Unleashing Math Thinking Power through Minecraft

Benefits and Tips for Educators on Making the Most of Minecraft for Math Education

By: Lisa Floyd

Inspired by a presentation on Minecraft by **Brian Aspinall (http://mraspinall.com/), this document could be used to supplement his Making in Minecraft slides.*

Introduction

This resource will focus on how to maximize the learning potential of Minecraft, a sandbox video game originally created by Markus Persson and later developed by Mojang. A quick Google Search will indicate that many educators around the world are using Minecraft in their classes to support and enhance student understanding of math ideas.

Teachers are harnessing the excitement, engagement and love of the Minecraft application to get students thinking more deeply about math ideas, their decisions and creations, and to make connections to the world around them.

Potential Benefits of Integrating Minecraft into Math Class

The Ontario Ministry of Education recently released a document, *21st Century Competencies: Foundation Document for Discussion*, which lists and describes the competencies that have been widely accepted internationally for helping our students "succeed now and in the future" (Ontario Ministry of Education, 2016, p 4). Many of the competencies are specifically addressed and developed through the use of Minecraft and are outlined here.

> *"Being free to build virtual worlds enables us to engineer systems beyond the physical world." (Wing, 2006, p. 35)*

Critical Thinking

Fullan (2013) describes critical thinking as the "ability to design and manage projects, solve problems, and make effective decisions using a variety of tools and resources" (p. 9). Papert (1980) supports exercises that "open intellectual doors" (p. 63). Minecraft tasks can be used to create experiences that can be otherwise challenging to design, which according to Drake (2014), should address real-world problems that may not necessarily have one clear answer. Digital tools such as Minecraft demand higher order thinking skills, which include "the ability to think logically, and to solve ill-defined problems" and "formulating creative solutions and taking action" (Ontario Ministry of Education, 2016, p. 12).

Creativity

Spend five minutes with a child as they show you buildings and landscapes that they have created in Minecraft and you will undoubtedly appreciate its value for harnessing creativity.

> *"Equipped with computing devices, we use our cleverness to tackle problems we would not dare take on before the age of computing and build systems with functionality limited only by our imaginations."*
> *(Wing, 2006, p 35).*

When schools provide experiences for students that help to enhance creativity, they are not only fostering the notion that multiple solutions are valued but also that "imagination is honoured over rote knowledge" (Upitis, 2014, p, 3). Research indicates that creativity is important for social development (Ontario Ministry of Education, 2016, p. 13). By providing them with a vehicle for creativity, students have the potential to pursue new ideas, which will help them to feel that they are making useful contributions (Ontario Ministry of Education, 2016, p. 13).

Communication and Collaboration

The *21st Century Competencies: Foundation Document for Discussion* (2016) suggests that "digital tools and resources represent a new realm of communications interaction in which the ability to navigate successfully is essential for success in the 21st century" (p. 12). In some classrooms, teachers have created opportunities for students to communicate globally in projects that involve creating in Minecraft (see link). Students have collaborated to design and build with one another as they make decisions on how to design and create their online worlds.

One of the reasons students tend to enjoy Minecraft is that it provides a vehicle for collaboration. Working in teams, learning from and contributing to the learning of others and using social networking are key components of collaboration in the 21st century (Fullan, 2013, p. 9). Minecraft helps to support collaboration which according to *21st Century Competencies: Foundation Document for Discussion* (2016), supports students to become creators as well as consumers of content (p. 13).

Below are examples of student build's from Scott McKenzie's Grade 3/4 class from New Dundee and Michael Frey's Grade 4/5 class from Cambridge. They linked up with Mr. Richard Campbell's students in Busan, Korea to build a shared world in Minecraft. This world was designed to represent the students' shared understanding of Human Rights.

Students worked together to build in Minecraft.

Students discussed Human Rights as they collaborated to create scenes in Minecraft.

Teachers, Scott McKenzie and Michael Frey describe the experience working on their project, "21st Century Learners in a Global Classroom", in which Minecraft was a key tool for collaboration.

