combination reactions in chemistry, allowing students to witness and learn heat's key role in the combination or the alteration of multiple objects and elements. As another example, Short points to how colors can change based on environmental conditions and the sun's location in the sky. He describes how *Minecraft* simulates *atmospheric refraction*, which is the deviation of light from a straight line as it passes through the atmosphere and is impacted by variation in air density and height. Thus, *Minecraft* players see a red tinted sky at sunrise, just as they would in the natural world.

Many direct links between *Minecraft* and engineering are also present. When playing *Minecraft* in survival mode, one of the earliest tasks is to construct a building for protection. As the game progresses, it is common for this building (or fort) to become larger, stronger, and more complex. It is also common to see players build and design machines, either for the inherent challenge of doing so or with a specific purpose. These structures often require working with electricity, which is possible in *Minecraft* given a fictional resource known as "redstone." Simply put, redstone can be thought of as a source of energy that allows locomotion (Brand & Kinash, 2013). In combination with circuits, switches, repeaters, and other objects, redstone enables electrical signals and power to be incorporated into complex machines, enabling players to build everything from drawbridges to flying machines. Circuits can be attached to a variety of triggering mechanisms, such as pressure plates and sensors, which can set automated tasks into motion.

Redstone circuits are animated so that players can observe the signals moving over the created networks, the triggering actions, and the completion of their journeys. While unrealistic when compared to the actual world, slowing the signal down significantly helps the player to better isolate bugs and solve operational problems in their designs. Students equipped with redstone in *Minecraft* can solve complex automation problems at their own pace, learn how basic circuits operate through exploration, and watch their creations come to life repeatedly. We also note that using *Minecraft* as a virtual demo tool could potentially save schools, money, and time since once a *Minecraft* demonstration is set up, it can be saved, re-used, and modified easily.

Minecraft as a conduit to more advanced topics. A quick search on YouTube will reveal a seemingly endless list of remarkable and complex creations accomplished in *Minecraft*, much like the Taj Mahal and Westeros examples from earlier. Because of its richness and extendibility, *Minecraft* ostensibly provides a gateway for many learners worldwide to explore more advanced topics or new areas of interest. A number of mods exist for the singular purpose of exposing young learners to advanced topics—some that may be well beyond what is usually considered accessible at a young age.

One example of such a creation is *Circuit Madness*, a world designed to teach students logic through *Minecraft*. The player must learn the functions of basic logical operators (e.g., AND, OR, XOR) to find their way out of each room, and in the grander scope, escape from the game's entire maze (Duncan, 2011). *Circuit Madness* is an example of a mod that could be hypothesized to act as a trigger for interest (Hidi & Renninger, 2006), for example, in electronics and computer science, and enable sustained exposure to game content, while possibly motivating players to build circuits on their own. Game experiences such as those provided by *Circuit Madness* could also play a role in addressing gender and cultural imbalances in STEM areas. Computer science and engineering, in particular, are two fields with significant and persistent deficits in terms of female participation (Jenson & De Castell, 2010). The idea that digital technologies can contribute to a more level playing field for all learners (which *Minecraft* certainly can be) is supported by the possibility to be represented digitally: real-life features of our identities, such as gender and race, could take a back seat to content and learning. For example, Mimi Ito's *Connected Learning* framework

(Ito et al., 2013), which includes use of *Minecraft* camps and servers for collaborative learning, is a leading candidate for such a vision.

Educator uses of Minecraft to increase engagement in learning. Because of *Minecraft's* broad appeal, educators in both formal and informal contexts quickly adopted the game to suit a wide range of learning goals. Its usage by teachers in schools and afterschool programs has grown rapidly,[2] for topics as diverse as history, foreign languages, social studies,[3] and mathematics (Bos, Wilder, Cook, & O'Donnell, 2014). *Minecraft* clubs have formed across the world, such as "*Minecraft* Mania," at the Children's Museum of Houston[4] as well as larger coalitions, such as ThoughtSTEM, a statewide network of afterschool *Minecraft* programs in California.[5] Ito et al. (2013) have proposed a "connected learning" framework as a fresh take on peer-support that is often mediated by technology. They predict that education will (continue to) shift from singular learning to be interest-driven, specialized, and fueled by the support of like-minded peers. *Minecraft* is an example of a technology that exemplifies this vision since it is an environment where students can easily pursue academically oriented goals for learning with the help of their instructors, peers, and families. In addition to the ideas for science education described above by Short (2012) for engineering, ecology, chemistry, and physics, we provide two more concrete use cases.

