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DIPLOMOVÁ PRÁCE

Teaching Area and Volume to 5th grade students with the help of Minecraft

Výuka oblasti a objemu pro studenty 5. ročníku s pomocí Minecraftu

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Odevzdáním této diplomové práce na téma Teaching Area and Volume to 5th grade students with the help of Minecraft potvrzují, že jsem ji vypracoval pod vedením vedoucího práce samostatně za použití v práci uvedených pramenů a literatury. Dále potvrzují, že tato práce nebyla využita k získání jiného nebo stejného titulu.

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ABSTRACT

This thesis is about a study looking into the viability to use Minecraft as a teaching tool in order to teach basic geometry. Using Minecraft Educational edition and based on principles from Self-Determination theory, two specifically tailored maps were created, one was a review towards area and perimeter, and the other one was directed towards volume, a new concept for them to discover. 15 fifth grade students, 9 boys and 6 girls, participated in this study, they were split between two separate groups that participated in this study. Children were given an assessment test to find out what everyone's level is at. Once completed they received tablets with a custom map and some worksheets to go along with it. Students progressed through the maps at an individual pace, with no time restriction they were free to explore in the direction they wished. When finished the children were tested again for comparison. Results have shown that students have the abilities to intuitively discover how to calculate volume after a quick area and perimeter review. Additionally, very positive responses have been expressed during the entire study with increased attentiveness and complete immersion. Potential uses of such discoveries could help alleviate the current work load that our current school system experiences.

KEYWORDS

Minecraft, Motivation, Video Games, Intrinsic and extrinsic, Geometry, Mathematics

ABSTRAKT

Tato diplomová práce je o studii, která se zabývá použitelností počítačové hry Minecraft jako plnohodnotný vyučovacího nástroj pro geometrii. Bylo použito Minecraft Educational edition, kde byly vytvořeny dvě speciálně přizpůsobené mapy, první jako opakující směrem k obsahu a obvodu, a druhá směrem k objemu. Zúčastnilo se patnáct žáků páté třídy, z toho devět chlapců a šest dívek. Dětem byl dán test a poté hra Minecraft na tabletu s pracovními listy. Studenti postupovali po mapách individuálním tempem a po dokončení testu byli znovu testováni. Výsledky ukázaly, že studenti mají schopnost intuitivně objevovat jak vypočítat objem. Potencionální využití takových objevů by mohlo pomoci zmírnit současnou pracovní zátěž současné zkušenosti školského systému.

KLÍČOVÁ SLOVA

Minecraft, geometrie, matematika, video hry, motivace, vnitřní a vnější

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1 Introduction

Over the last thirty years, since the black swan event called the birth of the world wide web, society has been immensely affected by the advancement of computer technology. Devices of all sorts, ranging from smart phones to other mobile devices have pushed this change even further evolving and allowing information transfer nearly anywhere in the world at a moment's notice. One area of technology which is gaining a lot of popularity and momentum are video games. The video game industry is a multi billion-dollar industry which is just expanding further and further. The perceived target audience are school children, yet the average age of a gamer is getting older as time goes on at around 35 years of age. (Jovanovic, 2023) These games can and are being played everywhere, traditionally in people's homes but also everywhere else like while travelling, while waiting in line, during an important meeting or anywhere really. With this kind of a following it comes to no surprise that such a tool could have unfathomable potential in the areas of education and learning. Traditionally these were created as a form of entertainment but they are terrific learning devices and teachers are beginning to see the potential in their use in a classroom setting. Video games bring forth a form of engagement which is difficult to parallel via traditional classroom methods.

As civilization advances, so does the amount of knowledge that it has at its disposal. Being more knowledgeable and informed leads to better decision making. The school curriculum tries to fit in more as there is more to be added in and as a result, material is pushed further back. With the motivational power of video games, it was tested if children can discover basic mathematical concepts, in this case, the volume of cuboid like shapes. 2 groups of fifth grade school children, 15 students in all, were given specifically tailored Minecraft maps along with worksheets to explore at their pace with the goal of learning how to calculate volume based on their prior knowledge of calculating area. These two groups were tested a year apart from each other. The children were given 2 maps, the first one was a review about calculating area and perimeter, the second one was about volume. There was a test given out before and after the activities to compare the results. There was an overwhelmingly positive response from the students in their approach to learning new

material. The students have shown to ability to understand this concept and to apply it correctly when they were guided with the help of the maps which used a grid system, a little less without a grid system.

Video games are relatively new tool considering how long education has been around for. There seems to be a very large amount of research regarding the detrimental aspects of video games. There does not seem to be the same amount of research diving into the benefits of video games. There is an even bigger void in research using video games to accelerate the current curriculum we have. Here is an attempt in increasing the human pool knowledge considering the use of video games in a school setting to speed up the learning process.

2 Theoretical part

2.1 Motivation

2.1.1 Maslow's Hierarchy

(Maslow, 1943, 1954)

In 1943 Abraham Maslow published his paper “A theory on human evolution”. This revolutionary document is where he goes on to explain and describe how motives are driven by needs. Not just that, but there is an order or tiers to these needs, and the needs of one tier need to be met before the individual can move on to the next tier.

The lowest tier on Maslow's hierarchy pyramid is physiological needs. Things like eating and drinking fall into that category. Most animals do not get past this category or are stuck there for extended periods of time. Anything that needs to worry about their next meal does not have this lowest tier of needs satisfied and will not be motivated by things from other tiers. If a person is hungry, but also lacks shelter, love, self esteem and self actualisation, then that individual's need to satisfy the hunger will be the strongest of them all. Once hunger's need has been satisfied, it will no longer be a need and that person can move on to the next tier of needs which is shelter.

When satisfying hunger goes from a question of how to a question of when, the organism has moved on to satisfying safety needs. Everything seems less important than safety needs at that point, even going as far as foregoing previously met and satisfied physiological needs. Satisfying safety needs means staying out of danger, but it also means safe from the elements and experiencing stability and consistency, an orderly world. Unfamiliar places, being confronted with new situations, experiencing outbursts of violence from others, the death of someone close, these are all things which make an individual feel unsafe and generates safety needs. In large parts of the world these days these safety needs are usually met, animals do not tend to roam the streets, we usually have a shelter a place to hide when needed. A

peaceful society running smoothly usually dissolves the safety needs that we require making us move up to the next tier or needs, the love needs.

If hunger and safety needs are both well satisfied to the point of them not being needs anymore, the need for affection and belongingness arises. The lack of friends, a significant other or loved ones such as children will make a person desire those things more than anything else. The lack of satisfying these needs is one of the most common reasons for maladjustment.

Once an individual has found belongingness, they move on to needing and desiring a stable high evaluation of themselves to satisfy their self respect, their self-esteem and as well as how they are perceived by others. This divides into two categories, first there is the desire for things such as strength, confidence, independence, freedom, adequacy and achievements. Second, there is the desire for reputation, appreciation, recognition and importance. Ignoring these needs leads to feelings of inferiority, weakness and helplessness which in turn leads to discouragement. Satisfying these needs produces self-confidence, strength and understanding of one's usefulness in today's world.

The need for self actualisation is the highest need and sits on top of this pyramid. One will still find needs which need to be satisfied and those are the ones that makes an individual whole. The individual's passion needs to be satisfied, this differs greatly from individual to individual. This can take form in a creative manner or in fulfilling a duty, basically striving to do the best one can do. People who reach this level are considered to be satisfied individuals and most people do not manage to reach this level and those who do tend to be the exception.

While this structure applies to most beings, there are always exceptions to the rule. This includes some people who have a higher preference for self esteem over love and belongingness. There are some creative people who strive for self-actualisation in spite of the lack of basic need satisfaction. Some people have a permanently reduced level of aspiration and will reach satisfaction by meeting only some basic needs. Some individuals have lost the need for love. Then there is the greatest exception, people who follow ideals, individuals who since a young age had all their needs satisfied and they grew a resistance to need-thwarting. These last are the few who can withstand opposing mass opinion and stand

up for what they believe in while facing hatred, persecution and rejection. Again, one must remember that these are exceptions to the rule and not the norm itself.

2.1.2 Self-Determination Theory

(Ryan & Deci 2000a; Vanteenkiste & Niemec, 2010)

Needs explain what motivates us in our day to day lives. However, where does motivation come from and what keeps it going or maintains it over a period of time. Intrinsic and extrinsic motivation are different parts of the same thing, motivation, and the question is what role does each play on the outcome of one's behaviour. In 1985, Edward L. Deci and Richard M. Ryan have published a book about Self Determination Theory called "Intrinsic Motivation and Self-Determination in Human Behaviour" which has since been accepted as sound theory in this area. (Vallerand, 2000) The theory describes the different stages of internal and external motivation as well as the characteristics for each stage and how the level of autonomy at each stage has changed in comparison to each other.

While intrinsic motivation is fueled by the enjoyment of the activity itself, extrinsic motivation is what powers the majority of activities we partake in our everyday lives. Extrinsic motivation means motivation from an outside source which is done in order to attain a certain outcome as opposed to doing it for the enjoyment of it. Organismic Integration Theory (Deci & Ryan, 1985) was introduced to explain the different forms of extrinsic motivation and the factors which strengthen or weaken the internalization and integration of the regulation for these behaviors. This taxonomy divides extrinsic motivation into 4 different subcategories all with varying levels of interest and autonomy along with their effect on repeat enjoyment.

The lowest form of motivation is amotivation, or the lack of motivation, this is the point where the individual's behaviour is lacking a sense of personal causation and any form of intentionality. The individual has no interest in performing said activity, foresees the outcome as fruitless or just not feeling like their competency level is up to par with the

requirements. It does not get any lower than this and any form of motivation is an improvement at the point.

The lowest form of extrinsic motivation, also known as External regulation, is representative of behaviours which are manifested in order to satisfy a demand or gain an imposed reward. This subcategory of extrinsic motivation is what people most commonly miss-identify as all of extrinsic motivation. Examples of this would be being paid for cleaning the dishes to get a weekly allowance or cleaning your room so that you do not get punished by your parents. This form of motivation can be useful to introduce some new task or experience that would have not otherwise been discovered. However, when an individual becomes accustomed to associating said activity with a reward or other external deterrent, once that external push leaves, the individual has a much lower likelihood to repeat the mentioned activity. A randomly received reward after a task can be motivating as it was not expected and is reflective of a true result. A reward being announced ahead of time undermines other reasons for doing specific things, overpowering as opposed to reinforcing them, in which case this competition becomes a form of control.

