Using Minecraft in the Science Classroom

Megan Pusey[a] and Grant Pusey[b]

Corresponding author: gpusey@churchlands.wa.edu.au
[a]Science Department, Penrhos College, Perth, WA, 6152, Australia
[b]Science Department, Churchlands Senior High School, Perth, WA ,6018, Australia

Keywords: Minecraft; video games; STEM; game-based learning; science

International Journal of Innovation in Science and Mathematics Education, 23(3), 22-34, 2015.

Abstract

With digital technology more accessible than ever, it is no surprise that students are spending an increasing amount of time playing video games. This study sought to investigate the educational value of digital game-based learning, or, the use of video games in the classroom. In this investigation, two Perth metropolitan schools trialled digital game-based learning by using *MinecraftEdu* as an innovative tool to teach science. The game provides a sandbox-style environment that allows students to interact with their digital surroundings in an extremely flexible way. *MinecraftEdu* was used alongside more traditional teaching methods at both schools to engage students in Earth Science and subsequent topics. Surveying students before and after the program took place and collecting anecdotal evidence during class through teacher observations assessed the value of the software. The comparison of the student surveys indicated a clear increase in student interest in science and the use of ICTs in school following the *MinecraftEdu* program. A majority of students, 84%, reported enjoying using *MinecraftEdu* in the classroom and 94% said they wanted to use *MinecraftEdu* in the classroom again. In addition to presenting student data obtained during the trial, information regarding the logistical issues with establishing and running the *MinecraftEdu* program, including lesson preparation and technology requirements, is also discussed.

Background

The rising use of technology

We live in an increasingly digital age with many aspects of our lives now relying on the use of technology. “Today we live in the presence of a generation of kids who have known no time untouched by the promises and pitfalls of digital technology” (Salen, Torres, Wolozin, Rufo-Tepper, & Shapiro 2011; p.30). Growing up immersed in technology has impacted on how today’s students receive and process information (Oblinger, 2004; Prensky, 2003). These *digital natives* grow up accustomed to operating in a digital world and may find a disconnect between their real-world experiences and the learning environment they encounter at school (Oblinger, 2004; Prensky, 2003). Consequently, teaching strategies have evolved over the years, integrating the use of technology into the classroom. Using computer-based simulations and educational games in the classroom is not a new idea; however, this study takes an additional step and looks at harnessing the popularity of commercial video games for use in the science classroom.

Video games as tools for learning

Video games are fast becoming ingrained in our culture, with a significant proportion of the population playing them (Entertainment Software Association, 2015). Children and adolescents are estimated to spend 60 to 90 minutes a day on average playing video games (Rideout, Foehr, & Roberts, 2010). Prensky (2003) estimated that adolescents will spend up to 10 000 hours playing video games by the time they are 21. The reasons individuals choose to play video games in their spare time are varied. Motivations include relaxation, socialisation and connecting with friends and family (Entertainment Software Association, 2015; Malone, 1980; Olson, 2010). Given the popularity of video games, it is not surprising teachers are beginning to use them in the classroom. Video games are a medium our students are familiar with; they are versatile, interactive and meet the learning needs of today's students (Van Eck, 2006). Interestingly, the skills required to play video games meet many of the Australian Curriculum's General Capabilities, including: literacy, numeracy, and Information and Communication Technology (ICT) capabilities (Australian Curriculum, Assessment and Reporting Authority, 2015).

There are many parallels between good pedagogy and good video game design. "Games create for players the kinds of domain-immersive experiences that resemble the most contemporary understandings about learning" (Salen et al., 2011, p.30). Video games are required to demonstrate attributes of effective learning environments, since at the most basic level, the player needs to learn how to play the game to win (Squire, 2004). An analysis of the most popular video games depicts utilisation of good learning design, such as increasing difficulty level, feeling of flow, goal orientation, and timely feedback (Gee, 2003; Oblinger, 2004). Video games are also designed to be intrinsically motivating through features such as challenge, fantasy, curiosity, control, and competition (Malone, 1980). The term "digital game-based learning" was coined by Prensky (2003) who investigated how the motivating nature of games could be successfully combined with curriculum learning goals. Although there have been mixed results, digital game-based learning has been shown to increase engagement and motivation in the classroom, and positively impact academic achievement (Gee, 2003; Erhel & Jamet, 2013; Papastergiou, 2009; Prensky, 2003; Van Eck, 2006; Wouters, van Nimwegen, van Oostendorp, & van der Spek, 2013).