Jeffrey Adams, a middle school science teacher in Toronto, used *Minecraft* to pursue such a goal. In a lesson to encourage students to learn about sustainable planning, he asked his students (80 seventh grade boys) to build their own model of a sustainable city in *Minecraft*. Students assumed roles, such as farmer, builder, or miner, and then were tasked with building a sustainable village. The products of their work including interviews and surveys suggested very deep engagement in the activity. Eighty-six percent of students expressed a preference to keep using games in their classes, and 80% of students in the class reported that *Minecraft* allowed them to "be more creative and do things [they] couldn't do before" (Adams, 2012, p. 11).

In a similar approach, teachers Karen Yager and Andrew Weeding (in Sydney, Australia) asked students in their science classes of 12- to 13-year-olds to design cities that minimized the use of energy and resources.

[2] http://fortune.com/2015/06/30/minecraft-teachers/.
[3] http://ww2.kqed.org/mindshift/2015/09/28/for-the-hesitant-teacher-leveraging-the-power-of-minecraft/.
[4] http://www.cmhouston.org/event/minecraft-houston.
[5] http://www.thoughtstem.com/home/programs/after-school-programs.

Here, students were given the choice of how to design, build, and present their models (e.g., physical vs. digital). Notably, 96% of the students chose *Minecraft*. Then, over the course of 5 days, students built out their virtual cities. To encourage students to think more broadly than engineering, students had daily in-world challenges covering multiple disciplines: English, mathematics, science, and foreign languages. At the end of the unit, students presented their cities to their classmates via a walking tour of their cities to show off their work, energy-saving features, and building designs. Yager and Weeding reported that their students primarily enjoyed the freedom *Minecraft* offered them and the ability to create functional models (West & Bleiberg, 2013).

These examples suggest that *Minecraft* has great flexibility when it comes to fulfilling the different needs of instructors. Further, in blogs and in person, educators often report increases in engagement, interest, and time-on-task with *Minecraft*-based assignments. To what extent these outcomes are due to Minecraft or teacher quality or other variables is unclear, warranting further examination. Given the popularity and flexibility of *Minecraft*, though, we view it as important to determine its efficacy alongside more traditional instructional methods. Some initial studies, however, suggest that *Minecraft*-based assignments positively impact noncognitive outcomes, such as attitude (Sáez-López, Miller, Vázquez-Cano, & Domínguez-Garrido, 2015) and creativity (Cipollone, Schifter, & Moffat, 2014).

MINECRAFT AS AN EDUCATIONAL RESEARCH TOOL

As educator uses reveal, the design of *Minecraft* makes it an appealing environment for thinking about teaching and learning. In this section, we discuss potential research foci whereby *Minecraft* could act as the learning environment. Specifically, we discuss three important areas that have already received some researcher attention but are poised for much larger research efforts: collaboration, creativity, and special education.

Collaboration and cooperation in Minecraft. *Minecraft*'s open world approach resists the competitive edge that comes with games such as racecar or fighting games. Barron (2003) suggests that for collaboration in groups, the more competitive the environment, the more students will focus on themselves instead of "learning for the sake of learning" (p. 350). So, instead of withdrawing into themselves, sandbox platforms such as *Minecraft* may encourage students to view learning (in-game) as playing and enjoy exploration of the digital space. Another advantage of using *Minecraft* in the classroom setting is that it capitalizes on the relationships already established between the students. Friends are more productive in dialogue during learning activities and elaborate on ideas; their past experiences with each other motivate them to nurture their friendship (Barron, 2003). Random assignment or strategic pairing of students to play together also may enable new friendships to form.

Other research on collaboration has implications for the study of *Minecraft*. For example, when in groups, students are known to complete tasks for the sake of the group, rather than simply out of self-interest (Slavin, 2015). In a case study conducted by Walker (2012), students were assigned collaborative building or writing tasks that required information gathered from *Minecraft* worlds, from the classroom, or from course textbooks. Tasks in the study ranged from "exploring secret rooms and traps within the Great Pyramid" to "collaboratively writing a modern myth following the common stages of Greek mythology" (p. 5). Additional challenges were made available to students who wished to pursue them on their own or in groups. Walker encouraged students to explore the game's open world, for the sake of fun and entertainment and to pursue knowledge. The varied tasks assigned provided short-term goals for the students to meet while they pursued the overarching goal of better understanding history. The new information attained through *Minecraft* could then be reinforced through peers, classroom materials such as textbooks, and the teacher's reiteration.

Minecraft is an inherently collaborative game, with teams often able to accomplish more together than alone, and often pursuing entirely intrinsically motivated activities (such as building the Taj Mahal). Support for collaboration was a key aim of the recent release of *Minecraft: Education Edition*,[6] which greatly reduces the technical hurdles necessary for groups to work together on class projects, by eliminating the need for a server, for example, and allowing one computer on a local network to act as host. Further, it provided a suite of teacher resources, such as prebuilt maps and large-scale recreations of objects (such as the human eye, see Fig. 4). These recent developments have positive implications for teachers and suggest new ways of tracking and evaluating collaboration around learning tasks that will be possible in the very near future.

