Minecraft in the Math Classroom

Methods, Benefits, and Difficulties of *Minecraft* Integration

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Abstract

The spread of technology is creating the need for teachers to evolve and adapt their strategies within the classroom. Teachers must continually improve upon their technological integration in order to teach students ever more effectively. Game-based learning has recently gained prominence as a plausible use of technology in the classroom. This thesis will discuss the classroom implications and application of game-based learning. Specifically, the use of the video game *Minecraft* in the high school math classroom will be examined. The potential of *Minecraft* as an effective teaching tool to advance the quality of student learning will be examined through a thorough investigation of the topic. Along with practical example lessons, the benefits and difficulties of such an implementation of *Minecraft* will be considered.

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Methods, Benefits, and Difficulties of Minecraft Integration

Introduction

The current state of math education in the United States is in undeniable need of improvement. Multiple studies have investigated the performance of American math students, and the studies have consistently revealed statistics that show the United States trailing other major developed countries in mathematical competency (Powell, 2007; Fleischman, Hopstock, Pelczar, & Shelley, 2010; Vigdor, 2012). As a result, there has been a recent surge of discussion in education circles revolving around discovering new techniques and practices to implement in the math classroom that will improve student involvement and understanding (Vigdor, 2012). Educators recognize that the current typical math classroom does not engage the learner in a way that creates a desire to learn and truly understand the concepts. The recent Common Core controversy over new methods of teaching math is a result of educators looking to revolutionize and reimagine the math classroom and spark a revival in student achievement. Common Core standards have been designed in an effort to shift the responsibility of learning more toward the students (Coffey, 2014). Other implementations that are being experimented with are the flipped classroom, student-centered activities that promote student investigation, and a variety of other educational techniques designed to modernize the math classroom en route to improved student competency in mathematics (Jacot, Noren, & Berge, 2014; Old Standards v. Common Core, 2015; Coffey, 2014). The following discussion will not seek to dissuade the use or benefit of these methods, but rather it will highlight and promote the use of an additional resource, namely *Minecraft,* that can be used either in

conjunction with or separate to these methods. As an argument for the viability of *Minecraft* as a teaching tool, the methods, benefits, and difficulties involved in the integration of *Minecraft* in the modern math classroom will be investigated.

State of Education in the United States

In the United States, a typical reaction to declining academic achievement is a call for increased concentration on the quality of education. When the Soviet Union unveiled the Sputnik satellite, the United States was confronted with the inadequacy of their current educational status. By successfully launching a satellite into space, the Soviet Union outpaced the United States in two humbling and worrying ways. First, they had beaten the United States to space, and second, they had shown that they possessed the rocket technology needed to fire nuclear missiles across immense distances, distances as far as mainland United States (Powell, 2007). A direct result of this revelation was the National Defense Education Act and a commitment to improve education by individual teachers (Powell, 2007). The National Defense Education Act increased the general funding for education with a focus on science and mathematics (Powell, 2007). Through this act the United States hoped to improve the educational prowess of its students enough to outpace Soviet advancements in space and develop countermeasures against the nuclear missile threat (Powell, 2007). In this case, the response to the revelation of lackluster education quality resulted in positive results. In the present time, the United States is once again being confronted by statistics that show a backward slide in achievement scores compared to other developed countries, specifically in mathematics. Every three years, the Organization for Economic Cooperation and Development (OECD) issues the Program for International Student Assessment (PISA). The PISA is

administered to 15-year-old students across 65 countries and is designed to measure student literacy rates in reading, science, and mathematics (Organization for Economic Cooperation and Development, 2013). The previous three PISAs have not reflected highly on the state of United States' education, specifically mathematics. The PISA 2009 showed improvement in the mathematics scores of American students compared to the PISA 2006 scores (Fleischman, Hopstock, Pelczar, & Shelley, 2010). However, the scores continued to remain below the average OECD scores. Further, the PISA 2009 scores do not appear to be indicative of overall trend since the PISA 2012 scores have shown another backward slide. From 2009 to 2012, the average mathematics score of the United States dropped by 6 points from 487 to 481 while the OECD dropped by only 2 points from 496 to 494 (Organization for Economic Cooperation and Development, 2013). However, the rank of the United States in relation to the other participating countries is even more alarming. The American average was lower than 29 other countries and not measurably different than 9 countries while being higher than only 26 countries (Organization for Economic Cooperation and Development, 2013). From this it is unfortunately easy to surmise that the mathematics aspect of the United States' education system is below-average, average at best, compared to the developed countries of the world. However, educators have not failed to notice this disparity. Therefore, similar to the response to Sputnik, educators of present day America are looking for ways to reinvigorate and improve the educational system.