"*Students were familiar with Minecraft, and had played with their friends locally, but this was a new experience. Students were meeting and working with other students from a very different culture, and they were successful collaborating. Their shared knowledge of how to build and construct a shared world, and careful coaching from teachers on how to communicate in a "chat only" environment, allowed them opportunities to work successfully on a variety of shared projects. Their enthusiasm had them working at home early in the morning, with students in Korea who were getting home in the evening from school. In this way, the students independently sought out meaningful collaboration."*

Computational Thinking

Another competency, not listed in the *21st Century Competencies: Foundation Document for Discussion* (2016), but is often listed in other similar documents around the world is Computational Thinking (Bars, Harrison & Conery, 2011). Computational Thinking "is a powerful cognitive skill that can have a positive impact on other areas of children's intellectual growth" (Horn, Crouser, & Bers, 2013, p. 380). Wing (2006) says that computational thinking gives us the "the courage to solve problems and design systems that no one of us would be capable of tackling alone" (p. 33). She also suggests that computational thinking should be added "to every child's analytical ability" (p. 33). In Minecraft, students build and design systems, create models and representations of real world artifacts, essentially acting as engineers, all of which Wing considers important components of Computational Thinking

(2006). In a sense, students can "code" Minecraft to make things happen, such as farming crops and controlling electronic circuits.

Engagement through Minecraft

Ginsburg (2002) suggests that "children possess greater competence and interest in mathematics than we ordinarily recognize" (as cited in Gadanidis & Namukasa, 2007, p.116). We should aim to create situations in which children are challenged to understand big mathematical ideas and have opportunities to "achieve the fulfillment and enjoyment of their intellectual interest" (Ginsburg, as cited in Gadanidis & Namukasa, 2007, p. 116). Children around the world choose to play Minecraft, so honing in on this, can be one way to help with engagement in classrooms. Research has shown that "students are more engaged, intrinsically motivated to learn, and more successful when they can connect what they are learning to situations they care about in their community and in the world" (Ontario Ministry of Education, 2016, p. 34). Technology, such as the Minecraft application provides access to "simulations to situate learning in the real world, and opportunities for students to link learning to personal interests" (Ontario Ministry of Education, 2016, p. 34). It has long been acknowledged, such as in the works of Piaget in the 1950s, that children build knowledge through experience and by enabling students with the freedom to explore their interests through technologies, we are supporting their development of reasoning and problem solving skills (Bers, Flannery, Kazakoff & Sullivan, 2014, p. 146).

Jim Pedrech, a high school teacher in Strathroy, Ontario, uses Minecraft extensively in his classes. In one project, students recreated their actual school in Minecraft.

Holy Cross Secondary School actual photo.

Holy Cross Secondary School built using Minecraft Tools (with textures).

Here is the video depicting this school project: https://www.youtube.com/watch?v=AtWBMtxdvs8

Enhancing Math Ideas

Spatial Reasoning Skills Development

Minecraft clearly promotes the development of spatial abilities, which research has shown can have a positive impact on students' future success in math and science (Newcombe, 2010).

Children's math reasoning originates from their pattern and structure awareness (Mulligan & Mitchelmore, 2013). Not only can students use Minecraft, dynamic software to manipulate figures and analyse patterns, they can explore what-if scenarios, helping them to make sense of the world around them (Sneider, Stephenson, Schager & Flick, 2014, p. 55). In her paper, *Fostering Spatial Understanding in Geometry*, Barbara Kinach (2012) suggests that spatial thinking can take on a variety of forms including building and manipulating objects and models. Simulations, such as those that can be created in Minecraft, "allow scientists and students to investigate the natural or designed world in ways that were impossible before" (Sneider, et al., 2014, p. 57). Visualizing relationships and making sense of the world is important for students to understand ideas in math class (Kinach, 2012, p 536). Students are able to build models and explore them in Minecraft. Dede (2014) suggests that virtual manipulatives help students to "master abstract principles and skills through the analysis of real-world situations (p. 2). Student creations can easily be shared in Minecraft which helps teachers to not only build on the knowledge of classmates, but also aids the teacher with sharing the various solutions and student contributions with the class (Dede, 2014, p .10).