Commercial video games with no obvious educational theme (e.g. *SimCity*, *Civilisation III*, *Portal 2*, *Minecraft*, *Kerbal Space Program)* are now being utilised as effective teaching tools in the classroom (Short, 2012; Squire, 2004; Teacher Gaming LLC, 2015). However, there is apprehension from teachers who are concerned that games made for entertainment could convey misinformation or foster misconceptions due to the trade-off between realism and fun (Oblinger, 2004; Van Eck, 2006). Certainly, the video game used in this study *MinecraftEdu*, is not a true representation of real world geology. However, instead of seeing this as a reason to avoid using the game, the teachers in the study used it to encourage critical reflection. Geoscience Australia (Davis, 2014) has tapped into the popularity of *Minecraft*, using it as a teaching opportunity by releasing a classroom poster describing key differences between the concepts seen in *Minecraft* and real world geology.

The important question is not whether teachers *can* use games to support learning, but *how* these games can most effectively be used as educational tools (Squire, 2005). This study seeks to present results that, in addition to providing additional evidence for the effectiveness of video games as teaching tools, may also offer practical guidance on how to implement video games as an effective educational tool in the classroom.

MinecraftEdu

Minecraft is an extremely popular commercial video game, initially created by independent game developer Mojang. Given its massive rise in popularity, Microsoft purchased the rights to the game from Mojang for $2.5 billion in 2014 (Ovide & Rusli, 2014). Over 20 million people have purchased the computer version of the game, a figure that does not include the copies purchased for other devices such as mobile phones, tablets, and consoles (Mojang, 2015).

Minecraft is an open sandbox game that allows players the freedom to create anything they can imagine, and is often compared to a digital set of LEGO. The game is designed to allow for creativity and openness from the player. Consequently, it provides a limitless environment for teachers to design activities that facilitate student learning in many different subjects. *MinecraftEdu* is an educational modification to the original *Minecraft* game and includes extra features to make it easier for teachers to control the game world and the users within it (Watters, 2012).

Study Design and Implementation

Participants

MinecraftEdu was used to teach the Earth Science component of the Year 8 Australian Curriculum at two Perth metropolitan schools. The participants in this study were Year 8 students aged 13-14 years old. This study involved two science classes from an all-girl private school (n = 47), and one science class from a co-educational public school (n = 29). The students were surveyed on their experience with video games, *Minecraft*, and Earth Science before and after the program.

Technical considerations

MinecraftEdu was deployed in a similar way at both schools. The *MinecraftEdu* server software was installed on a computer residing within the ICT department. In both studies, the classroom teacher was given remote access to the server computer in order to control the server settings. The server software is easy to use even for those relatively unfamiliar with video games. The teacher could also manipulate most of the server settings while they were inside the game. The computer network at both schools allowed students to connect wirelessly to the hostname or IP address of the computer running the server. In both schools, the *MinecraftEdu* server was only accessible while on the school network and was not available over the Internet. This meant students could not complete *MinecraftEdu* tasks for homework and any work completed in class could not be accessed at home. However, students could still operate the single player version of *MinecraftEdu* at home to sharpen their skills.

The *MinecraftEdu* software was installed on individual student laptops. Both schools involved in this study had a one-to-one student laptop program in place. The software was installed using a shared student folder containing an executable installation file allowing students to self-install the software in five to ten minutes. Students were provided with a set of step-by-step instructions detailing how to install *MinecraftEdu* and connect to the server. The private school students used identical medium performance laptops, whereas the public school students used one of four low-to-medium performance laptop models. The game performed well on nearly all of the computers, with a few students requiring additional assistance in both schools. Game speed was acceptable for all students, as the *MinecraftEdu* software does not rely on high-end computing power.