A new wave of educators are putting forth their best ideas to solve the problem of mathematics education in the United States. Certain portions of the new Common Core seek to teach math in a fundamentally different way in the hope that students grasp an

intuitive and practical understanding of what they learn. Using the flipped classroom

method in the math classroom has received an increase in popularity (Jacot, Noren, &

Berge, 2014). The idea behind the flipped math classroom is that students are able to use

in-class time to complete the "homework" assignment while out-of-class time is used to

watch a pre-recorded presentation of the day's concept. Therefore, the teacher will be

present to assist and answer questions as students encounter try out the new concept they

have learned. Proponents of this teaching method point to adoption of flipped classrooms

by major universities such as Harvard and the rise of video–based learning communities

such as Khan Academy as signals of its success (Jacot, Noren, & Berge, 2014). Math

classrooms are also experimenting with increased technological integration. One result of

this is that many schools are now providing tablets for their students to use in the

classroom. In fact, 2013 saw a 46% increase in the sale of tablets for educational use,

rising to over 3.5 million devices in sold for that specific purpose (Molnar, 2013). Each

of these methods have met with both success and failure; however, the prolonged impact

of each has yet to be seen. One very recent proposed method extends the focus of using

technology in the classroom to a fairly radical new degree. This method involves using

video games as teaching tools in the math classroom. Video games, such as *Portal 2*,

Angry Birds, and *Minecraft,* have all been used as viable teaching tools in the math

classroom (Jenkins, 2014). Using *Minecraft*, in particular, as a vessel for game-based

learning has grown in popularity among teachers.

Game-based Learning

As our current age of technology continues to expand, game-based learning is

finding a home in the classroom (Cicchino, 2015). A technical definition of game-based

learning is the provision of learning opportunities that "enable learners to make meaningful choices within problem spaces that may span the visual, spatial, and aural, and that provide learners with challenges that must be overcome" (Cicchino, 2015, p. 2). In practice, game-based learning typically refers to the use of entire or aspects of video games, or physical games, as the means through which a teacher instructs the students on specific learning objectives. It occurs both within the boundaries of the games and outside of those boundaries. Within a video game, game-based learning begins with the teacher designing an activity that makes appropriate use of the game's capabilities. The teacher is then able give the students instruction on how to interact within the game in order to progress toward the learning objective. However, the activity within the game may only be the starting point for further learning through classroom discussion. In fact, a study found that the primary use of video games in the classroom was often to encourage student discussion and collaboration (Groff, Howells, & Cranmer, 2012). Despite complaints regarding the idea of using video games in the classroom revolving around time constraints, cost, difficulty of teaching toward an objective, and student distraction from the topic within the game, game-based learning has been shown to be effective in the classroom when used properly (Groff, Howells, & Cranmer, 2012). Teachers participating in game-based learning have found that it led to increased student motivation (Sandford, Ulicsak, Facer, & Rudd, 2006). They have also reported greater student engagement in the learning process which led to improved problem solving and coordination with peers (Groff, Howells, & Cranmer, 2012). A study that delivers concrete evidence of the viability of game-based learning involved over 600 students and found that students who used a brain-training console game over a ten-week period

achieved 50% greater accuracy in half the response time on mathematical computations compared to a group of students who used traditional methods during that same time period (Groff, Howells, & Cranmer, 2012). The effectiveness of game-based learning still relies in part on the quality of the teacher though. A quote from a teacher interviewed by Jennifer Groff illustrates this point about using a video game in the classroom: "It's a tool, it's very much a tool, it's not an end product, it's a tool to engage children in learning" (2012, p. 44). The video game itself does not manifest learning, but rather it is a tool through which its specific implementation and accompanying discussion manifest learning.

Minecraft in the Math Classroom

The use of *Minecraft* in the math classroom is a specific example of game-based learning that adheres to the factors laid out above. *Minecraft* is an open-world, sandbox video game developed in 2009 that allows players to create nearly any object devised by their imagination. The basis of construction in the game is three-dimensional blocks that can be mined and placed according to the player's instruction. The near infinite creativity allowed by *Minecraft* has led many to label it as a virtual Lego world. This property of boundless creativity has also allowed *Minecraft* to be used in a diverse range of applications that the creator Markus Persson could hardly have imagined at *Minecraft*'s original release. One of these applications appears in the classroom. In fact, in the last couple years, the use of *Minecraft* has experienced a growing presence in education. MinecraftEdu, the registered teacher edition of *Minecraft*, was reportedly used by around 1,000 schools across the world at the beginning of 2013 (Bristow, 2013). Amazingly, that

number doubled to an estimated 2,500 schools by the end of 2013, and this number does

not include schools which are using the base edition of *Minecraft* (Bristow, 2013).

Teachers across a variety of classrooms are finding ways to effectively integrate

Minecraft. A middle school history teacher together with his students accurately recreated

an ancient Chinese town, allowing the student to simultaneously learn about the Tang

Dynasty, Chinese architecture, and Chinese culture while researching the city (Bristow,

2013). A high school science teacher created a replica of a human cell and its organelles

within *Minecraft* (Bloom, 2014). He then designed a handout with instructions and

questions for the students to fill out as they explored and learned about the virtual cell

(Bloom, 2014). One third grade teacher ambitiously implemented *Minecraft* across a

variety of subjects with her students (Stanbery, 2014). One of her activities involved

using the farming aspect of *Minecraft* to teach her students the correct process of farming

as her students grew wheat and melons (Stanbery, 2014). The variability of *Minecraft*

extends to the language learning classroom as well. A teacher teaching English in a

Japanese classroom developed an elaborate "city" in *Minecraft* where each building

involved different English language learning activities for the students (Siddiqui, 2013).

Many of the activities incorporated the need of collaborative learning between the

students so that they would facilitate each other's learning. An example of one of the

English teacher's activity buildings is a building where two students progress through a

series of challenges revolving around pinpointing the differences between their respective

rooms using English words (Siddiqui, 2013). These examples provide a glimpse into the

evident use of *Minecraft* in a variety of classrooms. The open-ended nature of *Minecraft*

releases it from the confines of a single classroom or activity, but rather permits any teacher to devise an activity applicable to their specific classroom and lesson.