The next sub-category of extrinsic motivation is Introjected regulation, put simply, regulation by self-esteem. This is the category where things such as guilt, pride, morals and so on belong. The word introjected stems from Latin meaning to throw inside, this is where autonomous motivation towards a task begins to demonstrate itself. External contingencies are no longer required and the whole process gives rise to feelings of internal control. This form is however quite taxing with its energy requirements and is not sustainable for a very long time.

Following that we have Identified Regulation. This is the stage where the individuals realize the benefit of an action at a later date, also known as planning ahead. Examples of this could be someone taking up regular exercising in order to lose weight down the road. An individual can start studying just about anything for just about any reason and it would end up being Identified regulation, the individual has identified with the benefits associated with planning ahead. Just like the previous stage, this one also comes from powers within one's self, however, this one does not require as much energy and can thus be sustained.

The highest level of Extrinsic motivation is integrated regulation. At this level, the individual basically fully assimilates the identified regulations. The actions are now done fully autonomously without any internal conflict. However, since the root of the reasons behind the individual's actions are still driven by an outside source as opposed to just pure enjoyment of the action itself, it is still considered an extrinsic motivator and not an intrinsic one.

The next step in that same direction leads us over to Intrinsic motivation. Basic needs theory (Deci & Vansteenkiste, 2003), a sub-theory of Self-determination Theory identifies three needs for which satisfaction is required in order to maintain motivation in a sustainable way. These are autonomy, competence and relevance. Autonomy being the biggest driver, the ability to do things on your own based on your own decisions is needed in order to maintain motivation. Control is a major killer of motivation, the more an activity is controlled by an outside factor, the less interest will remain for the activity at hand. The second need is competence, the individual needs to have the ability to succeed at the task or else the task will not remain enjoyable for a long time. Lastly there is the need for relevance, this last need is not as strong of a driving force as the previous two, but there needs to be some relevance in order for the activity at hand to be executed.

2.2 Games

2.2.1 What are video games

Video games are a relatively new concept, having only begun to spread commercially 50 years ago in the 1970's. (Wirtz, 2023) Along with their conception, their definition had to be created; what they are. Early definitions created by narratologists was that video games are interactive narratives. In other words, a video game is a story that we interact with. This caused the problem with games such as Tetris, where there is no story, but it is a video game nonetheless. (Tavinor, 2008)

Moving forward, Jesper Juul gives us a new definition of a game and breaks it down into 6 components. First it needs to be a rule-based formal system, second, it needs variable and quantifiable outcomes. Third, different outcomes are assigned different values, fourth, players exert effort in order to influence the outcome. Fifth, the player feels emotionally attached to the outcome and lastly, the consequences of the activity are optional and negotiable. These 6 claims are to be necessary and sufficient for any game to be called a game. The problem is that when we transition over to video games, these claims may not all always apply. (Juul, 2005)

Juul's definition is still very strong, but some additional clarifications need to be made. Video games by definition of the word would need to be on some form of electronic visual medium, but not just that but they need to require this digital medium in order to be categorised there. An example would be chess, if we made a video game of chess, does chess now become a video game? The reverse is also not possible, if we took a game like super Mario Brothers and tried to convert it to a physical game, then it would not work, there are some aspects of video games that cannot be replicated in a feasible manner. (Tavinor, 2008)

Games like flight simulator or Simcity do not have any set goals and players can just wander and go on endlessly. Additionally, simulators are used in training for hazardous or dangerous situations and those are not intended as games. So a game would need to have

entertainment as its primary function. This would leave the latest definition of a video game that of Juul's with the addition that the game requires the medium to be of electronic and visual form and that the primary purpose of said entity is to be for entertainment purposes. This definition will likely change and improve upon itself more as time goes on. When video games came to existence, the population had no idea what it was and what would become of it. Just like art, the definition of what it is will evolve and take many new shapes. (Tavinor, 2008)

2.2.2 Tech vs non-tech

When it comes to gaming, one big question that we are analysing is the use of games that require technology such as video games, or traditional games that we currently find in the classroom like card and board games. When considering the use of games that require modern technology or games that do not, then there are several things that one must weight. Cost is always an important factor, often the biggest one. Technological addiction is a problem that must also be weight out. Flexibility to modify the lesson based on needs as well as catering to the student's interest are key points that leads to success. The ability to experience things using multiple senses enhances the learning experience. Immediate feedback is also different in both types of games and are an important aspect to look at when deciding which direction to go.

When one looks at cost, the immediate reaction is that traditional games have a lower up-front cost over their counterpart, video games. Before one can use a video game in any setting a console or a computer is required, the same is not true for card or board games. When one considers that schools will also use computers for other non-gaming activities, the up-front cost drastically reduces itself as well. When the game becomes less relevant or newer and better options are available, then getting a new video game is about the same as new board game. The upkeep is much lower with the technological option, as you lose components from your physical games you will need to either replace them or accept your

game may not function as intended, the digital counterpart does not have this problem. The physical games also cost you significantly more in terms of physical space usage. The long term cost benefit here shows that digital games are the superior cost effective route to take.

Technology is addictive (Griffiths, 2009) and children that have brains still in development are much more prone to this. Yet, when we look at where civilisation is at, we need to educate these children about technology's benefits and dangers, how to use and behave with this powerful tool. Children will eventually find their way to technology and start exploring it on their own, there is no real way of hiding it without true isolation. A controlled environment, such as a teacher and their classroom, is the exact place that both things can be addressed. The classroom is a great controlled environment already used for learning. Having a teacher look over the whole thing, stepping in and guiding, explaining and educating when needed helps control the addictive aspect.

Changes made to physical games are done with orders of magnitude faster and easier than in video games. However, those changes are often permanent or can only be made a certain amount of times before the game is no longer modifiable or worse, unusable. Modifications to physical games can also cost additional material but the flexibility is nearly unlimited. Custom rules or variants are easy to apply to physical games, technically it should be just as easy to apply them in video games. Reality cannot enforce custom rules, we do, the same should apply in video games. Yes, there is a steep learning curve in order to create modifications, and these modifications do take a while to create, but at the same time, video games tend to have a much bigger and stronger community support. Additionally, once they are created, they are there to be used whenever, the original version is still around and the personal library of modified maps and modules grows over time.

The more senses are involved in learning, the more effective the learning will end up being. (Shams & Seitz 2008) Transitioning from physical to digital, one loses the senses of touch, but acquires more from the sense of hearing as sounds are a lot finer tuned, especially if wearing a headset or have some form of surround sound. More importantly, one gains the sense of immersion, where one controls their avatar in a digital environment. (Rigby & Ryan 2011, Rogers 2012) You chose when to go forward, when to jump, when to run into a wall

or walk into a hole. This sense of control leaves a much more lasting impression increasing the effectiveness of the given lesson.

One huge aspect of digital games is that they have immediate and constant feedback. Physical games also have relatively quick feedback, but focus is usually on one person at a time. Digital games are usually designed with minimal downtime for people which in result takes the children's focus away much less and they remain immersed inside the game until some next small pause or downtimes comes along. Since Physical games focus on an individual or a small group at a time, the rest of the participants have less to do and the time is not used as efficiently. Digital games are designed such that everyone should be able to be busy at the same time and getting constant feedback from potentially multiple sources. This results in minimal downtime and a constant stream of focus.

While addiction to technology seems to be an awful attribute to have, this one is relatively manageable. All other signs point to digital games being a much better choice over physical games. While exceptions do exist, the world is moving in a digital direction and utilising the potential of video games in the school environment is also the direction to go. Video games have increased interactivity. Video games have a much larger selection of available titles as they are easy to create and publish with no physical components needed. Video games are much easier to update, and with the amount of platforms available just increasing, so is their availability.

2.2.3 What are the positive benefits of Video Games?

Video games, being relatively new are not fully understood and as most new things scare people. This results in a negative portrayal via news and other media, and a lot of research has gone into finding the negative aspects of video games. Not a lot is known about the opposite, about the positive benefits of video games, due to the lack of exposure in this area. Video games do have cognitive, motivational, emotional along with social benefits. Not every single game will present all the same benefits, similar to food items where each one

has a different nutritional value different genres of video games will offer different benefits to be gained. (Granic et al. 2014)

Regarding cognitive benefits, the most visible benefit is surprisingly through first person shooters. These games help develop players to be faster and more accurate in attention allocation, they have higher special resolution in visual processing, they have enhanced mental rotational abilities. Compared to players who do not participate in first person shooters, their frontal parietal network is less active implying that they are better at allocating attention compared to non-gamers. Strategy games have cognitive benefits in that they help develop problem solving skills which later have positive benefits academically. Another cognitive benefit is that it enhances creative capabilities. Contrary to the other benefits, any game enhances creative capabilities which means that assuming everyone has the same starting point, a gamer will be more creative than a non-gamer. (Granic et al. 2014)

Children can either believe the entity theory of intelligence, where the child believes that intelligence is a trait that one either has or doesn't and cannot be changed. You will always be smart or you will not, intelligence is not gained and no amount of effort will change that. Then there are those who follow the incremental theory of intelligence, where becoming smart is something that is gained through incremental effort. Motivational benefits are generated through immediate and constant feedback. In video games you are rewarded for continuous effort. These manage to be continuous as they incrementally increase the challenge keeping you in the zone of proximal development described by Vygotsky. The benefits that video games bring here motivationally is that they induce feelings or points of view towards the incremental theory of intelligence. These children then end up seeing failure not as a representation of one's self worth, but as an indication that they need to keep working at it until they have it right. What happens with children who believe the entity theory of intelligence is that they do not know how to handle failure all of a sudden. Video games give us a very important lesson: Persistence in the face of failure reaps valued rewards. (Granic et al. 2014)

Emotionally, video games help generate positive feelings. This improves mood, it promotes relaxation, it wards off anxiety. Video games allow us to experience "Fiero", an Italian word for intense pride. This is achieved when overcoming a great obstacle or challenge, then the

culmination of your efforts results in a favorable outcome that you were seeking. Video games allow us to experience flow, some people call it being in the zone, it is when an individual is immersed in an activity that is rewarding, performed with a high level of control while experiencing a loss of consciousness. In other words, you become part of the world you were interacting with, reacting to it almost as smoothly as if it was reacting to you, and all this while the other world you were from is temporarily put on hold. Emotionally, playing video games makes people happy. (Granic et al. 2014)

Finally, we have the social benefits of video games. The typical stereotype of a gamer is that they are some lone child with no friends playing games alone and has zero social skills. This is very far from the truth. The amount of people that play with a friend is ever so increasing on a daily basis. People develop their social skills online as they have to interact with people. On a moment's notice one must be able to discern if one can be trusted or must be rejected, how to lead a small random group of players, all on the fly. Prosocial games, games where positive social interactions benefit the player, promote long-term positive social behaviour outside of gaming, helping others out and so on. In fact, violent games can also be prosocial. Playing violent cooperative games decreases access to aggressive cognitions. While the game is violent, during the game you are helping each other out and these traits carry on after the gaming is over. Lastly, games with civic experiences, mostly seen in massive multiplayer online role playing games where social groups and activities happen, tend to breed people who engage in civic activities outside gaming such as volunteering. (Granic et al. 2014)

As we can see, video games bring with themselves many benefits. As this area is still not as researched as one would hope, more benefits will eventually be discovered which will make us realise what kind of a tool we have at our disposal with video games.

