Using Virtual Crafting to Enhance Mathematical Learning

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Abstract

A research study was undertaken to examine use of a Minecraft Virtual Learning Makerspace (MVLM) to enhance mathematics teaching. The study took place in an elementary school in the west of Iceland. The participants were a group of seven-year-old students and their teacher using Minecraft to facilitate his mathematic teaching. The main purpose of the study was to examine the context of teaching and learning in a conventional classroom when students also work inside a virtual space. Video data was collected, students and teacher interviewed and observations carried out in the classroom. The data produced was qualitative, the analysis based on grounded theory principles and an interpretive paradigm. The key issues under consideration were: the role of teacher in a MVLM educational context and how the MVLM affects students' learning practices. The results suggest that the students were motivated and used the MVLM in a creative manner that enabled an understanding of mathematical concepts and solving of mathematical problems. The MVLM provided the teacher with opportunities to assign interdisciplinary, project-based collaborative tasks. The research indicated the importance of the teacher, as a conventional instructor and facilitator when preparing and guiding students in the MVLM. Moreover, during their work he ensured they had flexibility, that enabled their collaboration in a playful learning context. This facilitated their greater understanding of mathematical concepts.

Keywords: Minecraft (MVLM), primary education, pedagogy (GBLP), teaching methods, playful learning, mathematics education, iPad

Introduction

The research project was as a part of the European project **Makerspaces in the early years (MakEY)** that is a two-years European project that focuses on the potential of makerspaces which aims to enable creative design and making of digital and non-digital artefacts to foster digital literacy and creative skills of young children (Makey, 2018).

A Virtual Learning Makerspace (VLM) is a place in which people with shared interests, especially in computing or technology, can gather to work on projects while sharing ideas, equipment, and knowledge (The Oxford Dictionary, 2018). It is based on an electronic system that can offer online cooperation of various kinds that can take place between learners and teachers, together with online teaching and learning (JISC, 2003).

Computer video games are emerging as an instructional medium offering strong degrees of cognitive efficiencies for active, experiential learning, team building in multi-player environments and greater understanding of abstract concepts (Rice, 2007). Using game-based application in the field of education is often referred to as game-based learning (GBL) and gamification, motivating students by using game-based elements in educational settings (Kapp, 2012; Shatz, 2015). The main aim of GBL is to motivate students to learn (Burke, 2014). Using MVLM to support game-based learning is an ideal way to support students' learning, as it enables collaboration and sharing of information in an entertaining manner (Hennessey & Deaney, 2004; Passey et al., 2004). Games can become a platform for playful learning, where students learn to make sense of the world around them through a variety of playful, physical or virtual activities (Resnick, 2004; Kangas, 2010; Whitton, 2018).

Minecraft is a popular PC game among young children that gives them tasks to solve through virtual making. Minecraft is an example of VLM where students can gain knowledge and understanding via designing and making to solve tasks within different subject areas. This MVLM could potentially be a useful tool for building learning environments with groups of children (Brand and Kinash, 2013).

iPad tablets were used by students during the case studies to do their work inside the MVLM. Many educators consider iPad a promising tool to use in school education as they offer new opportunities for achieving aims of curricula (Johnson, 2013; Alyahya & Gall, 2012).
The article firstly introduces conventional makerspaces in terms of education and subsequently using a MVLM to support general education. Secondly, it reflects on the literature. Thirdly, overall aims, objectives of the

research project are introduced, and the research questions stated, and the data collection methods and analysis explained. Finally, findings are stated and discussed, and the research questions answered.

Game-Based Learning in Support of Young Children's Learning

Prensky (2001) related game-based learning to a generation shift and growing up digital (Tapscott, 1998), to how we think, learn and process information differently from former generations. He described game-based learning as being about fun and engagement, with the coming together of play and learning through the invention, creation and dissemination and use of digital games.

In the TEEM report teachers and parents recognised that computer games play can support skills development, as diverse as strategic thinking, planning, communication, negotiating skills and group decision-making, data-handing and application of numbers (Kirremuir & Mcfarlane, 2004). Furthermore, the report mentions skills that support the autonomous learner, such as problem solving, sequencing, deductive reasoning and memorisation, and others resulting from the learning context with children working in groups, such as peer-tutoring, co-operation and collaboration, and co-learning (Mcfarlane, Sparrowhawk & Heald, 2002).

Game-based learning can be experienced-based and exploratory, relying upon experiential, problem based or exploratory learning approaches (de Freitas, 2006). De Freitas presents some key findings from the literature, alongside a set of case studies from practice contexts. They indicate that motivation is a key aspect of effective learning, but it needed to be sustained through feedback responses, reflection and active involvement. The learning needs to be undertaken in relation to clear learning outcomes, as well as being made relevant to real work context of practice.

Role of the teacher in Game-Based Learning

The role of the teacher in game-based learning is an issue that needs more attention in research and is an important one to consider if games are to be used in relation to different subjects at school. There is acknowledgement of that the adoption and effectiveness of game-based learning largely depend on the teacher's acceptance (Bourgonjon & Hanghöj, 2011).

Much research on the role of the teacher in game-based learning focuses on the teacher's ability to motivate and engage students. Molin (2017) suggest a look at games as an opportunity for teacher learning and empowerment. He refers to Deweys theories of active, interactive and child centred learning and emphasises teacher observation and appropriate guidance. Applying Vygotsky's concept of zone of proximal development (ZPD) he stresses that in game-based learning it is important that the teacher can challenge the students and that the teacher designs his/her teaching so that it allows for a zone of proximal development, providing guidance/mentoring to facilitate scaffolding and deeper learning.