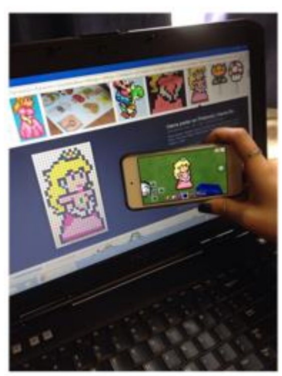
Connecting to the Math Curriculum

Use of Minecraft readily meets many curriculum expectations from the *Ontario Curriculum*. Here are some examples of how Minecraft can meet curriculum expectations in grades 7 and 8 math.

Number Sense – Proportional Reasoning:

- Solve problems involving the calculation of unit rates;
- By the end of Grade 7, students will: – determine, through investigation, the relationships among fractions, decimals, percents, and ratios.

Brian Aspinall, an elementary school teacher in Chatham, often uses Minecraft in his math class…

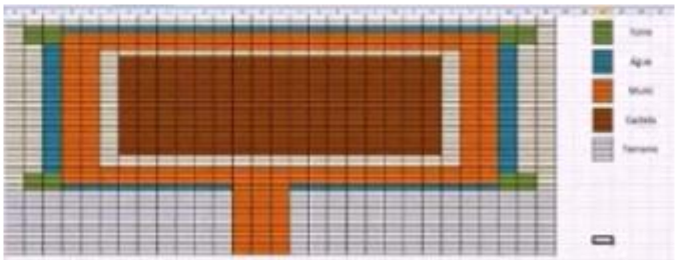


Measurement:

- By the end of Grade 7, students will: – research and report on real-life applications of area measurements (e.g., building a skateboard; painting a room);
- By the end of Grade 8, students will: – research, describe, and report on applications of volume and capacity measurement (e.g., cooking, closet space, aquarium size).

Take a look at some ideas that incorporate Proportional Reasoning and Measurement from Jim Pedrech and Francisco Tupy (http://dailyedventures.com/index.php/2015/06/23/francisco-tupy/):

Pedrech and Tupy suggest using a spreadsheet (or paper/pencil) and have students prepare “blueprints” for their Minecraft buildings. Students can plan the various views (top, sides, front, back) using a grid. This is effective for having students visualize each dimension. Students can use scale diagrams and make use of proportional reasoning.



Using Spreadsheets to prepare: Top-down, side view, front view to help students with accuracy and representation (Pedrech, Tupy, 2015).

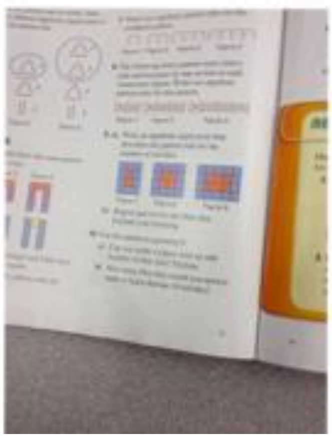
Using Graph paper to prepare: Top-down, side view, front view to help students with accuracy and representation (Pedrech, Tupy, 2015).

Patterning:

- determine a term, given its term number, in a linear pattern that is represented by a graph or an algebraic equation;
- make connections between solving equations and determining the term number in a pattern, using the general term (e.g., for the pattern with the general term 2 n + 1, solving the equation 2 n + 1 = 17 tells you the term number when the term is 17);
- solve and verify linear equations involving a one-variable term and having solutions that are integers, by using inspection, guess and check, and a “balance” model (Sample Problem: What is the value of the variable in the equation 30x – 5 = 10?).