MinecraftEdu is best suited to being played with a keyboard and an external mouse, as opposed to using a touchpad or touch-screen display. Students were recommended to bring in an external mouse for *MinecraftEdu* lessons. Spare mice were kept in the classroom to accommodate students who forgot to bring their own. Some students still opted to use the touchpad on their laptop, despite it being more cumbersome.

Design and implementation of *MinecraftEdu* science lessons

Given the focus *MinecraftEdu* places on rocks and mining, Earth Science was identified as a fitting first topic to teach using the game. An initial series of *MinecraftEdu*-oriented lessons based on the Australian Curriculum Year 8 Earth Science topic were designed and implemented. The Year 8 Earth Science topic focuses on minerals, sedimentary, igneous and metamorphic rocks, and the rock cycle (Australian Curriculum, Assessment and Reporting Authority, 2015).

The *MinecraftEdu* lessons were used in conjunction with traditional teaching methods (e.g. worksheets, teacher presentations, videos, and practical experiments) over the five to six week Earth Science program. *MinecraftEdu* was used as an instructional tool about once a week. Parents of students were notified that *MinecraftEdu* was going to be used before the program began, with an invitation to contact the teachers if there were any concerns. Table 1 outlines the series of lessons implemented at the public school with a similar program followed at the private school.

Table 1: Program of MinecraftEdu lessons implemented at a WA public school to assist in teaching Year 8 Earth Science

Lesson Week	Title of Minecraft Lesson	Time Allocated
1	Introduction to MinecraftEdu: Progress through the tutorial world and learn how to play	40-60 minutes
1	Find and Classify: Classification of Rocks, Minerals, Ores	20-30 minutes
2	Scientific Inquiry Skills: Finding depths and locations where certain types of rock are formed	40-60 minutes
3	Stratigraphy: Determine relative age of fossils by digging through layers of earth	20-30 minutes
4	Quiz Maze: Navigate a maze by correctly answering a number of questions about Earth Science.	20-30 minutes
5	Design and Build: Build a shelter which resembles a particular rock or mineral texture	20-30 minutes

The first *MinecraftEdu* lesson made use of an in-built tutorial world that required minimal teacher instruction, beyond the initial setting up of the game. All classes received a set of rules to abide by while using the game. The goal of the first lesson was to orient the students in the digital environment and teach them how to interact with one another appropriately. The tutorial world was well received by students and freed the teachers to assist students with any start-up problems.

Some of the subsequent lessons required the teacher to build a suitable in-game world for the students to explore before the lesson. For example, in this study one teacher prepared a world with stratigraphy layers for the students to dig through (Figure 1). Once created, the in-game world can be saved as a file and any repeat lessons using the same activity require little preparation. The ability to save worlds also facilitates the sharing of resources between teachers, allowing a bank of suitable worlds to be produced for particular lessons. Additionally, some later lessons in biology utilised a pre-built downloaded *MinecraftEdu* world of an animal cell imported from another teacher (EduElfie, 2014), dramatically reducing preparation time. Despite this, it was still necessary to check the world was appropriate in meeting the intended learning goals, and make slight adjustments before using it in class. Overall, the process of developing and reviewing *MinecraftEdu* worlds was very similar to the processes used to develop and review student worksheets.