The role of the teacher in game-based learning is an issue that needs more attention in research and is an important one to consider if games are to be used in relation to different subjects at school. A Swedish research with two five-month long studies where Swedish K-12 teachers were introduced to using MinecraftEdu as a classroom activity revealed that the game-based learning processes appear to be demanding on teachers, requiring them to take on various roles, each of which requires a specific skillset (Marklund & Alklind-Taylor, 2015). Examples of skillsets found were subject matter expertise, pedagogical foundation, technical know-how and gaming literacy. Buckingham & Burn (2008) remark that games are "almost invariable multimodal texts", that they often "combine many different communicative modes, such as "still and moving images, sounds and music, speech and writing, and so on" that can be "studied in ways that are at least analogous to the study of the written language" (p. 326). A definition of video game literacy traditionally refers to the ability to understand and to produce meaning with video games (Zagal, 2010), but it is not clear to what extent the teacher needs to be knowledgeable about the games employed or if the teacher needs to have a gaming expertise to support the learners.

There is acknowledgement of that the adoption and effectiveness of game-based learning largely depend on the teacher's acceptance (Bourgonjon & Hanghöj, 2011). In two case studies of teachers who use games for learning, conducted in Denmark and the Netherlands, Bourgonjon & Hanghöj stress the importance of balancing different knowledge aspects, not just game expertise, in game-based learning and that success depends on accumulation, balancing and renegotiations of different skills and knowledge aspects. In order to translate video games into

educational practice the teachers would need to balance their knowledge of games with at least three other aspects, summarized by Hanghöj as: curricular knowledge aspects, pedagogical practices of the school context and the students' everyday knowledge about games and game genres (tilvitnun vantar).

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Minecraft Virtual Learning Makerspace

Makerspaces in the educational context, according to Marsh et al. (2017), prescribe a model of learning-by-doing in which individuals can create and build artefacts that are personally and/or collectively meaningful. The possibility to play with material objects is considered to act as “a social glue” for people to come together and engage in collaborative and creative endeavours (e.g. Gauntlett, 2011; Honey, & Kanter, 2013). It follows that social interactions and learning practices in makerspaces often cross divisions such as age, gender or level of formal education and/or expertise (e.g. Halverson & Sheridan, 2014). In sum, making activities account for a complex set of socially and materially mediated practices that encompass not only processes of creating specific artefacts supported by a wide range of technologies and media, but also emotional, relational and cultural processes surrounding their use and construction.

The specific Minecraft software used for this project is an educational version that is set up as a Virtual Learning Makerspace (VLM) that includes both a Virtual Reality for making and Learning Management tools that helps a teacher to manage a class.

A Virtual Learning Environment is a computer programme that facilitates computerised learning and can be used both in the context of open and distance learning and as a support for face-to-face education within a conventional school context (Paulsen, 2003). Virtual learning environments are commonly considered learning environments mediated by computers and digital technology (Weiss, 2006). Wilson (1996) defines the VLE as ‘a computer-based environment that is a relatively open system, allowing interactions and encounters with other participants and providing access to a wide range of resources’ (1996:8). The Joint Information Systems Committee (JISC, 2002) defines virtual learning environments as components in which learners and tutors participate in online interactions of various kinds, including online learning.

A Virtual Learning Environment (VLE) (see figure 1) is a software system designed to help teachers facilitate the management of educational courses, especially by helping both themselves and learners with course administration. The system can often track learners' progress and may be monitored by both teachers and learners.

Hall (2001) describes VLEs (VLMs) (see figure 1) as terms used to describe a wide range of applications that track student training and may include functions such as:

- Authoring
- Classroom management
- Competency management
- Knowledge management
- Certification or compliance training
- Personalisation
- Mentoring
- Chat

- Discussion boards

The services provided by VLEs are aimed at teachers, pupils, administrative personnel and parents. Access to the VLEs is via the Internet or an intranet and there is usually an option to work offline. A key characteristic of the VLEs is that learning can take place ‘anytime, anywhere’ and is not dependent upon the traditional school timetable or whether the learning is taking place inside or outside the school building. It is therefore preferable that the VLE is connected to the users’ schools Management Information System (Vuorikari, 2004:9).

Many teachers have used Minecraft as a Virtual Learning environment inside their conventional classes, most often using a constructivist approach. Using Minecraft and a Virtual Learning Makerspace enabled the teacher in this research to set up circumstances for students to enable them to work with Mathematics tasks in the case study lessons. Minecraft is grounded on so-called sandbox building structure, which offers the player autonomy to move around inside a limitless virtual Learning Makerspace (Bebbington and Vellino, 2015). Users can create objects by using dissimilar blocks, such as wooden blocks, stone blocks, and dirt stone. Blocks are applied to change the environment; i.e., by building aeroplanes, bridges, houses, boats, etc. (Minecraft.net, 2016). Minecraft can be played online or offline and in a local network.

The graphics are based on simple 8-bit graphics and inspire users to explore and construct. As the game is a multiplayer virtual world, players can collaborate online in real time. The game has dissimilar game modes of differing natures: 1. Creative mode: unlimited resources, flying freely and instantly destroying blocks. 2. Survival mode: search for resources, crafting, gain levels, death and danger. 3. Hard-core: similar as survival mode, locked at hardest difficulty, only with single life.