2.2.4 Why are video games enjoyed so much by so many?

Many of us enjoy video games, are drawn to them, indulge in them using our own volition. Why do we keep going back to them? The common answer is that it is because it is fun.

Many of us have found ourselves playing and going back to games that we do not consider fun, so why do we go back? It turns out that video games are really good at satisfying certain needs, these needs are the same as ones that support intrinsic motivation as described by the Self-Determination theory. Competence, autonomy and relatedness are the three needs that are satisfied, this is done because of the game's high consistency, density and immediacy. Video games are quite immersive with a strong presence, they are an extension of the activities we already participate in and an extension of reality. (Rogers, 2017)

Through our lives, we experience reality with our senses, by seeing and hearing, now we have that opportunity in a virtual world where we also see and hear things and where we can also interact with that environment. Our relations with reality has three ways of taking form: we can be passive, we can be taking up active exploration or we can interact with it. When we are passive with our environment, we are just observers, watching the world as it passes around us. This can take shape in ways like looking out the window as we travel or when we are listening to instructions by someone or something else. As active explorers we go as we chose and we do as we want and at our own pace, this can be a walk in the park, reading a book or trying a new recipe. Lastly, one can interact with their environment. This option is not as controlled, but is often skill based, the better you become at interacting, the more favorable the outcome will become. Video games, especially the better ones, have elements of all three different forms of those realities. Games have passive cut-scenes, allow a high level of self-controlled exploration and have real time interaction which is also based off skill. (Rigby & Ryan, 2011)

This extension of reality that video games create is allowing a form of control that former forms of entertainment did not allow at such a scale. One is always able to read a book, watch a movie, but in those scenarios, we experience the events as a 3rd person's perspective, a spectator at most. A book or a movie is giving its most on its first pass through, you are curious to find out what happens next and once it is complete, the knowledge is gained and that first experience is only but a memory, no new suspense is built because there are no iterations and everything is final. On top of all of that, the spectator has no say and needs to keep up at the pace that the movie decides to hold. With a game however, knowledge gained the first time around is used on future attempts until a problem has been surpassed, opposite

to movies, knowledge enhances future repeats which get ruined by spoilers, not just that, but it is all executed at the user's pace. (Grodal, 2012)

Competence is the first need which gets satisfied via video games. As soon as a new game start being played, the new player must pay a certain "cost of admission" in terms of learning how to play it. The more intuitive the controls are, the lower the cost of admission for the game. Video games give constant feedback at every action taken, this allows the player to make immediate modifications which will in turn also be evaluated and given feedback upon. Video games are generally designed in a way such that difficulty increases, but not in a constant stream, but in waves. A player will struggle, will acquire a new skill or item, go through a small period of just being awesome until a new challenge arrives which needs to be solved yet again before progressing onwards. The challenges are again designed to increase in difficulty at a generally steady rate of growth continuously giving feedback on the progress made in satisfying the need to be competent. (Rigby & Ryan, 2011)

Autonomy may have been less abundant in the past as video games were in their infancy, but as time progresses, the dimensions of choice and opportunity have just grown immensely. Character customization has reached really high levels allowing players to have a unique identity of their own or as wild as the imagination can conjure up. Players have the freedom to explore content at their own pace, sometimes skip content or go back to it later should they wish to do so. Strategy games allow a player to choose their path to victory or defeat, in fact it is the point of said genre of video games. Open world games give a near limitless freedom of movement. Players are free to explore at their pace in their direction, specializing on what their chose to. (Rigby & Ryan, 2011)

Relatedness, in the context of video games, can be boiled down to "you matter". Same as with autonomy, in the early days of gaming this was not as readily available, these days it is probably the biggest need satisfier. Non-player characters are not real and thus should not matter, but a compliment from an automatically generated response will enhance someone's relatedness need. If a person can feel related to a character in a movie strongly enough to be caused to cry, then surely this is also possible in an environment which involved the player all that much more. People want to feel heroic, save the princess, these moments of relevance are not met on a regular basis, if at all for some. (Rigby & Ryan, 2011)

In multiplayer games relatedness becomes emphasized even more as you become an important member of the group. Relatedness breaks down to wanting to be acknowledged, wanting to be supported and wanting to have an impact. Here we start to have relatedness synergize with competence in end game content. People will have specific roles in challenging situations, people matter as they need to support each other but at the same time they need to play at a skilled level in order to accomplish their task, satisfying both needs at once. A different example of how relevance synergizes with autonomy would be in first person shooters, you work on a team with a common goal and each member matters, but each will use their style of play and in game preferences which will personalize that gaming experience. Teamwork synergizes autonomy a relatedness really well. Lastly wanting to have an impact in a social environment is as simple as making someone laugh, or it can be as complex as the mind can imagine. (Rigby & Ryan, 2011)

All this is being held together with consistency, density and immediacy. Consistency is the high likelihood of delivery on engagements and need satisfaction. Density is the ability to make that delivery at a high frequency. Lastly we have immediacy, today the world does not have the patience that is had mere decades ago. People want things and they want them now. As people have gotten used to availability on demand, everything must be immediate and video games do deliver there.

Those previous needs were things that get players started and drawn back into the game. However, there is another element which does lure players back into the game, immersion or presence. While many would think that people want to escape from one reality, it is the opposite as you are lured in. The sense that one is within the game, in other words, the players are being drawn in through the compelling storytelling or intuitive controls. This part of video games is all about the details, small or big. It is the authenticity of the game that makes people yearn for a bit more. This authenticity is not limited to content but also in interactions and if believable or completely outrageous. There is also emotional presence, or how much it is affecting us emotionally, are we emotionally invested or do we have an emotionless void towards it. Lastly there is also the narrative presence, in other words, how integral are we to the story? The more of an impact we have regarding the outcome of the

events unfolding, the more we are pulled, if we had less of an impact, then we would be drawn in less. (Rigby 2011, Rogers 2012)

All in all, video games have a build in template that is aligned with optimal learning. The past offered comparative school learning, but video games allow for individual leaning which leads to mastery learning. All while leveling up at your own pace.

“Studies consistently show that better satisfaction of integral needs is associated with greater enjoyment of games, as well as enduring learning performance, creativity, and the transfer of learning from one setting to another.” (Rygby, 2011)

2.2.5 What is Minecraft

Minecraft is a block-based sandbox game most closely resembling a digitalised version of LEGO. It is a game where blocks are broken down which can then later be placed back down or turned into tools and items. In Minecraft you can explore a near infinite procedurally generated three dimensional block world. The game offers a variety of biomes and multitude of non-player characters (NPC) for a fully modifiable environment. The game also uses redstone, a form of circuitry allowing programming inside of Minecraft.

First developed by Markus Persson and then Jens Bergensten taking over as the head developer, Minecraft continuously adds major updates releasing one to two major updates each year several minor ones in-between and continuous bug fixes and testing snapshots. (Henningson, 2022) Minecraft is currently on version 1.19.4, meaning that it has gone through 19 major updates and 4 small ones since the last major one. Each update adds new blocks or items into the game as well as new or updated game mechanics expanding the capabilities of Minecraft all that much more.

Minecraft comes in several versions. The first version was developed using the programming language Java, it was very customisable and very modifiable by the public with a lot of free content available. Around the time of its acquisition by Microsoft,

Minecraft pocket edition was being developed and later was turned into Bedrock edition. The main differences between these is that Java is more customisable and modifiable and content is almost entirely free while Bedrock is more supported across platforms but each addition becomes a micro-transaction. In November of 2016 Minecraft Education edition is released, a version of Minecraft that is specifically tailored towards schools. This version has unique features, it has additional teacher controls, a chemistry crafting component was added as well as new forms of programming. Additional spinoffs that came from this was Minecraft Dungeons, a dungeon crawling adventure set in the Minecraft universe and now Minecraft Legends, an action strategy spinoff. (Minecraft.net)

Minecraft is very customisable and can be approached from many different ways. The original game mode and most default settings is survival. The player has to gather resources with which to build a shelter to survive dangers such as hostile monsters that come out at night. With the game's official release was also introduced creative mode. In this game mode the player has access to infinite resources, can fly at will and is in effect invincible. With this mode the player is free to build to their heart's content without the threat of any kind of danger or without being limited by resources. Adventure mode was released in August of 2012 with patch 1.3 to allow custom gameplay and game mechanics. The last mode that the game currently offers is spectator mode which came out in September 2014 along with patch 1.8. In this mode the player just flies around and can explore the map that they are residing without the ability to interact with it. (Minecraft wiki, 2023)

Minecraft also offers multiplayer capabilities; this helps increase socialisation. Players can also improve teamwork when they interact with one another in the same world and work together towards common goals. Teachers can use the multiplayer options to create a learning center, a hub where students can use as a common area to meet and share ideas or look at examples. The teacher can also create a virtual classroom; this can be customised to various themes or to the liking of the class itself or based on what the class material is at the time of the lesson. Minecraft can enhance learning by providing opportunities for collaboration and problem solving.

3 Experimental part

3.1.1 Scientific questions

Mathematics has always been considered one of the harder subjects to master, it is one that an individual could in theory figure out all on their own. It is in fact a logical language and its use in a consistent way will always produce the same results. If all of the mathematical knowledge we have gained would be lost today, then in a thousand years we would come back to the same conclusions and come to the same results. The knowledge to calculate area predates the birth of mathematics, from as early as 1850 BCE, implying that it is very basic. This material is so basic that it is taught in grade school.

By the time they reach grade 5, children will have seen how to calculate areas of rectangular shaped figures on a grid. Can these children figure out how to calculate the volume of cuboids on their own using specifically tailored Minecraft exercises? Will a few hours of exposure give them the confidence they need in order to start solving such problems on their own?

Our ancestors have managed to discover this solution without guidance and with likely much less knowledge than today's children have. While the children will have only have a handful of hours, the progressive nature of video games will help them focus on their task at hand and be much more immersed into it. The children will have the autonomy to proceed at their pace and using the methods of their choice, the constant immediate feedback will have them wanting more. In the end the children will not fear problems of this kind and will be able to resolve them correctly without too much difficulty.