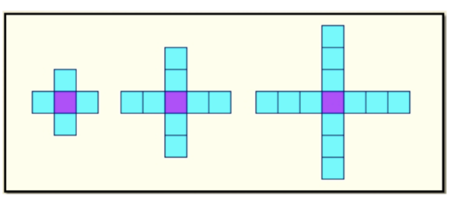
Take a look at some Patterning ideas from Brian Aspinall…

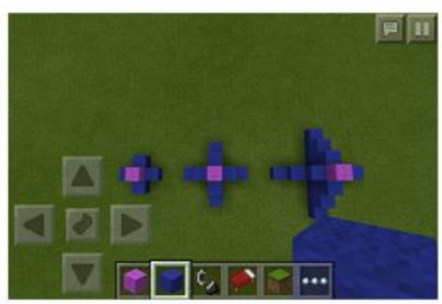
An alternative method to solving a textbook problem….



Term #	Term Value
1	5
2	9
3	13

Pattern Rule: 4n + 1





More Patterning Ideas from Brian Aspinall…

Can you identify the Pattern Rule?

Cross Curricular Potential of Minecraft

The possibilities for engaging students in multiple subject areas through Minecraft are endless. The more connections that students can make in their learning to prior knowledge and experience, between subject areas and to the real world, the more they will see the relevance and the more likely they will see the learning as authentic. Connections to Science can be seen in structure and in electronic circuits that can be created with Redstone, a powerful block in Minecraft. Other obvious connections include media studies, social science and literacy (see Making in Minecraft Presentation).

Enhance the Process with Other Tools…

1 – Google My Maps - Use Google My Maps to Measure around landmarks (with thanks to David Carruthers (https://thepluggedinportable.com/) and Sabrina Tyrer, Thames Valley District School Board for the tip).

2 – Use Google Cardboard to have students view landmarks to help with visualization.

3 – Make a 3D Model using Lego Bricks before building in Minecraft (or vice versa). Students make use of proportional reasoning and measurement by including a scale.

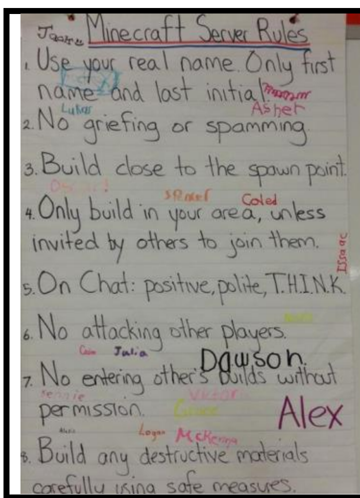
Incorporate Math Discussions

To increase engagement, and to ensure math thinking and reasoning is happening with the integration of Minecraft, encourage math discussions related to student builds. This also reduces the amount of screen time and helps to ensure the math curriculum is being drawn out. The role of the teacher is not to be an expert in Minecraft, but they should consider themselves experts in math content as well as pedagogy. It has been shown that “large-scale research directly links student success in mathematics to teacher knowledge of mathematics content and pedagogy”, according to Baumert et al., (as cited in Fields Institute, 2012, p. 2).

Children learn through “engagement with others: people and tools help us achieve what we cannot achieve alone” (Jaworski, 2015, p. 33). By allowing students the opportunity to share their Minecraft creations, knowledge of tools and to explain their reasoning, teachers can ensure the math ideas are being brought out and that students are understanding the math connections (Ryan & Williams, as cited in Mackle, 2014, p. 21). It is important that students have a voice in math class, just as we often expect them to share ideas in other classes (Miller, 2014, p. 14). Promoting communication can hold students accountable while helping them to see that the math is relevant in their Minecraft creations (Mercer, as cited in Langer-Osuna & Avalos, 2015, p. 1314; Jaworski, 2015, p. 24). Research shows that math discourse helps students to ask more questions, which will in turn help them to see meaningful connections, so long as educators “dare to let their [students’] questions and reflections take them forward” (Franzen, 2015, p. 1940). Gonzalez (2015) states that math discourse “empowers students to take responsibility for their own learning and the learning of the group members”.

Tips for Ensuring Effective Math Discussions with Minecraft

Many researchers suggest that teachers should develop ground rules for effective discussions (both online and in person) with their students. Ground rules might include: listening carefully, asking questions, taking turns when speaking and providing students with suggested phrases they should consider using (Wheeldon, 2006, p. 40; Bruce & Flynn, 2011, p. 310). The main goal is to ensure students know how to “question each other in productive ways” (Bruce & Flynn, 2011, p. 310).