Virtual crafting in Minecraft is a method that is based on using various blocks, tools, and materials that have been made to use inside the Minecraft world. In order to craft something, players must move items from their inventory to a crafting grid. A 2×2 crafting grid can be accessed from the player's inventory. A 3×3 grid can be accessed by using a crafting table.

The application is considered good for supporting Mathematics learning as it has a design and crafting, play and collaboration mechanisms (Short, 2012). Addition/subtraction, multiplication/division and ratios are the most obvious mathematical concepts used in the game, e.g. raw wood from trees can be turned into 4 wooden planks, gold or diamond can be turned into a full set of armour. Questions and use of algebraic formulas can be set on books, signs and walls. Dimensions of perimeter, volume and area are necessary to make symmetrical constructions, when making buildings with centred windows and doors. Geometry is essential when crafting circles from squared blocks. It is possible to generate them in pixel art and transcribe them to block patterns (Short, 2012).

Affordances in Terms of Interaction and Control in a MVLE

Students used iPads during the research to enter and work inside the MVLM. The iPad has many affordances that makes it an interesting tool for virtual making activities with young students to support the relationship between the students' cognitive and emotional engagement and their learning (Astin, 1984; Golland, 2011; Gonyea & Kuh, 2009). Portability and mobility are the key affordances of the iPad. It is like a book and easy to carry and move around. Students do not need to sit at a certain area to access digital content. With wireless connection, students can access web content and without a wireless connection, they can use applications and books anywhere and at any time.

Touch screen capabilities enables all students to control applications. The affordance of using fingers to control objects on the screen makes the iPad user friendly (Golland, 2011). Camera allows students to take picture snap shots instantly or video conference with peers or teachers at a moment’s notice. The iPad can be used up to 10 hours without charging it, that makes it a user-friendly tool to use in education.

Some claim that the VLEs have unique characteristics that might be used to improve students’ understanding and learning performances. It is therefore important for the teacher to identify the unique characteristics of the VLE that may improve his students' understanding and performances in an educational context. These characteristics can then be manipulated by the teacher to adapt the settings to his student's learning needs.

Zeltzer (1992) has proposed a framework regarding the characteristics of a VLE, along with three dimensions that he refers to as autonomy, presence and interaction. The environment offers also the user different interaction techniques, including navigation, selection, manipulation and system control, to interact with and manipulate the environment (Vince, 1999c). These techniques play a significant role in the users' making.

Among people working in virtual reality environments, an avatar is a representation of a user in a shared virtual reality. An avatar is an Internet user's representation of themselves, whether in the form of a three-dimensional model used in computer games or a two-dimensional icon used on Internet forums and other communities.

Over the past few years, a variety of desktop-based virtual reality environments like Minecraft have been created to enable social interaction. Nevertheless, their users' interfaces do not yet promote a strong sense of user embodiment (Cuddihy & Walters, 2000); this is illustrated by the lack of clearly defined mechanisms for allowing rich interactivity between avatars and other objects.

The user's control over their avatar, their personal representation within the virtual reality environment, is currently limited but nonetheless important. The concept of VLE is linked to the feeling of being in a location and a social setting other than where you are, and this means that you can control an avatar or another device at a distance. Different communication and embodiment representations, such as the avatar representation, may also give the sense of emotional presence (Lehtonen, Hyvönen, & Ruokamo, 2005).

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Many research projects show iPads as suitable tools in education because of their various affordances. Beebe's (2011) research showed students were more motivated to attend class and turn in their assignments and increased responsible for their learning. (Jennings, Anderson, Dorset & Mitchell, 2011) concluded that the iPad technology supports dissimilar learning styles. Ostashewski and Reid (2010) add that the key affordances of the iPad is that it is usable as multimedia database and interactions are easy via small touch screen.

Research Relating to Use of Minecraft as a Virtual Learning Makerspace (MVLM)

Researches indicate that usage of Virtual Makerspaces can increase student's social and emotional skills and improve their pro-social manners (Durlak et al., 2011). It can help them to become healthy establish fulfilling relationships, and to behave according to social rules. These abilities include clear communication, actively listening, collaborating, resisting unsuitable social pressure and looking for help when it is wanted.

Recent research on Makerspaces, according to Marsh et al. (2017) indicate that hands-on testing and making across multiple media and digital contents supports students' creative and critical engagement in disciplinary and transversal learning with various digital technologies and media (Ratto, 2011). Existing research suggests that making activities have the potential to support young people's creative and improvisational problem-solving, encourage students' agency, persistence and self-efficacy, and enrich young people's ideas and understanding in STEM and beyond (Bevan et al., 2016).

Marsh et al. (2017) literature review on Makerspaces further indicate that research also suggests how making activities can enhance peer collaboration and transform the traditional roles of teacher/other adult experts and students, enabling participants to develop and draw on each other's relative expertise (Vossoughi & Bevan, 2014; Reed, et al., 2016).

Several studies indicate that video games can support development of certain cognitive skills, such as visual and selective attention and concentration (Rosas, et al., 2003). Green and Bavelier (2007) research also, showed the benefits for students' abilities to pay attention to a larger number of objects and they increased their reaction

times, eye-hand coordination and manual dexterity. Video games, According to Green & Bevalier, (2007) research also enhance spatial skills and gamers often do better on Mental Rotation Test.