Facets of Lessons Incorporating *Minecraft*

Evidently, *Minecraft* has been chosen as a viable tool by many innovative teachers. However, the game-based learning brought about by *Minecraft* does not entirely abandon traditional teaching methods. Every teacher knows that it is important to identify a clear learning objective for each lesson to ensure learning occurs. Multiple articles on the basics of implementing game-based learning in the classroom emphasize this same importance of having a clear learning objective. Teachers are advised to label a definite objective that they wish their game-based lesson to reach, in order, that the lesson is worthwhile (Groff, Howells, & Cranmer, 2012; Sandford, Ulicsak, Facer, & Rudd, 2006). Just as learning objectives are typically tied to national standards such as the Common Core, the objectives of game-based lessons can also be tied to national standards. In his webinar, Jim Pike addresses how he has used *Minecraft* in his third grade classroom, specifically in the subject area of math, to teach lessons directly tied to Common Core standards (2014). It may take ingenuity at times on the part of the teacher to develop a lesson incorporating video games that covers a national standard, yet it is not a difficult type of ingenuity but the same type of ingenuity that teachers use every day to create innovative and engaging lessons that cover national standards. Similar to this is the importance that teachers use games appropriately. Any supplementary tools used by teachers to enhance a lesson, whether it be a video, book excerpt, or Internet resource, must be used appropriately by the teacher if it will benefit the students' learning. The use of video games in the classroom falls under the same requirement (Groff, Howells, &

Cranmer, 2012). The entirety of a game does not need to be used, rather the teacher needs to decipher which aspects of a game benefit the lesson and use those aspects (Groff, Howells, & Cranmer, 2012). Ancillary aspects that would distract or hinder the learner need to be identified by the teacher and avoided during the lesson. In one sense, this means that despite the fact that video games increased fun and engagement with the students, video games should not be used in the classroom for this reason. Rather, video games should be used because of the improved learning possibilities they bring to the table, of which increased fun and engagement are parts. In an interview covering game-based learning, one teacher addressed this idea of video games adding to and complementing, not supplanting, typical classroom instruction by saying, "I think, it should support teacher-led teaching rather than replacing it; it can become a lazy way of teaching if you are not careful. It needs to be targeted carefully" (Allsop, Yildririm, & Screpanti, 2013, p. 6).

Reflection time is another facet of traditional education that game-based learning draws. Providing time within the classroom for students to discuss the material covered in the lesson, their struggles and successes, is a key ingredient of enforcing the learning that occurred in the lesson. This reflection time and discussion is paramount in a game-based lesson (Sandford, Ulicsak, Facer, & Rudd, 2006). Often these type of lessons require discussion outside of the lesson itself to ensure students grasp the connection between what was done in the video game world and what it means in the real world (Pike, 2014). This link is strengthened in the students' minds when they can draw connections and reach conclusions by themselves, through teacher-guided discussion, in purposeful reflection time. Thus, despite game-based learning's apparent radical shift from

traditional teaching, it retains many of the attributes of traditional teaching that have been proven to aid learning in the classroom.

Therefore, there are facets of a *Minecraft* lesson that will be familiar to all teachers. However, there are other facets of the lesson that are unique to a *Minecraft* lesson as a game-based learning opportunity. First, foremost, and most obviously is the use of *Minecraft* itself in the lesson. Teachers who wish to use *Minecraft* will need to have a firm understanding of the mechanics and gameplay of *Minecraft*. While there are multiple sources available online for interested teachers to garner ideas for math lessons in *Minecraft* such as Stephen Elford's blog, teachers that thoroughly understand *Minecraft* will be able to devise new lessons tailored to their specific classroom (2015). *Minecraft* is both a single player and multiplayer experience. Users can play in their own unique world, or they can join with a group of fellow users to play together in the same world on a dedicated server. The latter experience will be the most useful in the classroom. It will manifest itself in the classroom as each student and teacher at a separate computer in the classroom, yet everyone will be connected on the same server and joined together in the same *Minecraft* world. However, this leads to three main difficulties for the teacher. The first difficulty is the ever present concern of teachers: classroom management. The concern of classroom management is now replicated in the digital space of the *Minecraft* world. As in a normal class, the teacher will have a lesson plan to follow and specific objectives to fulfill. Therefore, when the class enters the *Minecraft* world, the teacher will immediately have certain tasks the students need to complete. However, in line with the tendency for students to become distracted, the students may began mining blocks and creating structures in manners not appropriate for

the current lesson. Thus, teachers must work to manage the talking and focus of the students in the physical world as well as the attentions of the students in the digital world. The second difficulty arises as the teacher seeks to set up a server which will allow a streamlined and playable environment for all students and teachers in a single world. The final difficulty concerns the price involved with providing each student and teacher with their own copy of *Minecraft* to play on. Thankfully, there are tools available to teachers for assistance with these three difficulties. The foremost tool available for educators seeking to use *Minecraft* in the classroom is MinecraftEdu (TeacherGaming, 2015).

