Teaching Scientific Concepts using a Virtual World - Minecraft

By Daniel Short

Minecraft is a multiplayer sandbox video game based in a virtual world modeled on the real world. Players are able to build and craft everyday items using blocks.The cubic geometry of Minecraft lends itself to the teaching of various academic subjects. Minecraft also has a functioning ecology, with chemistry and physics aspects interwoven within the game that can be used to develop the scientific literacy of players. Here I describe various key scientific and mathematical concepts that are able to be modelled with the game for use in the classroom.

Introduction

With the advent of video games becoming a mainstream form of entertainment, overtaking movies in the amount of money grossed, as well as the amount of time spent playing them, they offer an alternative, if somewhat controversial way in which educational content can be delivered. As with all types of learning, students need direction and opportunities to reflect on their work (http://psychcentral.com/news/2011/02/17/using-video-games-as-a-stealth-teaching-tool/23615.html)

Minecraft is a sandbox (open world, freedom of how to play) building (analogous to Lego construction sets) video game written in Java and published by the company Mojang. It was released in May 2009 on the home computer platforms with an Apple iOS and Android release in 2012. The game play is centered on creativity and building, with players building (crafting) constructions out of textured cubes in a 3-dimensional world. The game starts with the player placed on a world generated by the program consisting of biomes containing plains, mountains, caves, deserts and bodies of water. The games time system consists of day-night cycles during which they are attacked by aggressive 'mobs'. In addition to the aforementioned 'survival' mode, there is also a 'creative' mode for building only. The game play includes the use of electrical circuits and logic gates which function much like their real-world counterparts. The game is appropriate for ages 6 and up with a developmental learning curve such that parts of the game (such as circuit building) can be mastered at higher grade levels. Use of the game in schools as an educational tool has increased significantly since the game's full release.

Minecraft as an educational tool has its own wiki (http://minecraftinschool.pbworks.com), educational 'mod' (modification) (http://minecraftedu.com/), and google group (https://groups.google.com/forum/?fromgroups#!forum/minecraft-teachers). The mod is an additional piece of software that allows instructors to control the game and game users. For example, students can be frozen, teleported, given access to blocks etc. The survival aspect of the game can be removed and the educational aspects focused on. Several teachers from various countries have developed instructional lessons using the MinecraftEDU experience; these range from simple tutorials on how to use the game in class to instructional units, some of which are described below.

History of Ecological Based Video games

The Earth based simulation 'Balance of the Planet' (1990) was designed to teach the user about global warming, jobs, health, food, wealth, and energy use. 'Sim Earth' (1993) was more of a simulation experience with players able to control the planet's atmosphere, temperature and landmasses. They would then place various forms of life on the planet and watch them evolve. The game modeled the Gaia hypothesis of James Lovelock (Lovelock, 1987) and one of the options available is the simplified "Daisyworld" model. Spore (2008) was written by the same author as Sim Earth and allowed the player to control the development of a species from its beginnings as a microscopic organism to an intelligent and social organism.

Various web based games focused on single scientific topics are available online [http://www.bunnygame.org, http://www.smogcity.com, etc.]. These are usually short activities designed around a central concept or theme. Web based games are in their most basic form glorified flash cards which by design lack the depth of content available in games such as Minecraft and as such are not the focus of this article.

Minecraft in the Classroom

The use of any video game, designed more for entertainment than learning is likely to raise the eyebrows in academia. I believe that pre-empting the 'game' as an educational tool, having well defined goals and constraining which elements of Minecraft are employed, will allow for its use in a variety of lessons in different subject areas. Introducing the game to a novice can be a difficult task due to the lack of instructions, for this reason many tutorial maps have been constructed. The previously mentioned MinecraftEDU mod is the perfect way for a novice to be introduced to the game.

The construction of full lessons to be used either in the classroom or online may take the form of single activities integrated into the normal classroom based lesson or full-blown adventure maps with a beginning, middle, and ending scenario. The following subsections provide an overview of how Minecraft has been used to-date in various disciplines, including examples of my own uses in a college based setting:

(i) Biology

Minecraft maps of the human body, including the vascular system, nerve cells and an animal cell are currently in development. Since these structures are not part of the normal game, these maps often make use of custom textures in order to visualize the component parts. Students are immersed in a visual 3-dimensional environment and are able to move in all directions. Cell functions are able to be investigated by moving and placing blocks in order to mimic cellular activity.