Costa, Sousa and Henriques (2017) research with 9 – 12-year-old primary school students showed they had difficulties to look at tablets and phones as educational tools but saw them rather as tools for entertainment. Nevertheless, the students learned when they are playing but better via games they have created themselves. The parents believed they could learn by playing games and the teachers thought they could enrich their knowledge in many areas and gain better social skills.

Research relating to Minecraft as a Virtual Learning Makerspace (MVLM) in Education

Gee (2007) and Squire (2011) argue that good videogames and their evolving cultures offer environment for problem solving. Learning can take place in such settings, since challenge and learning is at the centre of entertaining and motivation.

Minecraft is appropriate in the teaching of various subjects, such as Mathematics and science. It also offers incorporated electricity and electronics elements (Short, 2012). Many teachers have used Minecraft in educational settings as extra activity within their conventional class context, most often using a constructivist approach.

Minecraft has been popular in teaching non-scientific subjects, both in primary, secondary and higher education. Garcia-Martinez (2014) found out that that Minecraft has been used (especially in higher education) as a learning aid in Computer Art, Digital Storytelling and Writing and Rhetoric for English as another Language. Though, Minecraft was only partly applied to the courses, along with other tools.

Minecraft has newly been used to address issues concerning distance learning in several universities. Livingstone et al. (2013) explained by what means the University of the West of Scotland believed Minecraft to be a suitable teaching tool in online lessons including classes in dissimilar places. Numerous teachers do not feel enough prepared for the many technological potentials and restrictions offered by using Minecraft in numerous tasks and as an additional activity. Ertmer (1999) considered that these restrictions were dual; i.e., external issues, such as want of tablets or computers in schools, and teachers' negative attitudes and opinions. He stated in his research that several teachers were obviously against any technological changes. Nevertheless, there are various technological equipment's that can be used today and a fast search on the Internet will show teachers what's innovative in classroom technology.

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Recent research on Makerspaces, according to Marsh et al. (2017) indicate that hands-on testing and making across multiple media and digital contents supports students' creative and critical engagement in disciplinary and transversal learning with various digital technologies and media (Hughes, 2017; Ratto, 2011). Existing research suggests that making activities have the potential to support young people's creative and improvisational problem-solving, encourage students' agency, persistence and self-efficacy, and enrich young people's ideas and understanding in STEM and beyond (Bevan et al., 2016).

Marsh et al. (2017) literature review on Makerspaces further indicate that research also suggests how making activities can enhance peer collaboration and transform the traditional roles of teacher/other adult experts and students, enabling participants to develop and draw on each other's relative expertise (Vossoughi & Bevan, 2014; Reed, et al., 2016). In addition to these academic goals, research on Makerspaces in a children's hospital points out their emancipatory and healing value in supporting young patients to feel more agentive in taking charge of their environment, as well as of their learning and wellbeing (Krishnan, 2015).

Karsenti, et al. (2017) undertook a research in Montreal with students' third to sixth grade named Transforming education with Minecraft. The aim was to examine the values of using Minecraft in education. The research showed that the students were more positive towards the school, more independent, improved their reading and

writing skills, were more creative and better in problem solving, became better in using mathematical concepts, improved their communication skills, improved their skills in following instructions, became more organised and learned to respect each other. The research also underlined the importance of the teacher preparation. The students' work must have escalating effect to motivate students to learn more in the game, the computer facilities must be suitable. It is important to allow the students to form the project, to give them freedom and space during their work, to encourage their collaboration and to give them compliments. The teacher must underline the importance of politeness during playing and train the students in explaining their work and to realise what they learned that will help them to understand how education in Minecraft takes place. Finally, the teacher must use the Minecraft as a gaming tool and support students' playful learning.

The research Using Minecraft in education focused on the use of Minecraft at schools in Toronto (Petrov, 2014). The results showed possibilities for using the game to support students with learning disabilities by setting up circumstances echoing their daily lives. Using Minecraft is also a good way to increase student's social skills and digital literacy and to make them aware of Internet security. However, the activities depend on if schools have ICT facilities and some teachers don't believe in the values of using games to enable students learning. Another issue is lack of time to plan classes using new technological tools and teachers need to explore them in their own free time to understand how they work (Wood, et al., 2005).

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Bessie et al. (2018) research showed that 9-10-year-old autistic boys were able to have equal and ordinary communication with their classmates in Minecraft. Moreover, Minecraft can be a tool to teach and maintain social skills in autistic children. (Metzger and Paxton, 2016) came to similar conclusion or that using multiplayer games can increase students' communication at schools.

Sousa, Costa and Henriques (2017) research with 9 – 12-year-old primary school students showed they had difficulties to look at tablets and phones as educational tools but saw them rather as tools for entertainment. Nevertheless, the students learned when they are playing but better via games they have created themselves. The parents believed they could learn by playing games and the teachers thought they could enrich their knowledge in many areas and gain better social skills.

The Methodology

The research was undertaken with a group of seven-year-old students in a rural elementary school in the west of Iceland. The research study consisted of six 180-minute case study lessons; set up to meet the teacher's several tasks, using the MVLM. The lessons sequence was: 1. Introduction and giving tasks. 2. Individual learners work out solutions using the MVLM. 3. Learners build during an open learning session. 4. Learners build a pre-designed mean of transport. 5. Learners resolve a challenge of moving within the world. 6. Playful learning session, developing further some aspects of design and making. In this article only the first three sequences are being discussed.