3.1.2 Significance

Education is a part of nature, a part of us. It is in one's best interest to learn and become better at whatever was chosen to be improved upon. This is why education, the passing of

information to the next generation has existed since the dawn of civilisation. As society developed we gained formalised education. Today, our formalised educational system uses practices which are still ancient, some hundreds of years old. It is understandable, the field of psychology is relatively new and studies into education only really began a little over 100 years ago. While the concept “if it isn’t broken, then why fix it” does have its merit, the opposite side of the coin “because it can always be improved” applies much more when the concepts talked about are hundreds of years old.

Technology has been and is still is advancing at an increasingly accelerated rate. This technology has vastly changed the way people live their lives and how society behaves. 150 years ago there was no telephone and no television, seeing a moving image or the idea of hearing someone’s voice whispered to you at a distance was sorcery. Computers decided to speed up the technological advancement, according to Moore’s law the computational power of computers doubles every 2 years enabling technology to be developed ever so increasingly faster. This increase in technology does benefit society as it increases our quality of life. There is a downside, with more technology and more discoveries, there ends up being more things to learn.

The educational system does not evolve at the rate of technology, but it is evolving and tries to meet our ever changing needs. The advancement we are experiencing also give us new tools at our disposal, video games being one of these new tools. The difficulty is that people are not experienced with them and there isn’t as much in-depth research as one would hope. Video games have such a great potential for learning, theory states that they are ideal devices for learning purposes. Some research is beginning to arise and the general consensus from an almost unanimous standpoint was that it always generated a positive response.

Studies were made on how teachers in training could adapt to using Minecraft in the classroom. (Kim & Park 2018) Other studies then show how it is to use Minecraft as a teacher. (Meany & Pajic 2018) There were studies that tried supplementing material in spacial geometry to fill in the gaps during years where there were voids. (Foerster, 2017) A common trend among studies is that it seems to help the underachievers and the weaker students. (Foerster, 2017; Ming, 2020) Even studies that try to find problems with video

games admit to their potential and benefits. (Mataruga) There are also many opinion-based studies to see what the general consensus of the population is. (Whitton, 2007)

With more and more material being taught due to the nature of an advancing civilisation, content tends to be pushed back further and further. Video games being fully independent learning devices could help us cope with this unique dilemma. It is important to test the boundaries of what children are capable of with new tools we have at our disposal. If children can learn things faster at a younger age because we have the means to make it happen without causing any additional stress or discomfort while holding to an individualised approach, then this option needs to be explored. If results keep turning out to be positive, then perhaps with time the educational system will change to adapt to the times of today. And thus, research is being done to test the limits of children giving them full control over their pace. Perhaps this could be a first step in an educational reform.

3.2 Overview

3.2.1 Procedure

This entire process was conducted in the English Language and was mostly an individual activity, every student had their own device. It was administered by the author of this paper who was also the children's English language teacher during their scheduled time with this teacher. It began with the children being given an entrance test. Following that, they were given a worksheet along with a specifically tailored single player map for area and perimeter. Once they completed it, they were given a second set of exercises and another single player map, this time about volume. Upon completion of the second map, they were given the exit test to compare for progress.

The children were given the freedom to explore the problems in the practical part in any way they wished. The instructions given were as follows: "The map is divided into two going along the main road, on the left hand side you will have exercises that will help you understand the concepts, on the right hand side of the main road you will have exercises which will expand on that that knowledge. As you progress along the road, the exercises will get harder. I recommend starting on the left-hand side and closest to the start of the map, but you may progress in the order you wish. You will be asked to find the area, and later the volume, of certain objects. How you find them is up to you, you can count every single block if you want, you can also just break every single block and then check how many you have in your inventory, or... perhaps you will find some other trick." This was both explained as well as written on a blackboard which the student faces when they first log into the map. As this is being explained, the map is quickly being previewed on the projector screen for the whole class to see.

The default setting in the game was set to survival mode, however, if the students chose to, they could switch their game to creative mode. The reason for the default mode was that one of the options given at the start was the possibility to break the blocks and have them end up in your inventory. When playing in creative mode, the blocks get destroyed as opposed to disassembled and therefore do not end up in your inventory. Creative mode does however allow the ability to fly or more specifically it allows the player to toggle the effects of gravity in the game. This option gives the player to better way to visualise what is

happening as more points of view are available. The students were free to switch from one play mode to the other based on their liking.

No time limit was given for either of the written parts of the experiment. The same can almost be said about the practical part as there was no real given time limit. There was approximately 6 hours allotted for the practical part and if the children did decide to not do work and instead just do unrelated work, then the 6-hour time limit was enforced. Once a student has completed both maps and the associated worksheets, they were immediately given the exit test without waiting for others to finish.

No electronic devices were permitted other than the tablets that Minecraft was on and only Minecraft on them was permitted during this entire exercise. The children were otherwise permitted to use whatever tools they had at their disposal. The children were also permitted to briefly consult each other during the practical part, not during the tests, as long as it is brief and quiet enough to not disturb other people around them.

The students were given permission to relocate how they wish and make themselves comfortable. This also included going outside the classroom on the other side of a glass wall where there would be less distractions from students who may be consulting each other. When the weather was permitting and the whole class was interested, the relocation to outside was also among the realm of possibilities.

Once completed ahead of others, the student which managed to finish were allowed to work on assignments or homework which they still have pending. If the student had no other work, then they were being permitted to read a book, either one that they have already started, or one of the ones in the class library. This was done intentionally in order to prevent other students who have not finished to try and hurry through the activity in order to receive a perceived reward undermining the current intrinsic motivation with an external motivator.

3.2.2 My sample used

The entire activity was conducted on two groups of children aged ten to eleven years of age and enrolled in grade 5 at the time of this experiment. Both groups were of smaller than

average class size. The first group, hence forth known as group A, was a group of 9 children of which 4 were boys and 5 were girls. The other group, hence forth known as group B, was a group of 6 children consisting of 5 boys and one girl. The two groups were one year apart, while group A was in grade 5, group B was in grade 4. Group B was tested a year after group A was tested. Both groups did these exercises at a relatively similar point in their studies.

Both groups came from the same school and have been in the same environment. It is a private bilingual lower elementary school covering grades 1 through 5, having a cap of 50 students for the whole school and having a clientele comprised of highly wealthy families. The children undergo a double curriculum, a Czech one and an English one, from the start of grade one. This is a heavier workload, but they seem to be handling it without difficulty. The school itself was a small building in a quiet valley area on the outskirts of Prague. Grades 1 and 2 were together, grades 3 and 4 were together, grade 5 was alone on its own. The school being bilingual, each classroom had 2 teachers (one native and one English) that rotated every other day and each classroom also had an assistant.

This is a school which has a philosophy of not giving out rewards or punishments as a form of motivation. It does not give out grades, it gives feedback to individuals on their progress relative to themselves. The school does try to maximise the amount of activities that occur there, cultural, athletic, it tries to expose the children to as much as possible. The school does have a courtyard which is shared among the 3 classrooms and does not have a set schedule on who will use it when.

The year prior to them following along with this process, while in grade 4, the children did explore the concept of calculating the area of shapes traced out on a grid during the English portion of the curriculum. The children went as far as counting the squares on a grid, or learned to multiply one side by the other to get the area of rectangles. However, mostly only using a grid. Simple rectangles can be calculated, but more complex rectangular shapes need a grid to count out the squares. No other geometry has been seen in approximately a year prior to these sets of activities. No review was done prior to this, the students started the activities without much prior warning as to what to expect.

The students all have gained proficiency using Minecraft prior to the event as it was in use several times prior to that time inside that school year. It is a tool they have all learned to enjoy as it was also used recreationally on occasions when all work in class was done. At least half of the children used Minecraft on a regular basis outside of the school setting. Several children have acquired it as a result of us using it in school.

Of the two groups, group A had a slightly higher average skill level and was much more motivated to learn and do work. The spectrum of skills and the potential of both groups were similar, but group B was a smaller group with a larger amount of people with an underwhelming desire to succeed. To put it into perspective, all but one person from group A was interested and continued their studies in a gymnasium as of the following year. In contrast, from group B, there were only 2 people interested or considering going to a gymnasium the following year, in the end not a single student followed that route. Since there was a significant difference in the level of motivation prior to the exercise, it was decided to let that be one of the variables being observed. Everyone was given the same work, explanations and opportunities in order to not create any other variables which could independently modify the results.

3.2.3 Why Minecraft

Being a cube-based sandbox game, Minecraft is very versatile in its usage possibilities. Its versatility was one of the main reasons for its use. There are countless ways of going on about anything you want to do inside Minecraft.

Following the Self-Determination theory, three main things needed to be maintained: autonomy, competence and relevance, Minecraft delivers on all fronts. The intent was to give the children as much autonomy in their decision-making process to finding solutions. Another need was to find and use something that they are familiar with. Minecraft fills those needs extremely well.

The relevancy was approached from a different angle, as things are relative, rather than trying to find the relevance of playing a video game to do math, the focus was turned around

to push the relevance of math to play a video game. In other words, the children weren't using a different medium do try to solve problems, but using a medium that offered them problems to use. Simply put, it wasn't just a change of medium, but a change in how it is perceived. They weren't doing math using a video game, but solving puzzles which happened to need math in order to be solved.

As mentioned, competence is a key need to maintain motivation, picking a game that the children are already familiar with helps bridge the gap of familiarity. If games across all platforms are included, then Minecraft makes it as the second most sold game ever at over 238 000 000 copies at the time of this document. (Donato, 2023) The popularity and familiarity of this game makes it a much easier to work with. This game's popularity has also made it a familiar and thus welcoming environment.

The children are comfortable with the controls or get accustomed to them very quickly. The controls layout is a commonly used setup for today's first person and often third person genre. Movement is accomplished with the ASDW keys and direction is controlled by the mouse. If different platforms are used, such as tablet or mobile, then the children adapt very quickly as they are eager to have freedom of movement even if just virtual.

The Children also view this as enjoyable and something to look forward to. This is in fact one of the key reasons to using Minecraft. The idea is that they will be more motivated to learn or do educational activities while using Minecraft. Sometimes not even realising that they are learning things while participating in learning. Minecraft is something many of them already enjoy and participate in willingly in their free time. Now they can enjoy something that they consider themselves great at and while unknowingly applying Vygotsky's zone of closest proximity among the unexperienced Minecraft users.

Minecraft is a platform where people can customise and change their appearance. Being able to express yourself through your avatar is another alluring aspect of using Minecraft. Sometimes children are shy to express themselves and this is a door to self expression, something that the children sometimes lack. This small freedom is an empowering boost towards motivation as it gives the student more control over their direct environment.