For example, in a map designed around the human body, the premise of the map would be similar to the movie 'Fantastic Voyage', in that your friend is sick and you/the class has to go inside his body to cure him by solving puzzles and fighting bacteria and viruses, while all the time exploring the different aspects of the human body. Maps such as these are currently in development for integration into MinecraftEDU.

(ii) Ecology

Perhaps Minecraft's strongest application lies in the area of the biological sciences, specifically ecology. Biomes are climatically and geographically defined as similar climatic conditions on the Earth, such as communities of plants, animals, and soil organisms, and are often referred to as ecosystems. In Minecraft, biomes are created by the map generator and display different heights, temperatures (indicated by leaf color, water color, presence or absence of water or desert), humidities and foliage. Examples include: Forest, Taiga, Swampland, Extreme Hills, Desert, Plains Ocean and Tundra (Figure 1).

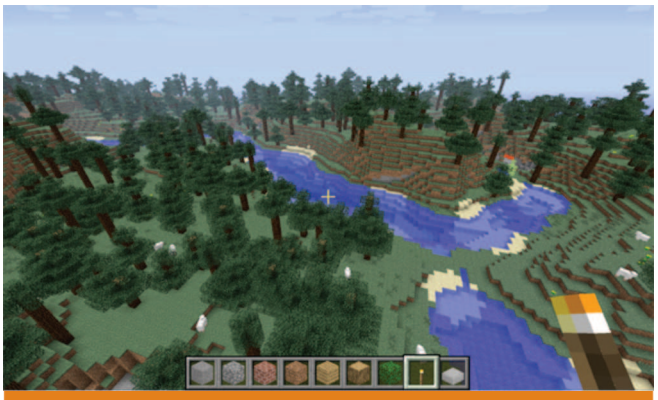


Figure 1: A typical Minecraft biome.

Trees vary in height depending on the biome in which they are located. Tree canopies are generated with leaf blocks which can be sheared to produce hedges. Trees come in three different types: oak, birch and pine. Trees require light and soil to grow. Trees may be farmed and are required for building simple tools. In the absence of coal, wood can be smelted into charcoal.

Real-world related animals include pigs, cows, chickens, sheep, squids and wolves. Hostile animals, fictional characters called 'mobs' can be switched off during game play. Animals may be farmed and reproduce when bred.

An enclosed Minecraft world (Figure 2) may be used to demonstrate Hardings, 'The Tragedy of the Commons' (Harding, 1968) (Grade 6 in US schools). When a population (a group of several players) inhabit the same area utilizing the same shared resources, those resources are rapidly depleted. This ultimately results in an unsustainable environment. This concept is commonly illustrated in the classroom with candy and/or goldfish crackers. To illustrate this principle using Minecraft, I built a self-contained world map inside a dome containing only trees. The model is played in two rounds, in round 1 the students are told to collect as much wood from the forested area as possible. Being a 'commons' type area, the space is very quickly laid to waste, which illustrates Harding's principle. In round 2, students are allowed to plant new trees and bound their harvest areas with fences, in which only they are allowed to farm. This leads to a more sustainable production of lumber.

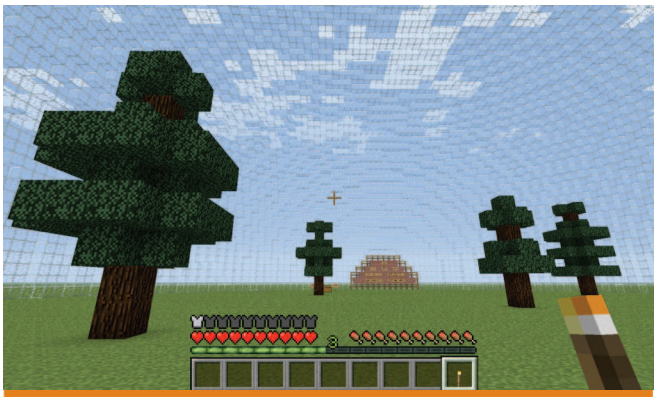


Figure 2: 'The Tragedy of the Commons' map.

(iii) Physics

One of the major differences between the game and real life is that most blocks (e.g., wood, stone, brick, dirt) do not fall when surrounding structures are removed, with the exception of sand and gravel. Gravity has an effect on most non-block objects in the game. Water exists in the liquid and solid states in the game. Source blocks are stationary but will flow if the block next to the source is removed. Water flows downhill and may be used to move items from place to place.