Cultivating and nurturing creativity. A growing body of evidence suggests that video game play is at least positively correlated with creativity, especially for children (Jackson et al., 2012). In some cases, frequent video game play has been causally linked to creativity either by way of game mechanics

[6] http://education.minecraft.net/.

Fig. 4 A recreation of a human eye in *Minecraft: Education Edition*. Groups of learners can go inside, witness the conversion of light into electrical impulses (that would then go to the brain), and even modify the eye's construction.

tapping into creative problem-solving skills or identity development (Bowman, Kowert, & Ferguson, 2015; Yeh, 2015); however, more research is needed to better understand what causal mechanisms are at play.

When positioned alongside over 50 years of research on creativity—which has focused on how to define, measure, and cultivate it (Sawyer, 2012)—*Minecraft* stands out from other video games in terms of its capacity for creative expression and uses of creativity in a science context (Garrelts, 2014). *Minecraft* has been frequently associated with *constructivism* and linked to Bruner's seminal work on the active construction (and co-construction) of knowledge (Bruner, 1991) as well as *constructionist* approaches to learning that emphasize constructivist principles in the context of interaction with and creation of artifacts (Papert & Harel, 1991; Schifter & Cipollone, 2015). In particular, constructionism challenges the idea that "verbally expressed formal knowledge" is a sufficient end point for education (Papert & Harel, 1991, p. 11). Rather, knowledge is seen as constructed by learners, in the context of creation, invention, and exploration. Brand et al. (2014) argue that *Minecraft* is ideally suited for constructivist learning and is likely to promote creative thinking because it shifts learning from experiences with predefined interactions to ones with a broad range of possible interactions. In particular, *Minecraft* "provides multiple depictions or perspectives of reality by allowing a variety of levels of detail and scale for building worlds in addition to full 3D freedom of exploration" (p. 61).

Arguably, *Minecraft* could promote creative thinking in at least two principle ways. First, it provides features that are known to promote creative thinking. For example, it combines the use of constraints (via the virtual world) with open-ended decision making, a combination that has been shown to promote creative thinking in a variety of contexts (Costello & Keane, 2000). Second, it is suitable for both collaborative and individual work, both essential for creative expression (Sawyer, 2012). Further, as a virtual world, *Minecraft* makes it easy to inspect anything in the game world from any perspective (inside, outside, upside down, etc.). The need for perspective taking and the skill to do so are known to be important for both empathy and creativity (Grant & Berry, 2011). Second, for decades researchers have pursued measures of creativity (Kerr & Gagliardi, 2003) leading to a wide range of approaches, such as tests of divergent thinking and problem-solving tasks that require insight. *Minecraft* presents a compelling context in which to pursue another prominent direction of assessment through the inspection of artifacts (Kaufman, Baer, Cole, & Sexton, 2008). In particular, because all activities in the game can be logged, it would be possible to inspect how learners change creations over time, how they make those changes (alone or together), and how they choose to express their ideas over time. While most measures tend to focus on traits or specific ways of thinking, *process* measures for creativity are often far more appropriate for learning and development, and the affordances of *Minecraft* align nicely with this need.

Minecraft for struggling learners. Because *Minecraft* offers a familiar interface (for many learners) and is vastly different from what students normally expect in school, some initial efforts are underway to use it as a tool for engaging struggling learners and to provide new avenues for participation. For example, Brian Kenney, a math teacher in Corona, California, set out to increase engagement of his special needs students by allowing them to explore geometry concepts in *Minecraft*. Specifically, his students created buildings and then labeled the geometric shapes and properties in their designs (e.g., parallel walls, right angles, complementary angles). Anecdotally, Kenney reported that it changed his students' willingness to engage in the material and also improved their attitudes toward the class.[7] Notably, there is strong evidence that preexisting *interest* in a topic increases engagement (Renninger, Nieswandt, & Hidi, 2015). Thus, whether that interest lies

[7] http://www.cta.org/Professional-Development/Publications/2013/10/October-2013-Educator/Games.aspx.

in *Minecraft* itself, or in the vast experiences it can provide, further research is needed to better understand the tradeoffs involved with *Minecraft*-based lessons, such as those related to time it takes to learn to play (if they don't already) and potentially negative impacts on students who do not normally play video games.