The environment that the game offers is very open and yet flexible; the creator can set up strict and hard enforced rules, the user is however free to explore how they wish outside those rules. The decision was to lift as many restrictions as possible to allow a degree of freedom, however, defaults were set for those that could be overwhelmed with options. This creates what one hopes is an ideal environment for the learner, they are free to explore and experiment and be in total control while being guided by invisible directions. By being in control of their environment, the learner immerses him or herself much further into the game and thus the problem being presented as well. The learner takes ownership of the learning experience and is in control of its development.

Minecraft is also very flexible for the creator. While coding in game does allow flexibility outside of the possibilities that the vanilla game on its own can offer, none of that took place this time around. The decision was made to not code as the concepts being covered were simple and straight forward enough that the base game was more than capable in delivering what was needed. Simple block placement allows for the construction of roads, walls or in this case, geometry exercises, some in the form of puzzles. With hundreds of unique blocks available and near infinite space to build upon, the ability to customise and build is bounded only by the determination of the creator.

3.3 Methodology

3.3.1 Entrance and exit test

The entrance test was needed in order to have a reference point to the children's abilities. An exit test needed to be done to compare the knowledge gained by the students during this process. Both tests were nearly identical, differing mostly with just the values at each question while keeping the questions the same. Each question had its purpose. Each question and associated diagram is also available in the appendix at the end of the thesis.

The tests were structured in a way to try to evaluate if the children truly understand the material at hand or if they were lucky with a few guesses. This was done by progressively making the questions not only harder, but changing the format and layout of the question in itself. It begins by asking how do you calculate perimeter, area and volume.

The first questions were to see if each student understood what perimeter and area were and how to calculate it. The initial idea was to see how they perceived it, to get a general notion of what they know. Repeating this question in the exit tests seems redundant at this time and did not really serve much of a purpose. This is a question that does not provide comparable data, however, it does give us relevant information. As it informs us of the children's perception of these concepts. One must however also take into consideration the expressive ability of a 5th grader.

The first problem to calculate, hence forth known as "rectangle", was a simple 3x5 rectangle on the entrance exam while it changed to a 5x12 for the exit test. The purpose was to see if the student can calculate the most basic rectangle and how they would approach it. The numbers were kept simple and straight forward to try and eliminate any arithmetic errors and concentrate solely on the concept.

The next question, hence forth known as "Wide L", was a 5x9 rectangle with a 3x6 section cut out in the top right corner for the entrance test while it was a 7x14 for the exit test. This question had most of the side's lengths marked off, one was unknown. The intent here was

to increase the difficulty of the question a little but still providing more information than was necessary and see what direction they take when they approach the question.

The following question, hence forth known as “Thick L”, was very similar to the previous one, it was a 8×7 rectangle with a 6×3 section cut out from the top right corner or an 8×9 rectangle with the exit test. The difference with this question is that there was a lot more missing information that the student had to deduct using his or her skills.

The next shape, hence forth known as “C”, was again an 8×10 rectangle with a 5×7 cut-out on the right-hand side, making it look like a square shaped C, the exit test had a 14×20 rectangle. The purpose of this was again to increase the difficulty by adding in an extra segment when parsing this shape. There were also several unknown sides that the student had to figure out in order to solve the whole problem.

The following question, hence forth known as “O”, was 6×6 square with a 2×3 hole inside it or an 8×8 shape with a 3×4 hole in it. This one was more complex in the sense that the hole inside the square had no set position or any indication how far it was from the edges. It certainly does not matter, but the student may not be aware of that.

What followed next was a question that was though of being simpler in some ways, hence forth known as “grid L”. On a Cartesian plane with a grid, there was an 8×13 blue rectangle with an 4×8 section cut out and a 4×2 red rectangle inside the blue shape. They were to find the blue area and perimeter; no values were marked but it was on a grid which they can count. This question was omitted from the exit test as after administering the entrance test it was though to have been too easy of a question which would not be bringing significant value to the test itself.

Then followed the last question from the first part of the test, hence forth known as “Grid Podium”. Again, this question was on a Cartesian plane with a grid, the difference with this one is that the X and the Y axis go through near the center of the shape. This again was omitted from the second test for the same reasons as the previous question.

Next began the section on volume. First it asked again what is volume and how do you calculate it. Volume can be a new concept for some of these students and the purpose again

is to see how they understand it. Again, same as for area, this question could have been omitted for the second test as it does not really test anything much.

The first problem to calculate, hence forth known as “box”, was a $3 \times 5 \times 4$ box, or $4 \times 7 \times 5$ for the exit test. Here the purpose was to see if they can add a 3rd dimension to what they have been doing up until now.

The second polyhedron, hence forth known as “Staircase”, was a 2-step stair. It was a $3 \times 5 \times 4$ box with a $1 \times 2 \times 4$ section missing in the top right corner. Here all the values of all the sides were given, the purpose was to see if they can do a multi-step calculation involving volume.

Next we had 2 boxes, hence forth known as “Two blocks”, $4 \times 4 \times 3$ and $2 \times 3 \times 6$, up against each other. Here we just made the problem a little longer, all the student needed to do is to calculate the two separate shapes.

The exit test also included an additional shape, hence forth known as “Funky”, which was not present in the entrance test. This was a $8 \times 16 \times 5$ box with two different overlapping cuts. It looked like the children were progressing relatively well as they were progressing through the material and thus an additionally challenging question was added to the pool.

The last question, hence forth known as “Abstract”, was a little more abstract. The children have been using the coordinate system and there was curiosity if they would be able to figure it out. The question asks what is the smallest sized cuboid which includes points $(2,5,8)$ and $(7,6,10)$.

3.3.2 The maps

Each map is accompanied with a worksheet that the children work directly into. The worksheets are available in the appendix at the end of the thesis as well as images to several of the questions.

Area and perimeter

This is the first of two maps that the children will be working on. This should be partially a review for most children, at this point as they covered this material in the previous year.

Map

The map was created using Minecraft educational edition. The world started out as a flat 3 block high grass world without structures. A primary road was built along one of the major axes in the game going northwards. Facing north from the origin, on the left-hand side you had parts 1, 2, 3 and 4, all led by roads that branch off from the main one, while on the right-hand side you had parts A, B, C and D, which also branch off but towards the right. The numerical parts were focused on discovering and understanding the basic concepts, mostly the lower parts of Bloom's Taxonomy. The alphabetical parts were more about expanding the understanding on the material and focusing on the higher levels of Bloom's taxonomy, like analysing and creating.

Part 1 is divided into 5 sections, 1-1 through to 1-5. The first one being an area of 6x4, the second one 14x3 and the third one being 8x8. The first three were meant to be easy and any of the methods that they would have wanted to use at this point, let it be counting each individual block, mining it out and letting your inventory tell you, or multiplying width by height. The last two problems all of a sudden were made of gold blocks rather than silver, identifying it as something different. These were made of a much greater scale at 17x45 for 1-4 and 35x36 for 1-5. These last were purposefully made large, the students could use any of the methods used earlier, they would all work, but some methods would be quicker than others and it would be up to them to find the quickest method. The hopes are that they will eventually want to move on, so they will all find the quickest way.

Part 2 was similar to part 1 but had gold rectangles inside the iron rectangles. This ends up being a little more challenging as they need to differentiate two different colours. The principle was the same, start easy which can be all broken up if done via a manual route, but leave the last ones bigger where an alternate method will be needed to solve the problem. Part 3 was nearly identical to part 2, however, rather than have gold blocks and iron blocks, there were iron block and voids or cut-outs. Part 2 and 3 are from a higher perspective the same, rather than have gold blocks, there are empty spaces. Will the students see it the same way or will they approach each type of question differently? Part 4 is combining all the layers together, iron blocks, gold blocks and empty spaces. With this many layers, there are many different routes that the students can take in solving these problems.

Part A is divided up into three questions. The first one asks to take 48 blocks and to arrange them to make an area 4 blocks wide, asks for the dimensions and if other possibilities exist. The second question asks how many rectangular shapes can be made with 24 blocks and to list/create them all. The last question was the same but with 32 blocks and to compare it to the previous one. Here the purpose was to try and see the link between factors of a number and sides of a rectangle. The questions developed from the first to the second and third attempting to build on that factor similarity.

Part B Is also split into 3 questions. The first one starts off with a rectangle and you just double the lengths of the sides. Each question you double the lengths of the sides. The purpose of this question was to see the relationship between the increase of area to the increase in side lengths.

Part C begins by asking the student to create a pattern of their choice. Then they are to multiply one side by 3 and the other by 4. The third part asks how it would be if each side would be increased twentyfold. Here we are again exploring the relationship between area and the sides of its lengths, just in a little different way then the previous question.

Part D tries to relate to realistic problems. Here the students receive a certain amount of fence segments and they need to fence off an area which will also have stables and other things. The second question expands on it and the third question makes you use the river as a fourth fence, needing to make only 3 sides. Here the children try to see applications while also aiming to maximise area with a given length of sides.

Worksheet

The worksheet associated with this map was 5 pages long. It alternates going part 1, then A, then 2, then B and so on. The children were welcome to follow it in that order but did not need to. You may do all the numerical parts first and the alphabetical parts later if you wish. It is strongly recommended to do the numerical part before the alphabetical part, but not necessary. However, it is best not to skip ahead until a section has been done as the difficulty builds on itself.

Volume

This will be the second of two maps that the children will be working on.

Map

The map started as a copy of the area map before the questions were added in. It has the same road layout and similar question setup where the left side is more about discovering and learning about how to calculate volume while the right side is about expanding your view and understanding of how volume works.

Part 1 also starts off with the basics. 1-1 starts off with a $6 \times 4 \times 5$ cuboid, 1-2 is a $2 \times 4 \times 3$ cuboid, 1-3 is $2 \times 3 \times 30$. The next two were again made intentionally large so that the children opt against counting or breaking every individual one. 1-4 was $16 \times 16 \times 16$ and 1-5 was $25 \times 26 \times 50$. The first three were meant to be simple, again, the students could break these and get to a result relatively quickly, however, significantly slower than the questions involving area. The last two questions were meant to discourage students in trying to break all the blocks and find a different way about it.

Part 2 to 4 progressed similarly to part 1 that as the questions progressed, they became more challenging. This being done in 3 dimensions meant that using gold and iron blocks was not a possibility as they are not translucent. The decision was to keep the traditional base of iron blocks and then add in glass blocks. This way the students can see through the objects in certain places and see where the division line is between the two various materials. Part 2 has cuboids with only a single cut-out made of glass inside it. Part 3 increased the complexity with the amount of glass cut-outs in the iron blocks. Lastly, part 4 had multiple layers of cut-outs, all clearly visible, but the student had to be careful.