The aim of study was to develop an understanding of pedagogy of using a MVLM to support mathematic teaching.

The objectives were to:

1. *Examine the role of the teacher,*
2. *Identify any pedagogical issues relating to the use of a MVLM in support of the development of students learning skills and understanding,*
3. *Observe the learning process in action, using a MVLM.*

The research questions for the case study were:

1. *What characterises the role of the teacher, when the MVLM is used?*
2. *What teaching and learning strategies influenced the MVLM activities in the classroom?*

3. *What elements of the MVLM 's affordances support students' playful learning?*
4. *What could be the value of using the MVLM for general education?*

The data was analysed using grounded theory. The raw data was collected during the different case study lessons and various data sources were used to triangulate the research and reinforce reliability. Data from each source was summarised and then used to generate the results and subsequently they offered a good degree of triangulation (Cohen et al., 2005). Other additional material was also considered through the literature.

The specific instruments implemented are listed against the research questions in the table below.

Table 1: Data collection methods used for the research.

	Data Sources	Q1 answer	Q2 answer	Q3 answer	Q4 answer
1.	Screen captured videos in the VRM	x	x	x	x
2.	Interviews with the teacher	x	x	x	x
3.	Interviews with individual students	x	x	x	x
4.	Interviews with the students group about the course and their work	x	x	x	x
5.	Overall videos of the conventional classroom activities	x	x	x	x
6.	Go-Pro videos showing individual students circumstances and his screen	x	x	x	x

The authors collected both videos and screen capture videos and based the analysis on grounded theory. Grounded theory consists of a systematic inductive strategy for collecting and analysing data in order to construct theoretical frameworks that describe the collected data. This enables the researcher to identify emerging categories in a set of data and then to develop initial hypotheses which can be tested iteratively. It focuses on obtaining an abstract analytical schema of a phenomenon related to a particular situation (Creswell, 1998).

The data was treated as follows:

1. A raw data was collected,
2. Data from each source was then summarised; for example, there were two teacher interviews, which were summarised separately and then used to generate categories together,
3. These categories were then discussed and conclusions drawn,
4. The process was repeated for all the data sources listed above,
5. Finally, the categories from all data sources were brought together under overall categories,
6. The categories were then used to triangulate the findings and were analysed in relation to each other and the literature and conclusions were drawn.

The specific software Transana 3.21 was used to enable the analysis of the videos and the interviews. Open coding was used in the process of data analysis based on grounded theory principles. In open coding the researchers form initial categories of information about the phenomena that was examined (Creswell, 1998). They with open minds to find as many ideas and issues as conceivable. Similar results are categorized into main categories and used for discussions and conclusions (Emerson, 1995).

Results

In this section, the categories established during the enquiry are defined and then discussed in the discussion section, in accordance with the literature. The research attempted to understand and interpret the learning experience of students within this context, in addition to understanding the pedagogy employed by the teacher:

a) The teachers approach to his work

The teacher’s role was identified as a fundamental category. It refers to the teachers’ responsibilities, in terms of managing and enabling the contexts of teaching and learning. The research highlighted how the teacher’s role in the MVLM context consisted of various dimensions, including technician, designer of instructional contexts, provider of information and facilitator.

The teacher preparation for the lesson include setting up the lesson plan with tasks according to the National Curricula, set up a Minecraft server, set up the educational circumstances inside the Minecraft world, make sure the iPads are fully functional and to register the students with their full name.

During the lesson the teacher gave the students peace and flexibility to think and talk. If they asked for help he never gave them a direct answer but rather used questioning strategies to activate their independency in finding solutions and to trigger their understanding. Developing questioning approaches also enabled the teacher to check the students understanding and ask them again to guide them further. This at the same time supported the students' cooperation and improved their thinking and learning engagement. The teacher also used the questioning strategies to show the students that they were able to help their classmates by asking them the same questions. Subsequently, they sometimes used the same question to help other students in order to improve in the project. However, the teacher must monitor the students inside the virtual makerspace to understand what they are doing, that enables him to help or step in if students need his assistance.

The National Curricula supports teachers' autonomy and allows them to run unconventional projects that often motivate students and offer them more interesting ways of learning. However, they must have freedom in their school to break out from their conventional teaching and the aims of the National Curricula. The teachers, also, must have support and be encouraged to try new ways in their teaching. Nevertheless, teachers frequently find it hard and too time consuming to make their own plans.

b) Students mathematic learning
The young students had to use prior knowledge and understanding to be able to solve mathematical problems and to find solutions. At the same time their knowledge and understanding were supported by peers, both in the classroom and the virtual makerspace in a cooperative learning context. Making solutions in a virtual world enabled their understanding of mathematic concepts as they had resolved tasks via making. However, to be able to solve problems and make solutions were dependant on their' capabilities of using mathematic skills. Sometimes students were able to solve problems through making without understanding related concepts. This again enabled them to understand the concepts.

Students were, often, able to solve problems in exams, like measuring a square because they had gained understanding from working with concepts by making solutions in the virtual world. The undertakings were, moreover, most often familiar to the students as mirroring elements in their' environment and this enabled their mathematic learning. Their social background was also often visible in their solutions.