Setting Ground Rules helped set-up Scott McKenzie and Michael Frey’s students for success as they worked in a collaborative online environment.

It is important that teachers be willing to sit back and allow for students to figure out how to solve the math challenges in Minecraft on their own (Bruce & Flynn, 2011, p. 311; Curran & Kersaint, 2015, p. 3). Monitoring and observing the discussion, online and in person is important, but the teacher can still play a role in "managing the flow of mathematics discourse" by asking questions that spark deep mathematical thinking and to ensure the curriculum expectations are drawn out (Curran & Kersaint, 2015, p. 2). Teachers should attempt to help students to see that their errors can be learning opportunities (Bruce & Flynn, 2011, p. 311).

The beauty of Minecraft is that teachers can assign varying "degrees of challenge", which is important for encouraging more diverse responses (Jaworski, 2015, p. 30-32). The teacher can play an important part in deciding which Minecraft creations and ideas can be shared and the order of which to share them in (Curran & Kersaint, 2015, p. 3; Stein, Engle, Smith & Hughes, 2008, p. 321). Teachers who use Minecraft have observed that when they initiate challenges, the students end up designing, building and creating in many different ways based on their own knowledge, readiness and creativity. Hopefully, with the right sequencing, students will see the connections between the math, their own work and the creations of classmates' (Stein et al., 2008, p. 321; Curran & Kersaint, 2015, p. 3). In the end, students should "develop a relational attitude to mathematics rather than an instrumentalist view" (Wheeldon, 2006, p. 41). The more the teacher can encourage the use of mathematical language while students are describing their builds in Minecraft, the deeper their understanding of the math ideas will be (Curran & Kersaint, 2015, p. 2).

With thanks to:

Brian Aspinall (http://mraspinall.com/)

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Francisco Tupy (http://dailyedventures.com/index.php/2015/06/23/francisco-tupy/)

References

Barr, D., Harrison, J., & Conery, L. (2011). Computational Thinking: A Digital Age Skill for Everyone. International Society for Technology in Education (ISTE). 21-23. Retrieved from: http://www.csta.acm.org/Curriculum/sub/CurrFiles/LLCTArticle.pdf

Bers, M. U., Flannery, L., Kazakoff, E. R., & Sullivan, A. (2014). Computational thinking and tinkering: Exploration of an early childhood robotics curriculum. *Computers & Education*, *(72)*145-157. doi:10.1016/j.compedu.2013.10.020

Bruce, C. D., & Flynn, T. (2011). Which Is Greater: One Half or Two Fourths? An Examination of How Two Grade 1 Students Negotiate Meaning. *Canadian Journal Of Science, Mathematics & Technology Education*, *11*(4), 309-327. doi:10.1080/14926156.2011.570475

Curran, D., & Kersaint, G. (2015). Orchestrating Mathematical Discourse to Enhance Student Learning. *District Administration*, *51*(12), 2-3.

Dede, C. (2014). The role of digital technologies in deeper learning. Students at the Center: Deeper Learning Research Series. Boston, MA: Jobs for the Future. Retrieved from: http://www.studentsatthecenter.org/sites/scl.dl-dev.com/files/The-Role-of-Digital-Technologies-in-Deeper-Learning-120114.pdf

Drake, S.M. (2014). Designing across the curriculum for “sustainable well-being”: A 21st century approach. In F. Deer, T. Falkenberg, B. McMillan, & L. Sims (Eds.), Sustainable well-being: Concepts, issues, and educational practice (pp. 57–76). Winnipeg, MB: Education for Sustainable Well-Being (ESWB) Press. Retrieved from: www.eswbpress.org/uploads/1/2/8/9/12899389/sustainable_well-being_2014.pdf#page=65

The Fields Institute for Research in Mathematical Sciences Sub-Committee. (2012). *Mathematics Pre-Service Teacher Education in Ontario: Consultation Brief Regarding the Extended Pre-Service Program*. Toronto, ON: Fields Institute, Research in Mathematical Sciences.