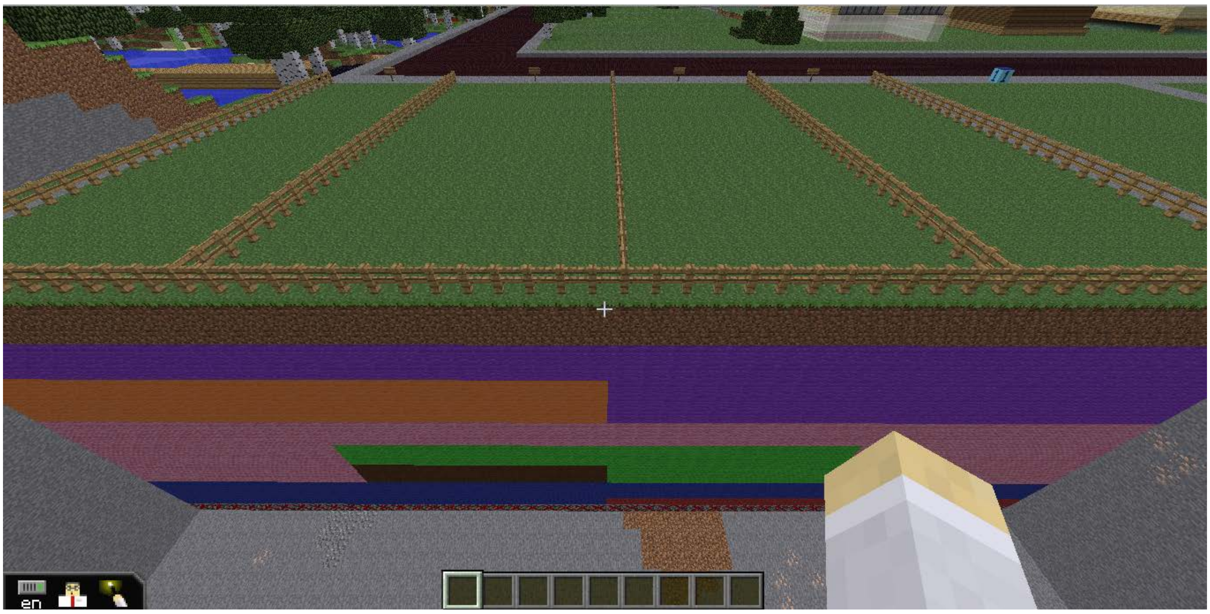

Figure 1. Screenshot showing the coloured earth layers beneath four student ‘dig zones’ used to teach stratigraphy. Students were unaware of the order of layers shown in this screenshot. Instead, students had to work together to dig through each layer, record data and collaborate to solve the overall puzzle.

The *MinecraftEdu* activities were designed to use a number of higher-order thinking skills represented in Bloom’s revised taxonomy (Churches, 2009; Karthwohl, 2002). For example, the classification activity required students to apply their understanding of rocks, ores and minerals to the world of *MinecraftEdu*. Additionally, the stratigraphy activity required students to analyse evidence found in the game in order to problem solve and answer questions about the relative age of fossils. Finally, the shelter building activity required students to create a structure using their current understandings of rocks and their characteristics. The activities were implemented using three different methods: digital worksheets, physical worksheets, and verbal instructions with no worksheet.

In both schools, *MinecraftEdu* was used in later science lessons to enhance other topics. For example, in the biology topic students created models of biological structures such as plant and animal cells (Figure 2) and the digestive system within the game. Students were then required to use the signpost feature in the game to label the components and describe their function. These subsequent lessons were easy to conduct at short notice, as students were already well accustomed to using *MinecraftEdu* in the classroom. Tasks that required students to create structures needed very little preparation from the teacher; students just needed an area in the *MinecraftEdu* world in which to build. These lessons provided the most flexibility for students and were always very well received.

Figure 2. Screenshot showing student models of a plant or animal cell. All cell organelles were required to be labelled with their functions described in a signpost.

Results

Teacher Observations

Teachers at both schools noted that students were excited when told that *MinecraftEdu* was going to be used in science lessons. Parent feedback at both schools was positive, with many praising the innovation. In lessons where *MinecraftEdu* was used, both teachers reported an anecdotal increase in student engagement and motivation. These was also highlighted by the survey results shown in Figure 3, with a majority of students reporting they enjoyed the use of *MinecraftEdu* and want to use it again.