Details and Capabilities of MinecraftEdu

MinecraftEdu is the preeminent mod available for *Minecraft* as an educational tool. Hundreds of users have created mods for *Minecraft.* According to the Gamepedia MinecraftWiki, a *Minecraft* mod, short for modification, is "anything that changes Minecraft's game content from what it originally was" (2015, para. 1). These users are typically called modders. Thus, each of these modders have taken the traditional game of *Minecraft* and tailored and tweaked it to fit their specific wants and needs. MinecraftEdu is a *Minecraft* mod developed by TeacherGaming, a partnership led by teachers Santeri Koivisto and Joel Levin, which focuses on the educational potential of *Minecraft* (Farber, 2015). This educational focus sets it apart from most *Minecraft* mods, but a second aspect of MinecraftEdu also sets it apart from typical mods. MinecraftEdu is officially supported by Mojang, the creators of *Minecraft* (TeacherGaming, 2015). Therefore, MinecraftEdu is able to sell officially licensed copies of *Minecraft* coupled with their MinecraftEdu mod (TeacherGaming, 2015).

Besides the official support of Mojang, MinecraftEdu offers a slew of enhancements and benefits that teachers greatly appreciate when using *Minecraft* in the classroom. At its foundation, *Minecraft* is a sandbox style video game which allows players to do virtually anything they want within the game. This is a key component to its educational potential; however, it also means teachers need a way to focus their students' attention on the task on hand when it is used in the classroom. MinecraftEdu gives teachers this ability through simple to click buttons in an in-game dialog box (TeacherGaming, 2015). Teachers can switch their viewpoint from Creative Mode, viewpoint of the avatar, to Spectate Mode, which allows for fast mobility and a bird's eye view for the teacher to easily survey the students (TeacherGaming, 2015). If a teacher wishes to garner the students' full attention, they can freeze all students so that they are unable to move or mine blocks but must focus on the teacher (TeacherGaming, 2015). Another aid for focusing student attention that MinecraftEdu provides is the ability for the students to mute students in game (TeacherGaming, 2015). This mute feature works both for type chat in the game and voice chat if the students are using headsets. For a lesson which requires students to only explore a pre-built world without building on the students' parts, the teacher can prevent students from having the ability to mine and place blocks (TeacherGaming, 2015). Certain facets of the *Minecraft* experience involve players fending off attacks from hostile computer controlled creatures or other players. If a player fails to defend themselves sufficiently, their avatar will be killed and forced to respawn. MinecraftEdu allows teachers to turn off hostile creatures and more importantly player verse player damage (TeacherGaming, 2015).

The above features of MinecraftEdu aid teachers with the classroom management difficulties of using *Minecraft* in the classroom. However, MinecraftEdu offers an equally impressive set of features to aid in the lesson delivery itself. The Assignment feature allows teachers to create multiple "assignments" for a given activity which students can view and mark as finished when they have completed that assignment (TeacherGaming, 2015). If an activity requires every student to have specific tools or items in their inventories, teachers can write a simple command in the menu and every student or specific students will be given that tool or item (TeacherGaming, 2015). This feature is extremely useful in the classroom where time is a valuable resource. It allows teachers to proceed to the activity with one button click instead of having to walk from avatar to avatar and giving the necessary items to each one individually. Another time-saving feature is the ability for teachers to set up teleport stations which they can label and quickly teleport everyone or select individuals to and from during the lesson (TeacherGaming, 2015). Therefore, teachers will not have to waste time leading the students across their world to the next activity within the world. The core of *Minecraft* gameplay is the building and destroying of blocks within the world. MinecraftEdu provides tools to make this process more efficient if desired by the teacher. MinecraftEdu allows teachers to fill or clear large sections of the world with a specific block type with a single click and drag rather than placing each individual block (TeacherGaming, 2015). In a typical *Minecraft* game, players can place or destroy a block only within a four block radius of their avatar. However, MinecraftEdu allows long distance building which allows the player to place or destroy a block up to 60 blocks away (TeacherGaming, 2015). In a scenario where a teacher is hovering above, supervising the students, this

feature will be useful to alter the terrain as needed from their raised position. The above

features are the most prominent and useful features offered in the gameplay of

MinecraftEdu, but it is not a complete feature list. The MinecraftEdu wiki provides an

extensive description of all that is offered by the MinecraftEdu mod.

   In order to address the difficulties of server accessibility and pricing concerns,

MinecraftEdu provides a streamlined solution. The base PC *Minecraft* cost $26.95 per

license (Mojang, 2015). Because of the partnership with Mojang, MinecraftEdu is able to

offer a discounted price on *Minecraft* licenses. If fewer than 25 licenses are bought, each

license costs $18 (TeacherGaming, 2015). If 25 or more licenses are bought, each license

costs $14 (TeacherGaming, 2015). Teachers will need to buy one license for each student

in the class including the teachers themselves. In addition, teachers will need to purchase

a server license for $41 from MinecraftEdu (TeacherGaming, 2015). By purchasing a

server license, teachers are given the streamlined hosting solution to address the above

mentioned difficulty. The server license permits the installation and use of the

MinecraftEdu Server Software which allows teachers to connect with their students and

play together in a single virtual world (TeacherGaming, 2015). The MinecraftEdu server

is simple to use since it is an officially supported server, and the MinecraftEdu wiki

includes additional information for user help regarding the server. The MinecraftEdu

server also addresses the possible issue of unwanted players joining the game. It has a

setting to limit the number of players who join a game; therefore, teachers can set the

number at the exact size of their classroom (TeacherGaming, 2015). Also, the server may

be set up to go through the school's LAN network which then allows for a secure

connection to only the computers on that network. In summary, for an average classroom

size of 25 students, math teachers seeking to use MinecraftEdu will spend $405 on

licenses. This price seems high at first glance, but it is much lower compared to the price

of $700 if the base *Minecraft* game were bought. It is also a one-time cost and may be

shared outside of the math classroom. The game could be installed and set up in the

school's communal computer lab and used by classes of history, art, English, and other

subject areas. The high starting price tag of integrating *Minecraft* in the math classroom

should not be a deterrent to interested math teachers because the extensive and lasting

options it provides assuage that price tag. Thus, MinecraftEdu addresses the server and

price difficulty.