Using the MVLM in the virtual makerspace cooperative context supported students to fulfil the aims of the Icelandic National Curricula in terms of acquiring the competence to use the language of mathematics to discuss, support and explain their own hypotheses and those of others, calculations and findings. Moreover, it helped them to acquire the competence to use mathematics as a tool to solve problems in their environment through using it in a virtual learning makerspace context.

c) Collaboration versus cooperation
The teacher gave the students both individual and collaborative tasks. He organised them sitting together in groups to enable multimodal communications, both in the classroom and inside the virtual world. The students, however, were inclined to cooperative thinking and therefore frequently cooperated when solving individual learning tasks. They were watching each other's progress during collaborative tasks and frequently taking responsibility for each other while working inside the virtual world. They were aware of each other effort and ready to help.

Students with learning problems often gained help from more capable peers e.g. reading for peers if they were not capable of reading instructions. However, they rather wanted to solve problems on their own to show their capabilities than impersonate other students work.

It was noticed that the students' culture played a role in their work. Their solutions were often influenced by known cultural artefacts designs found in their small fishing village and frequently used as a language symbols in the dynamic context of social interaction inside the MVLM.

This research study used Minecraft as a makerspace to enable individual, cooperative and collaborative learning (MVLM). The MVLM enabled students to build together and to share knowledge and give help because of skill they had gained during this game-playing learning process.

d) Using the technology
The students had prior experiences and skills in using the iPad and some of them had used Minecraft before. Therefore, training them in using the technology was not needed.

The affordances inherited in the iPads touch screen and the Minecraft software enabled the students' maker activities. Touch screen capabilities using fingers to move objects helped the students to gain control in handling virtual material during their making. It is vital to have a stable internet connection during lessons to avoid students getting disturbed during their work and distracted. It is also important to use the school's intranet as it ensures the cyber security. It is also important to register each student to the Minecraft Edu with correct full name as a user as this enables the teacher to identify students in the MVLM and step in if they ever behave badly or get lost in the game world, as it enables him to teleport them again to the educational settings.

e) Motivation while learning in the virtual game-based makerspace
Observing students at the start of the lesson it was obvious that they were keen to start on the mathematical tasks ahead, they had in fact to be restrained from entering the game worlds while the teacher explained the tasks, the context and scenario of the lesson and learning design. The teacher explained briefly the settings of the worlds that he had prepared for the lesson and introduced the guidelines and mathematical tasks to perform. They were simple tasks that relied upon students' understanding of certain mathematical concepts and on being able to read, write their name and count the basic numbers. When the students started working they seemed to get active immediately and quickly started chatting about the tasks they were taking on. The girls seemed equally interested in the tasks and as resourceful in exploring the possibilities of action, as the boys in the group. Furthermore, they all seemed to enjoy the playful approach that the game invited.

The teacher after having started the lesson retreated to a position that allowed him to follow the action on six iPads, where he could oversee the students' activities in the game world but remained passive unless asked specific questions or asked to assist when the connection was interrupted, or in-game rain started to inhibit the action. Students reported regularly on their own active learning, driven by the feedback from playing the game or exploring the possible actions to take. Occasionally some of them asked the teacher some questions, but mainly they compared their problems and were supported by peer advice or direct assistance. Some students were not able to read the in-game instructions on signs, but their peers assisted them when needed. This allowed less able students to achieve their goals, as well as those more able. The teacher was encouraging, if asked a question, but resisted providing answers or giving away hints to resolve the tasks. The students were therefore ushered towards completing the tasks, but still challenged.

Using the Minecraft Virtual Learning Environment motivated the students to learn mathematics. During the lesson the students were engaged in a learning activity in a playful manner. The conversations bore witness to that the virtual environment setting enabled them to both play together and to resolve playful learning tasks at the same time. Not only did they gradually finish their tasks but were also very keen on continuing to make new structures freely, moving around or flying in the world, engaged in various actions with their peers and playing with or herding animals that spawned into the game world. The students understood the MVLM activities as a game rather than serious mathematical study. However, they learned through their play and therefore enjoyed their learning.

f) Value
The virtual making activities frequently referred to elements in the Icelandic, national core curricula both overall aims, competence levels and the fundamental pillars such as literacy, democracy, equality and creativity. The expanded learning taking place honed students' skills not just mathematical skills, but also literacy and social and creative skills. Using a virtual game-based learning environment in a conventional school classroom enabled both the teacher's and student's work and prevented school boredom in a playful learning context.

The MVLM activities supported students to become members of a digital citizenry using digital technologies in a productive, responsible and democratic manner. The MVLM activities build up students' independence, self-reliance to some extent and willingness to resolve mathematical problems. In problem-solving situations, they frequently assisted fellow students with reading and understanding tasks, as well as pointing out ways to resolve them. This coordination increases helpfulness and collaboration within the student group, developing necessary social skills.

Discussing the Results

The teacher must be able to take on many roles when using video game-based learning and in this study the teacher's role was not only to teach. The teacher needed to know how to play Minecraft and set up a server and the Minecraft worlds for the students. Marklund and Alklind-Taylor (2013) discuss the teachers' role in their study. They state that the teacher needs to show many sets of skills and that the game-based learning was demanding for teachers. It's important for teachers to motivate their students and use of games in learning is a great way of doing that. Teachers can use, Deweys theories of active, interactive and child centred learning and proximal development (ZPD), to challenge their students, (Molin, 2017). When teachers use game-based learning they need to focus on many aspects and one of them is to see the moments when to step in and teach during gameplay (Watson et al., 2011). A great point to reflect on is that teachers are rarely invited to help design of educational games, it would indeed benefit both teachers and developers (Leinonen, 2010). Teachers often give up using games in education because they need more time to set up lesson plan and learn how games work, many teachers use their own free time to do that (Wood, et al., 2005).