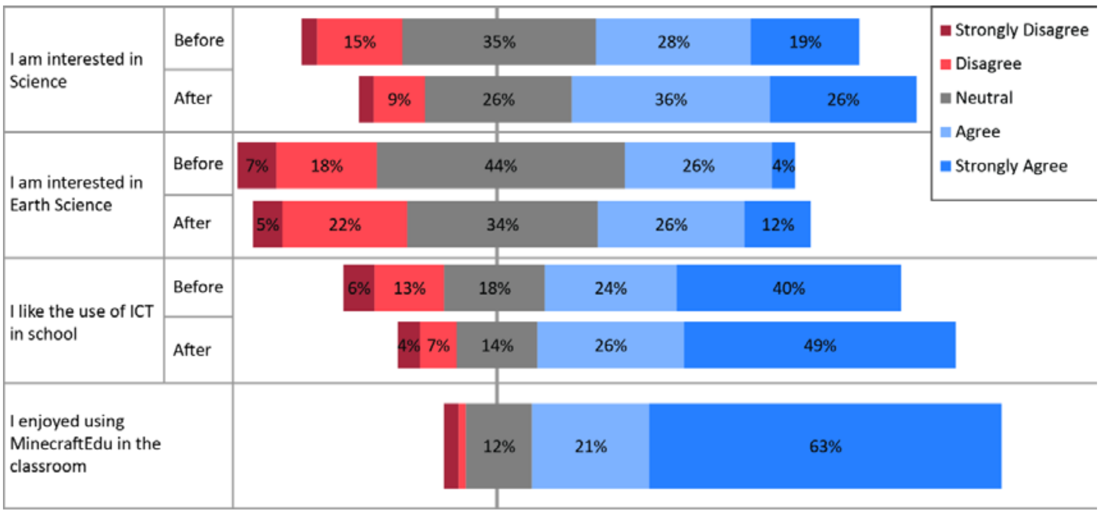

Figure 3. Student responses to surveys given before and after the Earth Science *MinecraftEdu* program, demonstrating an increase in overall perceptions of ICT and Science. Data from both schools has been combined.

Students were observed to be on-task and involved in discussions about the activity during all *MinecraftEdu* lessons. Students were also observed working together without prompting from the teacher. Often, students who were already familiar with *Minecraft* were observed helping less experienced students. Often, many students often expressed disappointment when it was time to end the lesson.

The most consistent observation at both schools was that a large percentage of students were excited about coming to science class, even underachievers and usually subdued students. Many students would ask when the next *MinecraftEdu* lesson was scheduled. The teachers felt their rapport with students had dramatically increased, and their students saw them as more “fun”. Other teachers often reported their students talking to their peers about the *MinecraftEdu* lessons in other classes. It was clear that students did not see the *MinecraftEdu* lessons as a regular science class, but rather a special activity, not unlike a dissection.

Physical worksheets were found to be the most effective way of complementing the *MinecraftEdu* activities. The worksheets provided students with information about what they were aiming to achieve by the end of each lesson and helped keep them on-task. By using a physical worksheet it was easy for the teacher to keep track of which students were on-task and how much of the activity they had completed. Importantly, students did not have to minimise the game to review the instructions on the worksheet. Using a worksheet (digital or physical) as opposed to just verbal instructions also meant students had a record of what they had completed that lesson. The worksheets also provided students with resources to assist with revision for formal assessments.

Student Responses

Students were asked a number of questions before and after the series of Earth Science *MinecraftEdu* lessons. Most questions asked students to respond using a Likert scale from 1 (Strongly Disagree) to 5 (Strongly Agree). Students were also given the opportunity to provide any other feedback or comments. A total of 76 students responded to the surveys.

Students were asked in the pre-program survey about their use of video games outside of the classroom and if they had played *Minecraft* before. It was found that 45% of students at both schools reported playing video games on a computer (Table 2). Mobile phones were the most commonly used device for playing video games at both schools, with 60% of students from the private all-girl school, and 72% of students from the public co-educational school reporting using mobile phones to play video games. The biggest disparity between the two schools was in the console category. Only 17% of students from the private all-girls school reported playing video games on a console device, compared to 55% of students from the public co-educational school. There was also a large difference between the schools in regards to how many students had played *Minecraft* before. Only 62% of students from the private all-girl school had played *Minecraft* before, compared to 90% of students from the public co-educational school.