There are countless *Minecraft* mods available for users to install onto their base

game. It would be beneficial for math teachers interested in *Minecraft* to investigate these

mods in case there is one fitted specifically for the lesson or lessons they have in mind.

However, MinecraftEdu provides the broadest and most useful tools for the typical

classroom setting in addition to the lower price point its privileged status of being

officially supported by Mojang provides.

<center>*Minecraft* **Lessons for the Math Classroom**</center>

"Sheep Probability" by Stephen Elford

It will now be useful to look at specific examples of how *Minecraft* can be used

effectively in the math classroom. Stephen Elford, whose blog was mentioned above, is a

secondary teacher experienced in using *Minecraft* in the math classroom (2015). His blog

MinecraftEdu Elfie contains personally written summaries of his experiences, thoughts,

and resources for the educational use of *Minecraft*. Elford has created multiple original

activities for use in his math classroom and provides templates and walk-throughs of

these activities for interested teachers to use for their own classroom. One of his activities

uses dispensers and sheep to teach the basics of theoretical and experimental probability

(Elford, 2015). The lesson is best suited for a statistics classroom that is just being

introduced to the subject of probability. The basis of the lesson is designed for one class

period; however, Elford discusses additional, related activities that may be added on to

provide more critical thinking opportunities for the students and extend the length of the

lesson to two class periods. Elford even provides a rough script on his blog which walks

interested teachers through the delivery of the lesson (2015). Further, the MinecraftEdu

World Library contains a link to download Elford's world, Sheep Probability, which

contains the structures for this lesson (TeacherGaming, 2015). It is worth mentioning this

further resource of MinecraftEdu. The MinecraftEdu website contains a link to the

MinecraftEdu World Library which is a selection of community contributed worlds

available for download and designed for lessons in varying subjects, including

mathematics (TeacherGaming, 2015).

Figure 1. Sheep Pens. When their button is pressed, each dispenser will put forth a random dye which students will use to dye the sheep surrounding the respective pen.

The lesson, Sheep Probability, begins with students investigating the contrast between theoretical and experimental probability using dispensers. Initiate the lesson by transporting the students to the sheep pens, as seen in Figure 1, and assigning each student a pen. Each pen has a dispenser whose nine slots are filled with nine different wool dyes. Inside the pen, each student will operate the dispenser nine times and dye the nine sheep surrounding the pen with those nine dyes. The students will then record the data of what colors and how many of each were dispensed. The activity is now subject to discussion as the teachers asks for results, what the students expected the results to be, and how the results could be improved to be closer to expected. The discussion at this point forces students to contemplate the difference between theoretical and experimental probability. The theoretical probability of a specific colored dye being dispensed is $\frac{1}{9}$ since each slot has a different dye, or in other words, each sheep should be dyed a different color. Undoubtedly though students will report results that state multiple sheep of the same color, evidencing the reality of experimental probability. The discussion is an opportunity for students to think critically and propose solutions to improve results. Proposed solutions may be performing multiple trials or investigating if the dispenser is truly random. Thus, the next step is to act on these proposed solutions by having the students perform multiple trials and recording the results. Once another discussion is had, students may decide the results still do not sufficiently meet expectations. Thus, it would be worthwhile to test the validity of the "randomness" of the dispenser. Elford suggests using a true random number generator, such as an Excel function, run multiple trials on this generator, and compare results between generator and dispenser. The generator step can be performed by students individually or together as a class. In a class discussion,

students may come to the conclusion that *Minecraft* dispensers favor a certain slot or are not truly random. Elford proposes that this portion of the lesson will take approximately 30 minutes and is a good stopping point (2015).

The Sheep Probability lesson shows the interdisciplinary nature of *Minecraft* as an educational tool. The basis of the lesson is to teach probability, and students do this in multiple ways. They will figure out the probability of a specific dye being dispensed and understand the relationship between probability and statistics as they compare the proposed probability with the actual ratio of dispensed dyes. However, this lesson interweaves fundamental science themes as well. The students follow the scientific method as they discuss the data of their first tests, propose methods to improve the results, and finally come to a conclusion of whether or not their data improved and why or why not. Also, students are exposed to the often stark difference between the theoretical and experimental when performing experiments. The activity serves as a good lesson that scientific experiments, specifically in this case probability experiments, are difficult to design and perform such that they adhere perfectly to the sound theoretical values proposed. Elford also provides further activities to extend this lesson to another class period. One additional activity asks students to breed sheep of different colors and record what color the offspring are. Using this information, students will attempt to guess the color and probability of it being that color for a mystery sheep based off of the sheep's parents. This extension deepens the students' understanding of probability as they contemplate and combine multiple factors. It also touches on the biological topic of Punnett squares as students discover what affects the offspring's color. One last extension to this lesson proposed by Elford is for students to develop their own probability

experiment within *Minecraft*. It may be an experiment involving dispensers just with

something other than dyes and different proportions, or it may be something entirely of

the student's own devising. Further information on this lesson can be found on Elford's

blog (2015). But this final extension provides students an opportunity to synthesize their

knowledge of probability in the creation of their own experiment. A crucial aspect of this

activity is allowing students to explore and create inside *Minecraft* with minimal bounds

and according to their imagination. Thus, the combination of these three activities

showcases the potential of *Minecraft* as an educational tool in the math classroom.