While working in Minecraft students experienced their work as play, not study – and this made them feel at ease. Some of them generally enjoy learning, but others have difficulties attending school because they were already bored with studying. For this reason, the teacher constructed alternative learning paths and experimented with new ways of teaching. Minecraft is a very student centred game that most students know how to play. The students taking part in this research enjoyed playing Minecraft, as one student express: "I wish we could always play Minecraft at school".

When the students are playing inside of Minecraft, they chatted constantly with each other, shared their experiences and showed other students how well they were getting on with the projects. This talk between students is very important for improving their skills in mathematics and for their social development. When the students were working in their workbooks they did not talk and share their experiences as much. In Minecraft they really found themselves playing a game rather than learning mathematics. That signals to the teacher that Minecraft is a great way to opt out of using the workbooks and give students the opportunity to learn in a fun and playful way. Many studies indicate that playing is meaningful in a learning environment and that students need to find themselves having fun while learning (Piaget, 1951). Games like Minecraft seem to motivate students to learn mathematics and let them participate (Habgood, Ainsworth & Benford, 2005). Minecraft invites the teacher to organise a variety of teaching methods. When playing Minecraft, students can work on enhancing their understanding of factors such as geometry, measurements, statistics, algebra, mathematical expressions and general mathematics (Bos et al., 2014).

This research study used Minecraft as a platform for mathematic studies that is a collaborative game-based learning environment (MVLM). Such environment can enable students to share knowledge they have gained during a game-playing learning process. Although educators in the past have not been willing to use video games in their educational settings, there is a growing interest to understand the use of video games as serious learning tools (McClarty et al., 2012). Collaborative educational games can both enhance students learning attitudes and motivation via collaboration (Sung & Hwang, 2013).

The MVLE is a VRL environment that supported during the research both students individual, cooperative and collaborative learning (Thorsteinsson and Denton, 2008; Thorsteinsson, 2009). It was, more over different from the classroom context mostly depending on individual approaches. Mello & Gobara research (2013) concluded that VLEs' can enhance collaborative interaction between students. Interactions occurred because students solved problems given in the beginning of the lessons with help from their peers, but they were also able to solve them independently during a written evaluation.

Using the MVLM inside the classroom enabled both cooperative and collaborative work and social interaction has been identified as an element of knowledge construction (Thorsteinsson and Denton, 2008). Students were given both individual and collaborative tasks and were most often thinking cooperatively when solving individual learning tasks. This mirrors Vygotsky's (1978) ZPD theory (The Zone of Proximal Development) for sharing knowledge during cooperation and collaboration. The concept is now used widely within social-educational research studies about teaching and learning including mathematics (Dunn & Lantolf, 1998; Lantolf & Pavlenko, 1995), information technologies and computer-mediated communication (Hung, 2001).

The ZPD concern the difference between learner capability of doing learning tasks autonomously and what he can do when supported by a teacher or via cooperation or collaboration with more advanced peers. Children, according to Vygotsky (1978), learn and develop through the guidance of the teacher and the influence of their culture. Through cooperation and collaboration, prompts and recommendations from their teacher using

different teaching methods, the student learns to finish a new task or understand a concept inside their capability to learn at that time (Kozulin, et al., 2003).

Educators who favour the ZPD theory (e.g. Slavin, Karweit & Madden, 1989; Johnson, 1998) consider, also, that social interaction is significant for learning since higher mental functions such as understanding, reasoning and critical thinking develop in social interactions and are, subsequently, internalised by individuals (Durlak et al., 2011). Children can complete mental tasks with social support before they can do them on their own. Thus, cooperative and collaborative learning is offering the social support and scaffolding students require to move learning forward (Woolfolk, 2001, 44).

It was noticed that the students' culture played role in their cooperative versus cooperative playing. Sometimes they were mirroring artefacts existing in the small rural fishing village. The MVLM can be visualised as an interactive, collaborative and cooperative learning tool (Thorsteinsson & Denton, 2008) in terms of socio-cultural practices. The traditional teacher-centred role can be altered by alternative models (Heinze, 2008; Bonk & Cunningham, 1998) and the emphasis put on guiding and supporting students as they learn to construct their understanding of their culture (Laurillard, 2002; Brown, Collins & Duguid, 1988; Cobb, 1995; Collins, 1990; Duffy & Cunningham, 1996; Pea, 1993). Cultural tools or artefacts, according to Cole (1997), include all the things we use, from simple things such as a spoon, table or transport vehicles to the more complex things such as language, traditions and beliefs. Vygotsky (1982) reiterates the point that using cultural artefacts in the context of social interaction formulae the most significant part of learner's psychological development (Shabani et al., 2010).

Students with learning problems often gained help from more capable peers e.g. reading for peers if they were not capable of reading. However, they wanted to solve problems on their own to improve their capabilities rather than impersonate other students work. Cooperative learning improves social interaction, which is important to meet the needs of students with learning disabilities (Slavin, Karweit & Madden, 1989; Johnson, 1998). Students learn how to interact with their peers in cooperative learning groups. Therefore, it is vital to increase their participation inside the school community (Metzger and Paxton, 2016; McInnerney and Roberts, 2004). Positive communications do not always occur naturally, and social skills training must precede and run alongside the co-operative learning method. Social skills include building and maintaining trust, cooperating providing supervision, and to deal with conflict (Goodwin, 1999).