Table 2: Comparison of percentage of students who play video games on various devices

	All-girls school (n=47)	Co-educational school (n=29)
Computers (or laptops)	45%	45%
Consoles (e.g. Xbox)	17%	55%
Mobile phones	60%	72%
Has played *Minecraft* before	62%	90%

In addition to posing questions regarding their general use of ICTs, students were asked specific questions about their feelings towards science and the use of ICTs to enrich education. The same students were surveyed before and after the program with the purpose of determining if a change in attitude was observed following the Earth Science *MinecraftEdu* program. As seen in Figure 3 student attitudes towards science and ICT were more positive after the program.

The most notable trend depicted in the data was that students who identified as being interested in science increased from 47% to 62%. The increase in interest in Earth Science was smaller, increasing from 30% to 38%. Students who identified as liking the use of ICTs in school rose from 64% to 75%. A large majority of students, 84%, reported enjoying (agree and strongly agree) using *MinecraftEdu* in the classroom. The public school students were asked an additional question about whether or not they wanted to see *MinecraftEdu* used in the classroom again. This question provided the strongest response with 94% of students either agreeing or strongly agreeing. Interestingly, only one student of 29 responded negatively to this question.

Students were given the opportunity to provide open-ended feedback about their classroom experience with *MinecraftEdu*. Most student responses to this section were positive. The most common feedback was that the activities were fun: *"I like how it was a different, fun way to learn about rocks. I think I took more from Minecraft than I would from a text book or taking notes."* Some students felt the activity was a good mixture of fun and learning: *"I like that it makes learning fun, you can muck around but do the work at the same time!"* Students also reported enjoying the collaborative feature of the activities: *"I liked the aspect that we could all participate at the same time."*

Negative feedback from students was limited and usually fell into one of two categories; difficulty operating the game, and not having complete freedom within the game world. A number of students found the game difficult to master in the beginning: *"I was not a previous player of Minecraft, so it was hard to start off with."* Many of these students were the same students who also reported not playing video games on the computer in their spare time. Some students were also not familiar with using a mouse to operate the software: *"it's just sometimes a bit hard to control with a [touchpad]."* The other common negative response was that the activities were too structured: *"we had to follow rules and do worksheets and we couldn't build or do what we wanted to do."* These students had perhaps mistakenly envisioned a class where they could simply play the game with their friends.

Discussion

Student Motivation

These results are not particularly surprising, given that it is already known that many students enjoy playing video games in their spare time. However, it was interesting to note that employing video games as a teaching tool increased student perceptions of ICTs in the classroom. Students reported enjoying the experience because it was interactive, collaborative, fun, and different to "regular" schoolwork. This result correlates with research published by Malone (1980) and Olson (2010), who reported similar reasons behind why video games are engaging.

It was interesting that student attitudes towards science as a whole became more positive, and not just towards Earth Science, the topic that was in the spotlight during the trial. This result suggests students experienced an increase in enthusiasm about coming to science class, given the possibility of having the opportunity to participate in a "fun" activity. These results are consistent with the large body of research already showing that game-based learning can increase engagement in the classroom (Gee, 2003; Erhel & Jamet, 2013; Papastergiou, 2009; Prensky, 2003; Van Eck, 2006). However, there were still a few students were turned off by the choice of game. Despite the positive results, the authors acknowledge there is no silver bullet for impressing all students as "no single instructional game can be expected to appeal to everyone" (Malone, 1980; p.21).