Part A-1 begins by asking how many cuboids can one make with a volume of 72. Each block in Minecraft measures $1 \times 1 \times 1$ m and thus they need to figure out how many cuboids can make that volume. A-2 doubles it and asks how many unique cuboids you can make with 144 blocks. Here again we look at the relationship between a volume and the lengths of its sides and how they make up some of the factors of the volume.

Part B, here the children try to see how much of a volume can be created with a finite amount of area. The children get 64 blocks and ask to hide the biggest box they can. The ground is

hidden; the children thus need to cover 5 sides of their shape. The second part increases the number from 64 to 128. The third part has the blocks it tries to hide suspended in the air, so you need to account for 6 sides rather than 5. Lastly the 4th part has it also suspended in the air, but used 128 blocks.

Part C tries to tie in real world applications a bit more. You start with the situation where you have limited amount of fencing and you need to try to fit everything inside, you also have several structures with a set volume which also need to fit. The students are free to be as creative as they want to be, the volume amounts were specifically chosen to be quite factorable. Different coloured blocks were made available for this exercise in order to make it much more visually pleasing and to allow the students to express themselves artistically if they choose to do so. The second question the students are asked to construct 3 sides of a simple building with a limited number of blocks. For the 3rd part of this section, the students were asked to calculate the amount of volume inside a building.

Part D was a single but very complex question which was meant to get the children to think a little more abstractly. The question was to try to find the smallest box which would fit inside 2 specific coordinate points. This was truly a challenging question meant to slow down the faster students as they stumble on this question and something that can be skipped by the students that are a little slower. It was a brain teaser that wasn't looking for a correct answer, but was curious about the approach that the student would take to try and solve the problem.

3.4 Results

3.4.1 Their evaluation

Any of the results or the students involved can be referenced to in the appendix sections of the thesis. The same holds true for tests and worksheets used.

Test questions with low relevance

The first area and perimeter question is one which with the exception of a single result was either done entirely correctly or left empty. This does not help us determine any relevant information from the children as there is no variance, it is either correct or not attempted.

The last question of the test, also known as “abstract”, is another question of nearly no relevance. Here we have a question which only a handful of attempts were even done and all of them were wrong, giving us little to no relevant information other than they have not reached this point yet. This question is similar to the last question on the students were working on during the practical part of the exercise.

The two grid questions are not very relevant either. They were put in originally to see various ways of calculating area, these two were put on a grid. These two questions were assumed too easy and were omitted in the second test. The tests were only corrected after the whole activity has been completed and it was shown that in fact this question was not as easy as it appeared. At that point it was realised how valuable of a comparison this could have been seeing as Minecraft itself is a block based game inside an invisible grid system. It is unfortunate as this question had quite the spread with only 33% and 47% of the perimeters were correct and only 13% and 40% of the areas were correct. This question also had many non-attempts, meaning the potential was everywhere.

Omitted children results

No children were omitted from the test results. It was considered to omit students that were not participating as it would skew the results. But as this paper is about motivation, this would not be a true representation, some people just do not wish to participate. One child was considered Student A4, this child wrote arbitrary numbers on some of the pages of the tests, and during the workshop he was mostly running around and either digging holes, planting trees or blowing up TNT. The decision was to keep this sample as the sample pool is already small and such behaviours are true motivational levels that teacher will come across.

Entrance and Exit test overall results

When ranking the children, answers were categorised as “OK”, “Almost”, “Wrong” and “Empty” in that order. “OK” meant that question was solved fully and correctly. “Almost” meant that the student did all the correct steps and should have gotten to the answer, but some arithmetical error occurred, or just perhaps forgot the very last step of adding the final values together. “Wrong” meant that the question was wrong and approached wrong. Things like calculating the net instead of the volume, using the wrong values, forgetting to calculate something or calculating additional things that were not present and many more. “Empty” simply means that the student left it empty.

From an overall view there is a clear sign of improvement. The amount of correct answers went up by 31% while the amount of unanswered questions went down by 33%. This is a clear indication that some of the children have learned and applied the material covered in the workshop while others have become confident enough with it in order to attempt the question. The amount of wrong answers has decreased by about 8%, not as significant of a change, but that is because it is a step in between. 47% of the children did manage to have at least one question which went from being empty to being completely correct, some went from being empty to being attempted and some went from being attempted to being correct.

Entrance and Exit Test individual questions Results

The first two questions were answered by almost everyone, 3 people didn't give an answer for how to calculate perimeter and 5 people did not give an answer on how to calculate area. The children used different ways to answer this, some explained how to do it by giving steps, others gave examples of how it is done and lastly, some children wrote some formula. The general consensus here was as student A9 states it: "add the sides". For the calculation of area, the students wrote the three different methods as well, giving directions and steps, by giving examples and lastly by giving some semblance of a formula. It was a surprising that nobody wrote that in order to calculate area you begin by drawing out a grid and then you count all the squares, as some children did use this strategy to calculate area.

Rectangle

The first question to be calculated was answered either correctly or skipped on outright on the entrance test. Three people decided to draw a grid inside the rectangle, however, one of them decided to fill it with a 6x12 grid, yet still calculated it correctly. For the exit test, there were no grids drawn and there were much less visible calculations written down. One child did get the answer wrong, but only by multiplying their answer by a factor of two at the end for an unknown reason. The same amount of people omitted this question on the exit test as on the entrance test, however, it was different people from the ones who omitted it on the entrance test.

Wide L

"Wide L" was the next question, the children had a much more varied response on the entrance test with 60% getting the perimeter correctly and 40% answering the area correctly. After the children finished the maps, this jumped up to a staggering 93% success on the perimeter and 67% of the area questions being correct. This is the first question where there is clear evidence of solid improvement. Three children continued to draw out grids and count the number of squares. Some of the errors from the entrance test were cutting the

shape correctly into two shapes to be calculated, but also calculating the perimeter of the cut shapes adding 2 newly created edges. Some children did not realise that there were hidden lengths that needed to be found, adding an incorrect amount of sides. Two of the children drawing grids in their shape either counted the amount of squares incorrectly or traced out and thus counted the wrong amount of squares. On the exit test, this question was completed very cleanly, people applied a cut, either rectangle and square or two rectangles, then calculated it using a minimal amount of steps, there was a clear path to the answer.

Thick L

The next question looks physically very similarly to the previous one, however, the results differ greatly. Considering perimeter questions, firstly, this is one of two questions where the result between the entrance and exit test went down. Second, compared to the previous question this one has one additional unknown side over the previous one, making it harder as there is one extra step. Yet there were a third more correct answers here on the entrance test compared to the preceding question. There is nothing that can clearly justify this result, it is believed that it could be just due to the variance possibilities of using a small sample group size. The results for the area portion of the question improved greatly, similarly to other questions, this one had an improvement rate of a 50% increase of correct answers. The errors committed on this question are exactly the same as the ones from “Wide L”. Both questions had a very similar shape and were all worked on the exact same way and thus probably why they all had the same errors.

“C”

This was without a doubt the hardest area question on the test. 40% and 47% results on the entrance test, the exit test was still an improvement, but only slightly, the smallest gains regarding any question going up to 47% and 53%. A main body and 2 differently sized appendages, this was approached from several ways. The majority of the children parsed the shape up into sections which they then calculated individually and added the results up together. One person continued with drawing out a grid inside the shape and adding up the

pieces. One last student instead used subtraction by calculating the size of the big rectangle, the size of the small one and then find the difference between them. Of course, there was a small group of children who did not actually leave any steps or hints of how they attempted the problem. The exit test results looked very similar to the entree tests, aside from there being just one better result, three children showed more steps and used the strategy of dividing and conquering.

“O”

This question was the second question where the correctness of perimeter results dropped from the entree test to the exit test. It was only a difference of a single person, but it was a decrease in performance. The area portion of this question was simpler but trickier than the previous example. Some students tried to add arbitrary lengths based on visual estimates to be able to parse the shape into smaller ones. Most realised that this can be solved relatively easily if you just subtract the hole from the shape. The number of correct answers from the first to the second test went up by 50%.

“Grid L” and “Grid Podium”

These two questions do not have anything for comparison, however, many observations were still taken. It was thought that having a grid would entice most to just count up the squares. While the amount of children that opted for that route went up 2.5 times compared to previous questions, the majority remained with the method of parsing up the shape and tackling each piece individually. Some children were calculating the perimeter counting the grids in a contour pattern, but doing the corners wrong. The Podium question was intentionally positioned so that the origin of the axes are inside the shape to see if the children would follow the axes or ignore them. For a few children these created permanent cuts which they integrated, causing them a lot more work as even more cuts were needed. These two questions had some really poor results, at most only a third of the answers were correct in either area or perimeter in both questions. Surprisingly again, the assumed harder question, “Podium“, was answered with much greater success than “Grid L“. It cannot be explained why the second question ended up being easier for the students.

“Box“

The first and simplest volume question wasn't even attempted by a fifth of the students the first time around and was answered correctly by only a third. The second pass through was much better with only a single person not attempting this question and nearly half (47%) managed to get it correctly. This is about as far as was expected from the children the first time around as this is content which they have not officially seen yet. Many different approaches were taken, one student kept trying to use a grid system and filled out the visible planes of the boxes. Several students tried calculating the net of the box as their attempt to calculate volume. The expectation was that the improvement here would be much greater on the second attempt, while it was there, it was not as great as expected.

“Staircase“

The expectation on the protruded L piece was that nearly nobody would get it the first time around. This was nearly correct with only 2 people managing to get a correct result. Nearly half did not even attempt the question as they had no idea how to do it. Of those that did, one tried to draw a grid on the shape and count the squares, the rest attempted to calculate the net of the shape. The exact method wasn't expected, but it was expected of them to not know how to approach these kind of questions. There was a 25% increase in attempts for the second round and a lot more effort was put into the question based on the scribbles and calculations associated with it.

“2 Blocks“

This question had the greatest amount of improvements among all questions. This is a question which was solved by cutting the shape into two simple blocks and then adding them up. The students that calculated it wrong did it by trying to calculate the net of the object instead. Only one had it correct the first time around and nearly 6 managed to find it correctly, 4 did while 2 had an arithmetical error along with the correct procedure. This question was much easier than originally intended.

“Abstract“

This was meant to be the true brain teaser of the test, to see if anyone may have really gone above and beyond in their understanding of volume in this short amount of time. This question resembled the last exercise of the workshop which was partially optional and

supposed to stall the students to allow the slower ones to catch up. The first time around there was not even a single attempt. The second time around, while nobody did manage to get it correct, a third of the pool decided that they can give it a try this time around. Their confidence in being able to attempt such a problem demonstrates that they feel like they have a sufficient understanding to proceed with it.