Minecraft can teach fundamental topics of mathematics, integrate multiple subject areas,

and, most importantly, provide a fun and creative environment for students to pursue

learning in.

"Breaking Blocks" by Author

Another practical application of *Minecraft* incorporates systems of linear equations and

can be used in the algebra classroom. The varying amount of time required to break

different blocks when mined is the game mechanic of *Minecraft* upon which the lesson is

built. For example, if a player uses a stone pickaxe, lapis lazuli blocks take 1.15 seconds

to break but cobblestone blocks require only 0.75 seconds. Using these constants,

teachers can ask students to build a structure on their plot comprising of a set amount of

blocks which is then able to be destroyed within a given time limit. In preparation for the

lesson, the teacher must select a collection of blocks containing three different breaking

times for a given tool with which students will build their structures For example's sake,

we will settle on a stone pickaxe and select stone and lapis lazuli with 1.15 second

breaking time, cobblestone and brick with 0.75 breaking time, and dirt and nether rack

with 0.75 breaking time (a chart depicting the mining times for each block and tool in the

game is hosted on the *Minecraft* Wiki (http://minecraft.gamepedia.com/Breaking)). The

Minecraft world prepared for the lesson should include prepared 9x9 plots of land for

each student to build their structure on. Beside each plot should be a sign labeling the plot

and a chest filled with stacks of the chosen blocks and tools. Optionally, the teacher may

include aesthetic items such as torches and picture frames in the chest. While unnecessary

to the educational aspect of the lesson, these items add to the creativity and freedom

students can express in Minecraft. A display detailing the breaking time of each block

should be visible from each plot. Figure 2 provides a possible arrangement within a world
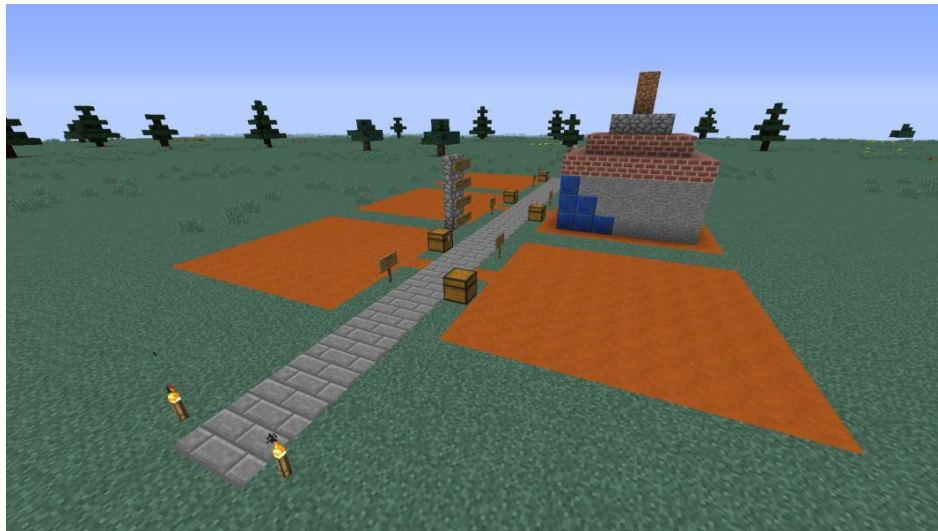
for this lesson.

Figure 2. Layout of Plots. Each student has their own plot where they
can build their custom structures, as scene in the screenshot.

At the start of the lesson, the teacher and students enter the *Minecraft* world. Once

each student selects a building plot, the teacher may freeze activity and have students

solve a system of three linear equations with three unknowns. Beforehand, the teacher

must have decided on the number of blocks to be used in each structure and how long the

structure must take to break down. Thus, the first two equations will relate these

parameters. Next, the teacher chooses one category of blocks of a single breaking time

and asks students to individually settle on a fixed number for how many of those blocks

they will use in their structure. The third equation in the system is simply assigning the

variable of the chosen category to this number. Using the above example selection of

blocks, the system of linear equations would appear as:

$$1.15x + 0.75y + 0.2z = 75$$
$$x + y + z = 100$$
$$z = 30$$

In this case, the teacher has decided the structure must be destroyed in 75 seconds and

will use 100 blocks. The teacher told the students to limit how many dirt and netherrack

blocks they will use, and this student set the limit at 30 blocks. After the teacher has

provided this information, students will solve their system of linear equations, and

therefore allocate how many of each category of blocks they will use. Once this is

accomplished, students may commence on the actual building of their structure. When all

students have finished their structure, the teacher will start a timer and the students will

breakdown their structure as quick as they can. Students will write down their individual

time as soon as they break their last block. The goal for the students is to finish as near to

75 seconds as they can.