Teacher Feedback

Undoubtedly, the first lesson for both the students and teachers was a steep learning curve. For some students this was the first time they had ever played *Minecraft*. These students needed at least one (if not two) lessons to learn how to play the game before meaningful learning about science could take place. *MinecraftEdu* comes with a well-designed tutorial world that shows players how to play the game. Teacher reports indicate that subsequent Earth Science lessons were more enriching once the students had mastered the game controls. It is therefore advisable that in the absence of class time, students are given the opportunity to familiarise themselves with the game at home, perhaps with a small single-player homework task.

The teachers running the *MinecraftEdu* sessions needed to know how to operate the game at a basic level in order to effectively control and monitor students. However, teachers certainly do not need to be experts or know more than the students. *MinecraftEdu* has been designed with teachers in mind and has some added features such as the ability to "freeze" and "mute" students – vital tools for controlling the flow of a lesson (Figure 4). If a teacher has never played *Minecraft* before they would need to invest some time into learning how to play the game before using it in class. Indeed, Ketelhut and Shifter (2011) elaborate that for successful implementation of game-based learning, teachers need time to develop a familiarity with the game, models of successful implementation and just-in-time support.

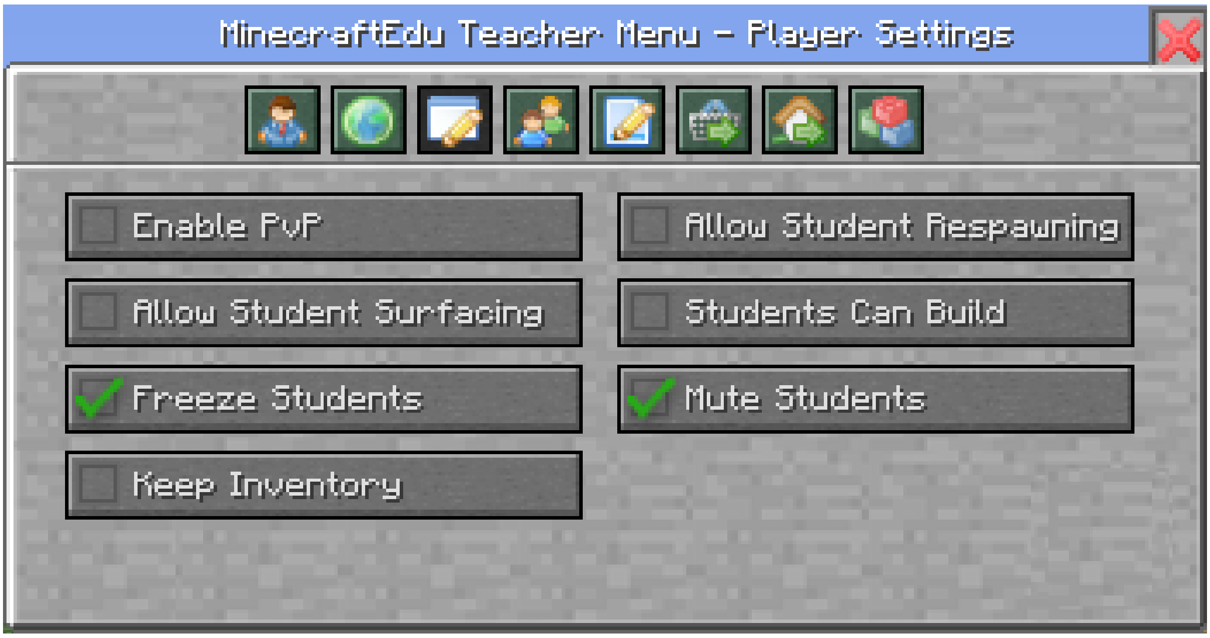

Figure 4. Screenshot of the teacher menu showing some of the additional teacher controls, such as freezing student movements and building control.

The *MinecraftEdu* website (Teacher Gaming LLC, 2015) provides a range of resources for teachers including forums, downloadable worlds made by other teachers, and technical support. However, it can be difficult to locate resources that match specific learning goals or curriculum points given that the use of *MinecraftEdu* in science is relatively new. The absence of pre-built worlds requires teachers to invest some time into designing activities for their students to complete in *MinecraftEdu*. Teachers also found that they could obtain important feedback regarding student learning within the *MinecraftEdu* worlds directly from students during each lesson, directing improvements for subsequent lessons.