“Funky“

This question also has no comparison. This was added in the second test as a question which was supposed to be more complex than the previous volume questions aside from the abstract one. While there is no previous data, the fact that 7 out of the 15 attempted this last question speaks strongly about how the children perceive their own abilities. 2 of the students even managed to solve that last one correctly, an impressive feat.

Individual students' results

As the student's teacher, it was possible to know them based on their abilities outside of this study. One thing that was found was that the generally stronger students did relatively poorer than the weak students, this has happened to other researchers as well (Foerster, 2017; Ming, 2020). One could argue that there is more room for improvement for the weaker students and that is a valid argument, but only if both are growing, some of the usual strongest students have some negative advancement, they had a worse result on the exit test as opposed to the entrance test. Some of the weaker students had the most amount of improvements. One possible theory for that is that the more advanced students are bored and some of the easier questions aren't necessarily worth their time and effort. These questions went from being answered correctly in the entrance test and left completely alone in the exit tests. It would be hard to believe that the smartest students lost knowledge while the weaker ones gained some. It is believed that the results should be even higher than they currently are and that the true abilities of the students are even higher.

Another potential reason for this occurrence is that some of the children were competing with each other. As they all had worked at their own pace, some finished before others.

During the post exit test interview, we talked about how the second time around the test was tremendously easier than the first time. This then led to some students, Student A8 in particular, into competing by trying to outdo their peers in how fast they can then write the exit tests. This would have led to carelessness and poorer results as can be seen in the results. Student A8 was one of the faster and stronger students in the class, one of the days the student was ill one day and thus fell a little behind. The student managed to catch up but was not the first to write the exit tests. Later, that same student was found to be bragging about his time to other students.

Finally, the last reason for why one student, student B1, could have done poorly was because the parents of the child happen to be going through a separation. Emotional distress can throw around motivation as needs and priorities are re-evaluated and re-adjusted. It is not outside the realm of possibilities that the student decided that it has already shown its abilities on the entrance test and found it not necessary anymore to show it a second time. However, it could have been other reasons and perhaps, however unlikely, the student did lose knowledge in the process of completing the workshop.

Stronger students doing worse isn't a rule, on the contrary, Student A7 however did not have poorer results like the others, but instead excelled. As was expected of someone their age, they should know the basics of area but not quite the basics of volume yet. After the workshop the student wrote the exit test flawlessly aside from the last page which is left blank, perhaps missed. In fact, Student A7 is a representation of what was expected of the students pre and post activities, in reality, these are the ideal students.

The sample size of students did include 3 students that had a real aversion to work outside of this exercise. Student B5 demonstrated that they were clever and understood the material via the workshop, however they did not feel any urge or need to write the tests and scored with a negative result. The other two students showed signs of improvement, one of them tremendously. One of the students, student A4, regularly does not do any work at all, with this student it is a monumental step forward that questions were even attempted. The third student, B2, went from only answering only a few questions which were certainties and leaving out the rest. On the exit test the amount of correct answers did not improve, but

around twice as many questions were attempted which shows a great step in the forward direction.

The rest of the students all had steady gains, some a little more, some a little less, but in all, the results were positive. Not everyone managed to get everything correct, but there is a clear progression in the improvement of the students. Some went from not answering to answering, some went to from answering incorrectly to correctly. It is difficult to give exact figures as many students fit into several categories and there were many various degrees of improvement across the rest of the students. If broken down to averages, there was an improvement of approximately 1.9 questions per test.

Class Comparisons

Having had two groups participating with this activity meant that a variable could be introduced for comparative studies. For this to be executed correctly, both groups needed to be of relatively similar skill level. Since the skill level and the aptitude towards work of the two groups varied quite significantly, it was decided to use this as the variable for comparison among the two groups.

The activity took place during the last few weeks of school. The children shortly afterwards moved on from that school as the school only goes up to grade 5. This allowed the activity to remain hidden from the upcoming group. The only thing that group B had learned prior to doing the activity was that they will be doing something really enjoyable and it will involve Minecraft. When group B began this activity, they had little to no notion of it left because many Minecraft activities had taken place up until that point.

This being a very small sample size, even one compromised set of data points could overwhelmingly alter the results. There was a student from group B, student B1, which did not answer vast portions of the exit test including almost the entire second half. This student is generally one of the stronger students in the class, however, this student has been going through family problems. A decision was made to exclude the student for the comparison between the two classes as having this student would unfairly.

Immediately as expected, we notice that the second group, group B, is the weaker of the two groups. Group A is answering a lot more and correctly in the first half of the entrance test. Group B is leaving a lot of the answer blank in the first half of the entrance test, they seemed to have difficulties remembering how to calculate area. Over half the people did not even attempt the area questions and of those that did, none of them managed to get any of them correct.

The second half of the entrance test was relatively closer in results, however, group A still managed to have far greater results. Group A managed to answer some of the area question correctly, it appears that 3 of the students there have had some former experience with calculating area. Group B did not answer a single one correctly, however, a far greater relative amount of students went and attempted the area problems during this first time around.

Interestingly enough, group B seems a lot more confident and a lot more correct with the perimeter calculations of the entrance test, this is the only place where group B has marginally better results over group A. No explanation can be found to describe this phenomenon, but it is an interesting fact.

When we observe the exit tests we notice that both classes had a significant overall increase in correct answers. Group A's rate of correct answers went up 34% in the area and perimeter portion of the test. Group B went up by 52% for this same first portion of the exit test. One could argue that the reason why group B managed to have a higher rate of increase in skill is because group B had a much lower starting score and thus did in fact have a lot more room for improvement over group A. This comparison makes it difficult to say which group had a greater rate of improvement when both had different starting points.

Comparing the second half of the test, the area portion, we notice that Group A had increased the amount of correct answers by a massive 67%. This is a stark contrast to group B who remained stagnant and did not improve nor decline from the entrance to the exit test. Why did one group succeed this greatly while the other group did not progress at all. Group B was after all a weaker and less motivated group, but after the entrance has shown us, also had a different starting point. It could be that the students have not fully grasped area in order to comprehend volume.

It could also have been the student's lack of interest in writing these tests. This school does not have consequences for failing to do work and the exit test was no different. Perhaps both groups were motivated differently, the group A had students that were competing with each other, but also in general were very studious. Group B has students that were more interested in free time and playing outside. Looking at Self-Determination Theory, this would classify group B as amotivated to do work and group A has managed to reach the Introjected regulation stage. While the stages have been identified, the reasons behind them is still unknown.

Another observation has been made regarding the results, the ratio of correct to incorrect to empty answers that group B managed to attain in the first half of the test is very similar to the ratio of correct to incorrect to empty answers that group A managed to attain in the second half, the area portion of the entrance test. In other words, the results ratio group B produced in the first half of the test is similar to the results ratio group A produced in the second half. While we cannot compare the results directly because they are different questions, what we can do is compare their rate of improvement as both seem to have a similar starting point and potential left ahead. Now we are comparing group A growing the number of correct answers by 67% while group B grew by 52%, a much closer result.

Comparing individual questions there wasn't anything noticeable happening. All questions had a similar level of difficulty across both classes. Other than the calculation of perimeters on the entrance test, all questions were treated similarly. What was difficult for one group was difficult for the other and the same applies to easier questions.

3.4.2 Exercise Results

The exercises were not given any particular grading system, here we will be evaluating how they worked, their strategies, how they perceived this whole activity and how it all happened.

The Procedure

Group A began the main activity with some technical difficulties. The students were writing the entrance test and were to get a tablet with Minecraft one at a time as they finish the test. The tablets went through an auto update some moments time prior to the activity and were thus not synchronised with the current version of Minecraft. Each tablet had to be fixed individually. As each student finished their entrance test, they waited in line for a tablet to become fixed. When a tablet was fixed, the next student received it. Students could have opted to have waited for instructions and explanations but instead decided to go explore and figure things out on their own. Every student was eager to start and see what awaited them. When the last student was ready to begin, even that student had decided to just begin rather than potentially have a simpler time. At that point explanations were offered to everyone at once and there was no interest, everyone was very focused on the map and solving the exercise sheet.

The fastest student to finish the area and perimeter map finished it somewhere around the hour and 45 minutes mark. Most students finished that maps somewhere between two and a half hours, some of the stragglers took up to three hours, but quickly caught up once they saw that everyone was finishing. There were two girls that were not progressing very much and doing other non educational activities. They were asked to skip ahead to make sure that the volume section is covered. Of the two girls, one of them is one of the brighter children in the class, now known as student A1, and the other is one of the least, now known as student A6. Student A1 was asked to work on the right side of the map, where there are examples higher up on bloom's taxonomy, this student has earlier shown that they already understood how to calculate volume. Student A6 was asked to do the opposite and work on the left side of the map where the student is meant to discover how to calculate the volume of a shape, this student was one of the slower in the class and needed to build a solid foundation.

Shortly after beginning the map student A6 comes up and the following conversation follows:

Student A6: I don't know how to do this.

Teacher: Well how did you end up calculating area in the previous map? Let's say something like this? (*a 4 by 6 rectangle is drawn on a grid*)

Student A6: You multiply 4 by 6

Teacher: Ok, why?

Student A6: Because there are 4 here and 6 there

Teacher: So how is this problem any different?

Student A6: This one also goes up

Teacher: How far does it go up?

Student A6: It goes up 5 floors

Teacher: Is each floor the same?

Student A6: Yes.

Teacher: What else do you think we could perhaps do?

Student A6: Never mind, bye! (*The student then runs off to continue to do work*)

Student A6 became the student who had the greatest gains among any student. This student went from almost leaving it all blank, answering only about a third of the questions to getting it almost all correct on the exit test.

The volume map was completed a little quicker than the area map. Given the option, many children did opt to take the slow and lazy way and mine the cuboids out in the first map. However, as they progressed, many have quickly realised that it takes a lot less time to solve a simple equation than it is to dig out a large area and carried that newly gained knowledge over to the volume map, thus solving it relatively faster.

The finish times for the second map were scattered around a lot more. The first students were permitted to read books once they finished. It was meant to be a relaxing activity, but

not one that could provide outside influence to the results by enticing the students to try and finish the entire activity faster, this seems to have worked. Some students did however compete amongst themselves to see how fast the exit test can be written and thus probably did not give their best result as they were focusing more on time than on correctness.

Group B did not have any technical difficulties at the start, however to keep the scenario the same, a similar amount of instructions was given to group B as to group A. Due to logistics and timing differences, the children did not begin exploring the map immediately after finishing the entrance test. This resulted the entire class starting the first map at the same time, all other starting conditions were kept as similar as the other group as possible.