Minecraft uses a color system of dyes which can be combined to create new colors. There are currently 16 dyes, including seven 'primary' dyes (red, yellow, blue, green, white, black and brown) seven 'secondary' dyes (orange, cyan, purple, gray, light blue, pink and lime), and two 'tertiary' dyes (magenta, light gray).

The sun rises in the east and sets in the west. Atmospheric refraction is displayed in game with a red sky during sunrise and sunset (Figure 3). The moon shows all eight lunar phases.

Figure 3: Sunrise over Minecraft world.

Minecraft features block circuits which can be crafted into a number of logic gates similar to real life digital electronics. Large assemblies of logic gates can be formed into digital circuits such as: adding machines. Power is provided via torches and repeaters which can be used for applying timing delays to your circuit. More advanced circuits can be crafted such as delay circuits, monostable circuits and clock and pulse generators. Large scale circuits have been crafted such as a 3-D stereolithography interface with the real world (Elford, 2012).

(iv) Chemistry

Smelting of iron and gold ore using a furnace produces the pure metal. Sand may be heated in order to make glass or turned into sandstone. Cakes can be crafted from wheat, eggs, milk and sugar. Explosives (TNT) may be crafted from gunpowder and sand unlike its real-world multistep preparation.

Stephen Elford, an Australian primary school teacher, has developed a basic states of matter and phase changes simulation (solid, liquid, gas) using players as particles. A four-by-four area is bounded with wooden blocks, this area simulates the solid phase. Students enter the area and are told that they are particles of matter with limited mobility. The area is made larger by burning (simulating an increase in temperature), leading to a phase change to the state of a liquid. Students have more freedom of motion as the liquid phase but are still constrained by the boundaries set a further distance away. Finally, the last boundary is removed simulating the gas phase (Elford, 2012).

David Vreman has constructed a 3-dimensional periodic table of the elements, which uses sign posts to highlight key properties and uses of each element (Figure 4). Whilst chemistry is perhaps not the strongest component of the game, a modification (mod) of the game called 'MineChem' is available for free which allows further exploration of the elements.

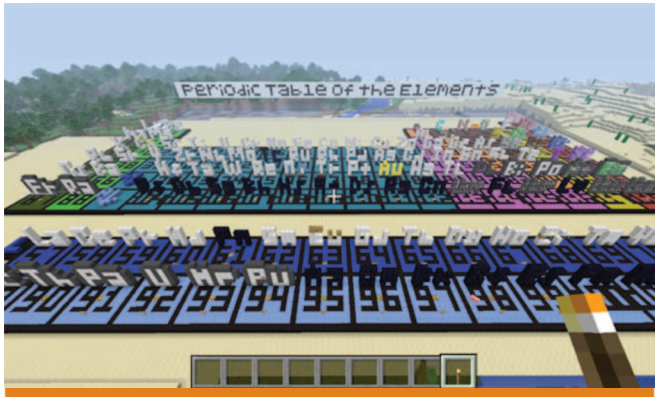


Figure 4: The periodic table in Minecraft.

Addition/subtraction, multiplication/division and ratios are the most obvious mathematical concepts put forward by the game, for example raw wood from trees becomes 4 wooden planks, 9 iron bars make one block of iron, 24 pieces of iron, gold or diamond make up a full set of armor. It is possible to set questions and use algebraic formulas on signs, walls and books.

Measurements of perimeter, area and volume are required to make symmetrical buildings with centered doors and windows. Geometry is important in the generation of circles from squares blocks. Circles may be generated in pixel art and transcribed to block patterns (Figure 5).

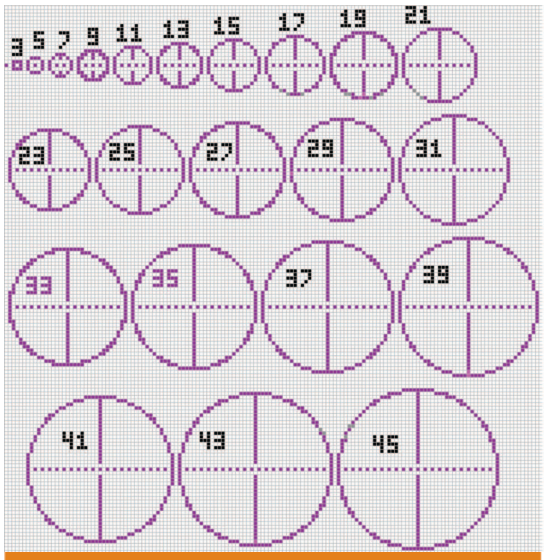
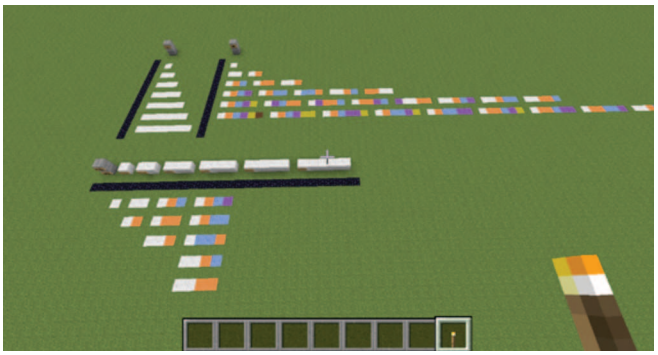