Both teachers found that activities that required students to use higher-order thinking skills, such as building models within the game, were the most successful and engaging lessons. The open-ended aspect of these activities allowed students to demonstrate their depth of understanding of the topic. Activities that required the students to apply their knowledge with clear objectives in a creative environment resulted in the highest level of application. Examples of these tasks include building shelters resembling rock types, building cells (Figure 2) and a model of the human digestive system. The teachers involved in this trial found these types of lessons excellent alternatives to traditional platforms such as posters, paper cut-outs or plasticine models.

Conclusion

This study sought to investigate the effectiveness of utilising *MinecraftEdu* as a teaching aid for high school science classes, focusing on Earth Science. In addition to providing useful, practical information pertaining to the most effective strategies for deploying *MinecraftEdu* in the classroom, the study obtained high quality data regarding student perceptions of video games, science and ICT in the classroom. *MinecraftEdu* was successfully deployed with students in three Year 8 science classes at two different Perth high schools, providing information to facilitate a contrast between students at a private all-girls school and a public co-educational school.

Implementation of the program was not as simple as a traditional lesson, requiring coordination with the school ICT department to set up a local *MinecraftEdu* server. Additionally, students needed some guidance in installing the software, and the students who had not played *Minecraft* before required help learning how to play the game. However, following the initial lesson, subsequent lessons required substantially less work from the teachers. Additionally, the systems employed to support the use of *MinecraftEdu* in the classroom are now in place, with little work required to expand the use of the software to other classrooms.

Students at the private school were found to be less active with video gaming before the trial began, particularly with console games. Despite this, the level of engagement from students during the program was found to be similar at both schools. Student perceptions of ICT use in education became more positive following the trial. Importantly, student interest in science increased following the use of *MinecraftEdu* in the classroom. The program provided a way for students to become more engaged in the Earth Science topic than if they were subjected to a more traditional pen-and-paper lesson.

It is important to note that the teachers in this program have strong backgrounds in video gaming, which assisted tremendously in the research. For successful implementation of game-based learning, teachers need time to develop a familiarity with the software involved (Ketelhut & Shifter, 2011). This idea reinforces the importance of effective teacher training for the successful deployment of digital game-based learning.

Overall, the data from this study provides promise for the use of *MinecraftEdu* for innovative education in science. The results from this program indicate that digital game-based learning has proven itself again to be an engaging and motivating way to teach, and provides another step towards this movement gaining traction in Australia (State of Victoria, 2011). Many studies, including the one presented in this paper, have shown that digital game-based learning is a powerful motivational tool and increases student engagement (Gee, 2003; Erhel & Jamet, 2013; Papastergiou, 2009; Prensky, 2003; Van Eck, 2006; Wouters, van Nimwegen, van Oostendorp, & van der Spek, 2013). However, there is little evidence to support whether game-based learning increases academic achievement - an ideal area for future research. It has been proposed that effectively evaluating student learning with new innovations could prove difficult (Van Eck, 2006). With this challenge in mind, the authors hope to conduct further study into the effectiveness of game-based learning at their respective schools in the future, with an objective of evaluating any learning benefits that may be present.

Acknowledgements

The authors would like to acknowledge the support provided by Penrhos College and Churchlands Senior High School. The ICT departments at both schools provided invaluable support in setting up the infrastructure needed to run *MinecraftEdu*. The Science departments at both schools were also very supportive in encouraging innovative teaching practices and lending their expertise when required.

"A school culture that cultivates innovative practice based on greater teacher agency is needed for authentic game-based learning to find traction in the classroom" (Chee, Mehrotra, & Ong, 2014, p. 1).

Most importantly, the authors thank the students in Dr Pusey's and Mrs Pusey's Year 8 Science classes for participating in the program, completing the surveys and not being afraid to have a go.

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