The students had prior experiences and affordances in using the iPad and some of them had used Minecraft before. Therefore, training them in using the iPad interface was not needed. Many researchers have documented the developmental benefit for young children in terms of using appropriate interactive technology (Couse & Chen, 2010). Beschorner & Hutchison (2013) describe the iPad touchable interface as a feature which makes the tool potentially suitable for young children. Astin (1984); Golland (2011) and Gonyea & Kuh (2009) consider that the affordances in iPads for virtual making can support the relationship between the students cognitive and emotional engagement and their learning. Haugland (1992) considers that a purposeful use of technology can encourage the cognitive and social growth of young students.

Touch screen capabilities supported the students making affordances as they could their use their fingers when moving obstacles like in conventional crafting. Different interaction techniques played a significant role in the students making (Vince, 1999) and this refers to students' autonomy, presence and interaction (Zeltzer, 1992). Being able to control objects seen on the screen makes the iPad also, a useful tool using virtual material during their making inside the MVLM (Golland, 2011). It, moreover, increased the students' abilities to interact and control the circumstances and their making while working inside the virtual world that again supported the relationship between the other students' cognitive and emotional engagement and their learning (Astin, 1984; Golland, 2011; Gonyea & Kuh, 2009). It, also, enabled the students control over their MVLM avatar, supported by increased sense of their user embodiment (Cuddihy & Walters, 2000) and gave their personal representation sense of emotional presence during joyful makers' activities (Lehtonen, Hyvönen, & Ruokamo, 2005 and Beebe, 2011). Nevertheless, still the iPads user interfaces do not support a strong sense of user embodiment (Cuddihy & Walters, 2000) because it lacks defined mechanisms for allowing rich interactivity between avatars and the virtual material during making.

It is vital to have a stable internet connection during lessons to avoid students getting disturbed during their work and distracted. It was also an extra load for the teacher to get them started again. According to Bradley and Russell (1997), repeated technical difficulties and the expectation of faults throughout lessons are likely to decrease teachers' self-confidence and a lack of technical support is also likely to lead to teachers avoiding ICT, because of fear of faults affecting the lessons (Cuban, 1999; Preston et al., 2000).

The MVLM was set up on the school's local network and password protected. However, the activities were internet based and therefore vital to beware of any risk of unauthorised cyber-attacks getting access to personal data, making them possible to change it or to threaten the students security (Act no.77, 2000). With new technologies new capabilities arrive for students, but also new responsibilities for educators, in terms of children' security (Byron, 2008). It is also important to teach students about the dangers associated with children using the www.

In this case the iPad tablet enabled access to the MVLM, where students carried out their work. Using the iPad has the potential of moving the focus in lessons from teacher centred education to a more student focused learning (Alyahya & Gall, 2012). During the lesson the students were active in a self-directed activity, except for the very beginning when the lesson arrangement was being introduced. The study confirmed a positive impact on students' motivation and cooperation (Johnson, et al., 2013), as the students were very keen on resolving the tasks, they were spurred on and their motivation maintained by feedback in-game, as well as from their peers and the teacher. This is in line with research confirming motivation as a key aspect of effective learning, that needs to be sustained through feedback responses, reflection and active involvement (De Freitas, 2006). Having completed their mathematical tasks, the students were motivated to carry on making, building their own structures and to have fun playing the game. Learning with Minecraft also fostered students' agency and collaboration.

The virtual making activities frequently referred to elements in the Icelandic, national core curricula, both overall aims, competence levels and its fundamental pillars, such as literacy, democracy, equality and creativity. The expanded learning taking place honed students' skills, not just mathematical skills, but also literacy and social and creative skills. Using a virtual game-based learning environment created a playful learning context for students that supported their creativity, but also enabled the teacher to reconsider his pedagogy and learning designs. This created conditions that supported students as self-directed learning and members of digital citizenry using digital technologies in a productive, responsible and democratic manner.

Conclusions

The research examined the use of a MVLM to support mathematics learning in an online game-based context. The teacher was a key element in the research as he had to show many sets of skills during his work. He was a computer administrator, a planner of a lesson referring to the National curricula, an instructor giving students tasks and a facilitator supporting students with guiding questions during their work.

Most of the students were familiar with the MVLM from playing games at home. Subsequently, their enjoyed their mathematical studies in a playful manner. Their discussions during their cooperation and collaboration played an important role in terms of supporting their social development and learning in general mathematics related to geometry, understanding of concepts, measurements, counting and mathematical expressions.

The MVLM enabled students to share knowledge they gained during a game-based learning process and to help and support each other during problem solving via cooperation. Using the MVLM inside the classroom enabled students' social interaction that helped them sharing knowledge during lessons. Their social interactions were significant for their learning and helped them to develop mental functions such as understanding, reasoning and critical thinking. Thus, cooperative and collaborative learning offered them social support and moved their learning forward.

It was noticed that the students culture played role during their learning mirroring artefacts existing in the small rural fishing village that supported their understanding of their culture. Students with learning problems often gained help from more capable peers e.g. reading for peers if they were not capable of reading. The touch screen capabilities and different interaction techniques, also, supported the relationship between their cognitive and emotional engagement and their learning.

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