Figure 5: Circles in Minecraft.

Minecraft uses x, y, z coordinates to establish a player's location. North, east, south and west are defined in-game with the sun rising in the east and clouds flowing west. Navigation is possible through the use of coordinates, a compass and maps. Companies such as Maple are experimenting with displaying 3-dimensional images of mathematical functions (graphs) in the Minecraft world. Viewed from inside the game, the functions are able to be explored and changed in real time.

I have constructed a map called 'Fibonacci World' which uses geometric shapes and various block pattern puzzles for discovery learning (Figure 6). These exercises are based on regular classroom exercises adapted with comparable ease.



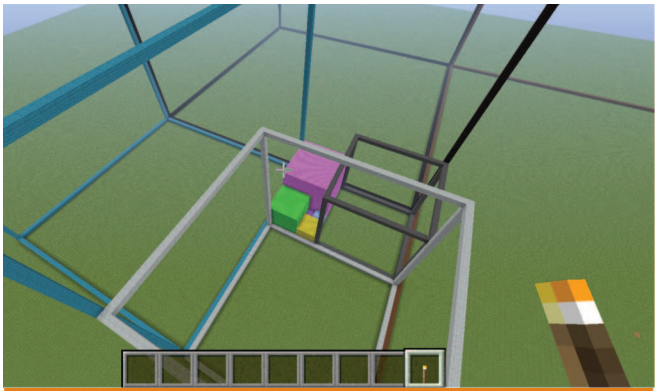


Figure 6: (a) Integer patterns in Fibonacci world. Each integer (1, 2, 3, 4, …etc has x number of patterns formed from blocks which correspond to the Fibonacci sequence.
(b) Fibonacci numbers in 3-dimensions.

(v) Geology and Geography

Cliffs, hills, mountains and ravines are generated by the game and are unique to each map. Beaches are generated next to oceans or lakes. If a lake is generated in a snow biome, it will freeze. The ability to configure a map using data imported from a Geographical Information System (GIS) has seen the development of Minecraft analogues to real world terrain. It is now possible to model any location on the Earth's surface.

Types of rock found in the game include obsidian, sandstone, stone, cobblestone and gravel. Minerals include diamond, gold, iron, clay and lapus lazuli. Mods have been developed to increase the number of available minerals. The minerals behave much like their real world counterparts with metals craftable into tools and clay being craftable into brick.

Conclusion

The use of video games in the classroom can supplement the use of other media, educational programming, web based videos, etc. Video game use represents another tool in the teacher's toolkit. Research suggests that simulations and immersive virtual worlds are increasingly being used to supplement traditional teaching methods Kirriemuir & McFarlane, 2003).

Minecraft itself is already being used to illustrate scientific concepts in classrooms across the world. At the present time, development of educational activity maps to be used as part of lesson plans is increasing. A number of teachers are sharing their development process using a combination of online forums and videos. Development of maps is not currently limited to teachers. A number of users of the game have created maps either as academic projects or proof of concept.

A Minecraft world can be designed by the instructor which would host a series of lessons in any one or a combination of the above areas. Exposure to any of the above concepts would have a positive effect on students, exposing them to various scientific concepts which can be related to real life experiences.

My goal with this article was to give some insight into the current happenings with what I believe to be an incredible opportunity for science instruction. From an academic's perspective, beyond the instructional opportunities that have been addressed here, the most exciting aspect of Minecraft is the ability for collaborative lesson design between instructors. The game lends itself to multiple users inhabiting the same world, be it instructor-student or instructor-instructor. Minecraft, is in my view, a game-changer in the field of science instruction.

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