Discussion should follow immediately upon completion of this last step in the

Minecraft activity. Classroom discussion is one of the greatest strengths *Minecraft*

lessons. Discussion of this activity should revolve around students' success, or lack of, in

destroying their structure in the allotted time. Students may find they could not destroy

their structure in time because of various reasons. The dialog may bring up the need to

double check the work in their equations, the selection of their fixed number may have

affected them, or they could come to the realization that they could not move straight from block to block breaking each in perfect succession. In this case, their speed may have been affected by a lack of player control or they may recognize that *Minecraft* imposes a delay between the breaking of one block to the next. This point is an important topic for the teacher to emphasize and let students expound upon. It is not directly related to the lesson, but it allows students to exercise problem solving and experiment evaluation skills. These are skills essential for designing and optimizing experiments, skills that can be applied in every area of life under the guise of finding the ideal route to solve problems that arise throughout the day.

General Guidelines for Minecraft Lessons in the Math Classroom

The preceding lesson is of the author's own creation; subsequently, this serves as a good reminder that the creative power of *Minecraft* does not exist just for students, but for teachers as well. Interested teachers should not use only created lessons found online, but rather they should play around in *Minecraft* for themselves and create activities stylized for their individual classrooms. Two specific math lessons within *Minecraft* have been provided. They have been put forth as points of inspiration to stimulate interested teachers with their own ideas for using *Minecraft* in the math classroom. The possibilities of *Minecraft* are not limited to these two topics but can be applied to nearly any mathematical topic so long as the teacher can be inspired with the design for the activity, remarkably similar to the process of generating any traditional lesson activity.

When designing a math lesson using *Minecraft,* it is important to remember the basic mathematical skills students should learn and how *Minecraft* can aid in the development of those skills. *Minecraft* is a hyper-geometric influenced environment. The

basic building blocks are cubes, and players must manipulate these cubes during their building and mining to create both different and larger geometric shapes compared to that base cube. *Minecraft* inserts players into a geometric environment in which they must exercise spatial awareness and reasoning to effectively interact with the environment of the game. The Common Core Initiative recognizes that "dynamic geometry environments provide students with experimental and modeling tools that allow them to investigate geometric phenomena" (Mathematics Standards, 2015, High School: Geometry: Introduction section, para. 8). Thus, fundamentally, *Minecraft* addresses a technique which Common Core emphasizes as a way to improve the ability of geometry students.

The basic skills of arithmetic such as addition, subtraction, multiplication, and division have a large, though often behind–the–scenes, role in the gameplay of *Minecraft*. The crafting system of *Minecraft* relies heavily on arithmetic formulas. In general, players will combine varying quantities of varying items to craft a new item. For instance, to craft an iron pickaxe the player must combine two sticks and three iron ingots in the correct layout. Thus, to effectively use the crafting system, players must mentally calculate the resources needed to craft a specific number of a certain item. Typically, players are performing these calculations without realizing it, yet the calculations are often multi–step and not so simple as the crafting of each item often has a varying number of factors associated with it. Continuing the example of crafting an iron pickaxe, the player must first mine three iron ore blocks and one wood block. The three iron ore blocks must be smelted down in a furnace to generate the required iron ingots. Each iron ore block will give one iron ingot, but the player must ensure the furnace has enough coal

to smelt the iron as each piece of coal will only smelt 8 items (Smelting, 2015). Also, the

one wood block will give the player four planks which will in turn generate four sticks

per plank. Thus, the players will recognize that one wood block breaks into sixteen sticks.

Using these gathered resources, the player will then be able to craft an iron pickaxe.

Thus, it is clear that many arithmetic calculations are performed by the player to create a

single item, and these calculations are increased if the player wants craft multiples of an

item. In fact, players looking to craft the maximum number of items with their given

resources solve basic linear programming problems. The first standard in the Standards

for Mathematical Practice put forth by the Common Core concerns the ability of students

to problem solve. The standard states:

> Mathematically proficient students start by explaining to themselves the meaning
>
> of a problem and looking for entry points to its solution. They analyze givens,
>
> constraints, relationships, and goals. They make conjectures about the form and
>
> meaning of the solution and plan a solution pathway rather than simply jumping
>
> into a solution attempt. (Mathematics Standards, 2015, Standards for
>
> Mathematical Practice section, para. 2)

A student's ability to problem solve cannot be underestimated as a basic skill for

mathematics. *Minecraft* forces players to problem solve on a continual basis. Whether

finding a way to protect oneself from harmful creatures, devising a method to ensure

access to enough food to survive, or deciding how many resources are needed for a

building project and how to obtain them, players are continually problem solving as they

play *Minecraft*.

The skills of geometrical reasoning, arithmetic, and problem solving covered above represent a few of the basic mathematical skills which *Minecraft* addresses for the typical player. Targeted lessons and activities within *Minecraft* are not needed to draw out these aspects of *Minecraft*. They are foundational to the gameplay of *Minecraft* itself. Yet teachers interested in using *Minecraft* in the math classroom should keep these properties of *Minecraft* in mind and look to emphasize one or more in their lesson. The student will be exposed to all of these properties by simply playing the game, but the teacher should look to develop an activity which focuses the learning of the student on a specified property or properties.