Going well beyond STEM, the *Minecraft* community has also produced content specifically focused on inviting autistic players to the game. One of the most well-known servers for players with Autism is *AutCraft*, a *Minecraft* server "dedicated to providing a safe and fun learning environment for children on the autism spectrum and their families."[8] The server addresses all relevant aspects of autism, including promoting healthy social interactions, establishing a "safe space," emphasizing anti-bullying principles, and providing a place of acceptance. Kate Ringland, a researcher, spent 60 h observing interactions between players to better understand how the server worked and why it was especially suited for players with autism. By analyzing how players searched for, practiced, and defined social skills, she found improvements in how players were interacting socially in the game (demonstration of transfer outside the game has not been studied as of this writing). She concluded that *Minecraft*, despite (or perhaps, because of) its lower-end graphics, was a suitable environment for learning social and emotional skills (Ringland, Wolf, Faucett, Dombrowski, & Hayes, 2016). These conclusions are supported by recent evidence that children with autism are better able to acquire social skills with robotic partners (Cabibihan, Javed, Ang, & Aljunied, 2013), whereby such interventions can act as practice for autistic learners in an environment that does not include direct, and potentially stressful interaction with humans.

CONCLUSION

We have described the game of *Minecraft*, how it is played, how and why educators are using it, and have provided suggestions on the kinds of research questions that are pertinent given these developments. We argued that *Minecraft* is unique as it does not fit the mold of other successful video games and is simultaneously flexible enough to be used for a wide range of educational purposes. In this final section, we briefly discuss the relationship between the *Minecraft* phenomenon and cognitive development, followed by a concluding discussion of possible future research directions.

[8] http://autcraft.com/.

Minecraft and cognitive development. While young children may consider watching *Minecraft* how-to videos or exploring the pixelated Arctic with friends as a hobby (a theme of popular YouTube shows filmed in *Minecraft*), their constant engagement is hypothesized to aid in forming emergent digital literacies (Holloway, Green, & Livingstone, 2013). In many ways, the use of *Minecraft* in curriculums is a nod to Vygotsky's theory of play in the mental development of the child. The theory calls attention to four aspects of play: the child's needs, inclinations, incentives, and motives to act. Vygotsky equates play with wish fulfillment. The desires of a toddler and a kindergartener are not comparable; the child's aspirations and self-perceptions change over social interactions and time (Vygotsky & Cole, 1978).

We have indirectly argued for multiple ways that *Minecraft* addresses Vygotsky's aspects of play, and how the game can be used to fulfill whatever goal or fantasy the child desires to craft. Perhaps the most prominent aspect lies in sociability, where time spent in the digital realm can spark a "sense of shared purpose and identity" among players in spite of the technological gap between generations (Brand & Kinash, 2013). We have emphasized *Minecraft*'s digital medium since it allows participants to experience a series of grand episodes and go well beyond what is possible in the classroom and the real world. Shane Asselstine, a featured educator from 2014 on *Minecraft* Edu (the predecessor to *Minecraft*: Education Edition), describes noted improvements on student group work:

> *We have also used* Minecraft*Edu in survival mode maps. In these maps students are more focused on aspects of cooperation, citizenship, and resource management… They really learn the value of working together to accomplish a goal. I am also always amazed at the details students can remember from a close call, or a grand discovery of resources.*

Our view is that teacher and parent reports of children accomplishing amazing feats in *Minecraft* are a signal that cognitive and developmental sciences should take note and work to incorporate more of it into the global education research agenda.

Beyond Minecraft. We have attempted to make a case for *Minecraft* as a unique game that has implications far beyond the small, entertainment goals it began with in 2009. As an open-ended game, *Minecraft* does not emphasize mastery or any of the traditional goals video games tend to impose on players, such as leveling up, unlocking content, or sharing through social interaction (Fullerton, 2007). Rather, the focus of the *Minecraft* community and its players rests on the ongoing possibility of doing things that have yet to be done. The phrase "sandbox box" game is based on an apt metaphor in that players have the chance to explore and play with ideas and are only bound by the tools made available to them. Deep links between *Minecraft and* science, communication, and engineering are being pursued very quickly by teachers, but too slowly by researchers. How we leverage this powerful tool and merge it with education to promote learning, engagement, interest, and in developmentally sound ways are all open questions.

What will the world look like 10–15 years from now? What will it mean to have an entire generation of scientists, engineers, and artists who grew up using *Minecraft* to express themselves? While it may not be possible to ever answer this question confidently, more research is needed to understand the impact dramatic use of *Minecraft* is having on children. Each time a child collects a resource, changes their avatar, discovers diamonds in a deep mine, designs a redstone circuit, coordinates what to build next with their friends, we should nudge them in ways that maximize the potential long-term value of the skills they are acquiring. But, we should also marvel that they do this by their own volition, and importantly, stay out of the way.

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