Franzén, K. (2015). Being a tour guide or travel companion on the children's knowledge journey. *Early Child Development & Care*, *185*(11/12), 1928-1943. doi:10.1080/03004430.2015.1028401

Fullan, M. (2013). Great to excellent: Launching the next stage of Ontario's education agenda. Toronto: Ontario Ministry of Education. Retrieved from: www.edu.gov.on.ca/eng/document/reports/FullanReport_EN_07.pdf

Gadanidis, G., & Namukasa, I.K. (2008). Teacher Tasks for Mathematical Insight and Reorganization of What it Means to Learn Mathematics. *Tasks in Primary Mathematics Teacher Education.* Springer Science & Business Media. 113-130.

Gonzalez, M. (2015). From Quiet Straight Lines to Noisy Grouped Students: Creating Math Discussions. *Ohio Journal Of School Mathematics*, (71), 1-3.

Horn, M. S., Crouser, J. R., & Bers, M. U. (2013). Tangible interaction and learning: the case for a hybrid approach. *Personal and Ubiquitous Computing, 16*(4), 379–389.

Jaworski, B. (2015). Teaching for mathematical thinking: inquiry in mathematics learning and teaching. *Mathematics Teaching*, (248), 28-37.

Kinach, B. (2012). Fostering Spatial Understanding in Geometry. *Mathematics Teacher*, *105*(7), pp. 534-540.

Langer-Osuna, J., & Avalos, M. (2015). 'I'm trying to figure this out. Why don't you come up here?': heterogeneous talk and dialogic space in a mathematics discussion. *Zdm*, *47*(7), 1313-1322. doi:10.1007/s11858-015-0735-y

Mackle, K. (2014). The Power of Talk in the Mathematics Classroom. *Mathematics Teaching*, (239), 21-22.

Miller, G. (2015). Five Strategies for a Better Math Argument. *New Teacher Advocate*, *22*(4), 14-15.

Mulligan, J., & Mitchelmore, M. (2013). An evaluation of the Australian 'reconceptualising early mathematics learning' project: key findings and implications. In *Proceedings of 37th Conference of the International Group for the Psychology of Mathematics Education*, Springer, Kiel University, Germany, pp. 337-344.

Newcombe, N. S. (2010). Picture this: Increasing math and science learning by improving spatial thinking. American Educator, 34, 29–35. Retrieved from: http://www.aft.org/sites/default/files/periodicals/Newcombe_1.pdf

Ontario Ministry of Education. (2016). 21st Century Competencies: Foundation Document for Discussion Retrieved from: http://www.edugains.ca/resources21CL/About21stCentury/21CL_21stCenturyCompetencies.pdf

Ontario Ministry of Education. (2005). *The Ontario curriculum grades 1-8: Mathematics.* Retrieved from http://www.edu.gov.on.ca/eng/curriculum/elementary/math18curr.pdf

Papert, S. (1980) *Mindstorms: Children, computers, and powerful ideas.* New York: Basic Books.

Sneider, C., Stephenson, C., Schafer, B., & Flick, L. (2014). Exploring the science Framework and NGSS: Computational thinking in the science classroom. *Science Scope*, *38*(3), 10-15.

Stein, M. K., Engle, R. A., Smith, M. S., & Hughes, E. K. (2008). Orchestrating Productive Mathematical Discussions: Five Practices for Helping Teachers Move Beyond Show and Tell. *Mathematical Thinking & Learning*, *10*(4), 313-340. doi:10.1080/10986060802229675

Upitis, R. (2014, November 8). Creativity: The state of the domain. In People for Education, Measuring What Matters. Toronto. Retrieved from: http://peopleforeducation.ca/measuring-what-matters/wp-content/uploads/2014/11/People-for-Education-Measuring-What-Matters-report-on-creaativity-and-innovation-2013-14.pdf

Wheeldon, I. (2006). Peer Talk. *Mathematics Teaching*, (199), 39-41.

Wing, J. M. (2006). Computational thinking. *Communications of the ACM*, *49*(3), 33-35