Benefits of *Minecraft* in the Classroom

Minecraft is a relatively new appearance within the classroom, yet teachers have already reported on the benefits witnessed by its introduction. David Smeaton orchestrated a study in which he surveyed 17 teachers who had experience using *Minecraft* in the classroom (Smeaton, 2013). The study aimed to assist in answering the question, "Is *Minecraft* a useful teaching tool?" (Smeaton, 2013, p. 1). Respondents were teachers from a variety of disciplines, including three math teachers. The relatively small sample size of the survey can be attributed to the foundling stage *Minecraft* currently holds as a teaching tool, yet despite this Smeaton's study provides concrete feedback from teachers with first-hand experience of *Minecraft* in the classroom. Overall, the results of the survey were very positive. Over three quarters of surveyed teachers agreed that *Minecraft* developed the following benefits for student learning: self-directed learning skills, greater motivation and participation, and greater inclination to complete classwork (Smeaton, 2013). These responses align with the responses of participants

from multiple other game-based learning studies. One teacher in a study responded with

"The kids just adored it…the motivation level was really, really high" after participation

in a game-based learning project involving video game consoles (Groff, Howells, &

Cranmer, 2012, p. 45). Teachers from this same study emphasized the teamwork and

problem-solving skills which game-based learning produced. After the project, a teacher

recalled, "They were definitely working well together effectively, sharing things, making

decisions, a lot of critical thinking was going on as well" (p. 46). The interactivity of the

lessons excited and engaged the participating students and the sparked these noted

positive learning behaviors.

      A key benefit to *Minecraft* and general game-based lessons is their ability to bring

uncommonly pronounced abilities of students to the forefront. Teachers noted students'

willingness to help out their peers with difficulties in-game. Even students who were not

typically seen as leaders or vocal took on new roles in the game-based lessons as they

found an opportunity to share with their peers in their area of expertise (Groff, Howells,

& Cranmer, 2012). Secondary STEM teacher Peter Tromba observed this emphasis on

non-traditional roles which *Minecraft* provides. He has used *Minecraft* in his lessons

multiple times and regarding the less engaged and detached students, students who,

according to Tromba, "were talented and gifted but not necessarily identified as such", he

noticed they "cleaved to the world of video games" when they were played in the

classroom (2013, p. 20). *Minecraft* accentuates the distinct and commonly un-touted, yet

valuable, areas of expertise which students may have. Consequently, Tromba noticed that

students who were typically uninclined to partake in discussions or give their input on

activities gained confidence to express their thoughts amongst peers and teachers (2013).

Minecraft accentuates this aspect as a result of it being easy to learn but having a high level of mastery. Therefore, students experienced in *Minecraft* may be inclined to help less experienced peers learn the basics of the game. It also gives these students the ability to use their *Minecraft* knowledge as a springboard for their group's achievement. In fact, when Matthew Farber, author of *Gamify Your Classroom*, interviewed MinecraftEdu co-founder Santeri Koivisto and asked him about the best way to deal with a mixed collection of *Minecraft* abilities within the classroom, Koivisto responded that grouping experienced players with beginners fosters great peer support and a transfer of knowledge between peers (Farber, 2015). Koivisto went on to say, "This is a great way for teachers who want their teaching to be more interactive, more conversational" (p. 99).

Following the upturn in enthusiasm within the classroom is the possibility of difficulty in classroom management. One respondent to Smeaton's survey noted, "Although the learners are highly motivated to play, the teacher needs to be quite strong with classroom management" (2013, p. 12). The need for strong classroom management comes from the combination of the unique setting of a computer lab, collaboration amongst students to accomplish the *Minecraft* activity, player activity within the game, the novelty of playing a video game in math class, and the simple element of student fun. When students are having fun, their enthusiasm and outward expression naturally increase which can lead to issues with classroom management, but chatter stemming from the excitement of learning is an improvement over chatter stemming from the boredom of learning. The chatter is also due in large part to student conversations revolving around ways to accomplish the *Minecraft* task. Thus, interested teachers should be aware of the need to exercise good classroom management when implementing a

Minecraft lesson, but it should not be daunting to the teachers once they understand the generally positive source of the need for this management. One final worry of game-based learning to address is that it may stifle student creativity by laying out a strict, step-by-step path that students have to follow to win the games objective. In the case of *Minecraft,* the foundation of player driven goals upon which *Minecraft* is built dispels this difficulty.

Conclusion

Minecraft is still in the infancy of its implementation in the classroom, even more so in the math classroom. Yet teachers who have already ventured to implement *Minecraft* in their classroom have reported inspiring success. The early reports of success have caused the small population of teachers using *Minecraft* to experience rapid growth within the last couple years. The Internet contains resources, such the MinecraftEdu World Library, MinecraftEdu's forums, and the blog MinecraftEdu Elfie, to aid math teachers interested in using *Minecraft.* Still, interested teachers should harness the fundamental principle of imaginative creativity and freedom which *Minecraft* offers and not be afraid to design their own lessons and activities to use in their classroom. Using *Minecraft* as a teaching tool offers an awesome opportunity for math teachers to improve the intrinsic desire for learning in their students and garner the ensuing benefits. David Smeaton answering the driving question of his survey "Is *Minecraft* a Useful Teaching Tool?" with a resounding "Yes" ought to offer the integration of *Minecraft* in the math classroom a great confidence in the brightness of its future.

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