Group B was also doing the exercises during much nicer weather and decided to work outside during parts of the time. This minor setting difference could potentially have large consequences. While this was individual work, when in closer proximity to each other such as was the case of group A, children will randomly at time mingle with each other and often the topic of conversation is the work itself. This is Vygotsky's zone of closest proximity in action where the children help each other advance as they discover and share these discoveries among themselves. Group B being outside did not have the same amount of opportunities to mingle, breaks and snacks did occur, but those topic change during those times.

Both groups took very similar amounts of time to complete their work. The entrance test took between 30-60 min; nobody was outside of that range. The exit tests were much faster and all exit tests were completed in the 10-25-minute range. The perimeter and area portion map and associated activities took longer ranging from just under 2 hours to just under 4 hours, the volume section took around 90 min for the fastest person and everyone was completely finished within the 150-minute mark.

Work on the maps

When the students were given the maps, the default setting was set to survival mode, this was to enable several of the functions the game has to offer, such as breaking and picking

up blocks. This however turns off other functions that the game would have such as freedom of movement in any direction without being pulled by gravity, also known as flying or floating.

Most, if not all students did modify their setting to toggle these options, then they returned the tablets. It has been noticed that these options were used, but not uniformly, the area maps tended to remain in survival while the volume map switched predominantly over to creative more. Volume question do need a 3rd dimension, while an entire plane can be seen from a larger range of angles, a 3-dimensional object does have height and visualisation is immensely enhanced with the ability to fly around. Many children still used scaffolding, an in game tool used for creating temporary climbing locations, traces of them can be seen across their maps. Basically they switched between modes as they needed or best saw fit. In the end, only 2 tablets were found to be in survival mode after the students returned them.

Beginning on the left side of the area and perimeter map, some children did begin by digging out the entire area and counting how many blocks ended up in their inventory. This did not last long for most people. Many children did use a strategy of breaking a single row to have the length of a side be exact and not take any chances in miscounting. Interestingly, one child was found to cover the areas as a method for counting, using subtraction. The strategies that the children used were repeated throughout the maps, most students would mostly not switch between strategies as they progress forward. The volume map showed the near exact amount of variety as the area maps with the exception of the addition of scaffolding.

The right side of the map was where the students started to diverge one from another with their answers. Part A of the first map was pretty similar across the board, some students did not list all the examples, but other than that, no real variance can be found.

Part B and part C was about finding the relationship between perimeter and area growth with B being symmetrical and C was not. Some students did catch on to that concept almost immediately, most did manage to find solutions for part B. Part C was a little more complicated as the directions could have been a little clearer. Part C added a small new element, the students needed to come up with their own pattern which they were to copy over afterwards. This seems to have caused some confusion, some did not know how to replicate their pattern, one replicated a row and a column but did not fill in the box, there

were several interpretations to the question. The last question was one which forced the student to find a different way to get to a solution, rather than building it when it could be calculated. Nearly half the students left that question blank.

Part D was enjoyed by the students quite a bit, it allowed them to be creative while solving their problem. The goal here was to have them maximise areas with set perimeters. While not all areas were optimally created, everyone managed to create areas that were sufficiently large enough in order to fit all the requirements.

The volume map's right side results began the same as the area and perimeter map. Part A was answered by most students quite consistently, several decided to leave out all the possibilities, but all answered something and all of them correctly. Part B was a huge jump in complexity, the students were asked to attempt finding the largest volume a certain net can create. Only some of them understood it enough to answer this question correctly. Part C was again much more relaxing as they had to construct a ranch. Most students just built it to make it fit, none of the students were trying to optimise the amount of space that could be gained with a specific perimeter.

Very interestingly, a fair portion of the students, over half of the students, decided to spend some time in a leisurely way inside the map itself. Over half of the students have left some form of additional structure or a piece of self expressed art or even just planted some trees or bred some animals. Fast, slow, hard working or not, nearly every student left some form of personalisation on the maps they were working on.

Children's perception

The children were very eager and curious to try a game that was going to help them learn principles of geometry. One of the true differences between the two groups was that the first group was much more eager than the previous one, the first group started with Minecraft recently while the second group has gotten used to using Minecraft as part of their learning tools. In both cases the result was the same, none of the students could wait to start and as soon as they received a tablet their awareness of their immediate surrounding dropped

significantly and they were on their own exploring the world that was created for them. Their focus was solely on the environment that they had complete control over. All but 2 tablets demonstrated that the students have opted to turn off survival mode and put it into creative, allowing them the ability to float and move around in 3 dimensions giving a real time changing perspectives of what they were currently working on. Everyone worked at their own pace, some explored ahead and then came back. Some decided to leave the subject expanding questions for the end as opposed to throughout.

The response was unanimously positive. The least active children went from not doing anything in class to doing some exercises in Minecraft. The children have managed to become so immersed that they forgot about taking breaks when it was time to have breaks, these students are very often impatient and do not forget about breaks very often. The children were feeling very confident about the exit test and about their ability to calculate volume after finishing the two maps. Several times the children have asked why we do not do activities like that more often, reaffirming that this is a very strongly positively viewed activity by all.

3.5 Discussion

In this thesis we asked ourselves the following questions. Can these children figure out how to calculate the volume of cuboids on their own using specifically tailored Minecraft exercises? Will a few hours of exposure give them the confidence they need in order to start solving such problems on their own? After having observed two separate groups of fifth grade students complete these exercises and their coupled assessments, it is with confidence that we can say yes.

Looking at the results alone, we can see that there is improvement and this method and tool does provide a benefit in the classroom. Not every one of the fifteen children participating in this study did come out with a terrific result, but if we take out the extremities on both ends or even just do a simple average, then we see a clear positive trend. While a small sample size was used to carry out this study, this only lessens the accuracy as the response was overwhelmingly positive.

From the moment that the study was announced to the children there was general excitement towards it. Some students were excited to play one of their favorite games in a classroom setting, others were curious what it would all be about; nobody was disappointed. This excitement was reaffirmed when the children decided not to wait around and do nothing when a technical problem arose, a common thing among them, but went directly to solving the exercises. The students were immersed such that they did not notice when breaks or lunch came along, some needed to be told repeatedly, more evidence that they were deeply in, absorbing the course material.

One could question how well the material was absorbed. They definitely felt more confident after the exercises, their confidence did not however reflect their success level. They were solving the exercises correctly on the greater parts of the maps, but did not do as well on the assessment which followed the activity. This would lead to think that perhaps the grid like structures of Minecraft may have still been needed for the students to imagine it correctly. This could explain why some were trying to draw out a grid like structure when trying to solve the questions. It is after all being discovered independently and earlier than normal.

Group A advanced a lot more than Group B, that is an obvious and clear result we can see. Was it because group A had a better starting point or was it for different reasons such as the fact that group A had more opportunities to mingle while group B did not have as many? This was intended as individual work, but this classroom had less room per student and was more prone to socialise. This brings us a second variable to consider. However, if we look inside each group, we notice that trends do emerge. The worst students tended to improve the most and the best students were skipping some of the easy questions, an emerging trend with other research (Foerster, 2017; Ming, 2020).

To what extent can using video games in a school setting help improve the school's efficiency? Technology's task is to make our lives easier and better. Each government is working on their own strategy on how to implement technology into their current curriculum. If we use an example such as this study, we could intergrade technology into the school system as opposed to the current strategy of adding it to the system. Increasing one's digital literacy and becoming a digital citizen does not need to be done separately but can be done alongside other things. Not only did the children learn to navigate their digital environment, but did so with enthusiasm and while independently discovering how to calculate volume of cuboids.

3.5.1 Future suggestions

While individuals are all different, people are all similar in many ways. Each little factor can possibly influence the results in some particular way. The more we know about what each individual factor does, the more we can stack these factors to see not only their dependencies but also how they affect the overall result. Along with finding as many details, there are also methods and processes that can modify the results or give us the information we are looking for. Here is a non-exhaustive list of different ways that the study can be performed or extended.

Feedback forms would be a huge benefit to the research. Understanding what the students are feeling or how they feel about the activity gives us a concrete answer as opposed to

assumptions based on observation and random interactions that occur. Feedback forms can be specifically tailored to specific details and gives us that many more perspectives. This can be directly built into the test and worksheet itself having the student answer the questions but immediately inform us on how they felt about it. This could also have the student's stress level decreased as talking about feeling is usually done in casual environments and not in testing ones. More studies will have to be carried out in this area.

The activity was executed using an ipad. Minecraft is offered across many versions but also across many platforms. The price of admission that various platforms demand differs from one to another. This learning time affects the degree of freedom that the student may experience and as a result could affect the student's competence within the game itself netting a potentially greater or lesser amount of total motivation and thus have different learning and absorption capabilities. A different platform also allows mobility flexibility, a tablet is a lot more mobile and can allow the student to be located where they want and feel most comfortable, additionally they offer more accessibility as they are mobile devices and not a fixed terminal, this can affect their ability to get and give help as a tablet are a lot more flexible. There can be physiological differences based on how the student is sitting at a computer compared to being in a more natural position with the use of a tablet, yet another variable that can change the outcome of our learning abilities.

Having a larger sample size will give much more precise and detailed results. With a small sample size abnormalities are a lot more prominent. With greater participation you get more robust and quantifiable results that would permit more decision making at the directional level of the educational system leading to a potential reform and overhaul of how we learn. If children can absorb things sooner, then more material can be absorbed leading to a more knowledgeable society that has the potential to accelerate its own progression even more. The current sample of data has given us an insight on the fact that it works, but with more data, we can quantify this in order to be able to justify the changes being made and their cost effectiveness.

Having some restrictions can be interesting to observe. The idea was to give as much autonomy as possible, but this can be detrimental to less motivated students and those that do not have any motivation to start with. Without the will to start on their own, having too

much autonomy can overwhelm the student and make them feel even more lost than they were before. Restrictions do not necessarily need to be interpreted as forms of control but more like opportunities to grow creativity. The student is still very free to do things on their own, only with a different set of rules.

Doing the activities at different times in the day could also lead to varied results. Energy levels go up and down during the day and are also affected by how we eat and absorb energy. Perhaps the motivation gained using a tool such as Minecraft could compensate for the loss of productivity that is caused by shifting energy levels. Perhaps performance may not be affected as much and will have much smaller differentials in productivity levels. This could lead to a more efficient structuring of the lesson plan or how daily structures look like across subjects.

A different approach could also be to use timed intervals for the activity. The current setup ran the activity back to back on a daily basis and completed from start to finish during the course of a week. Having the children have periods of time between the sessions could perhaps have a higher absorption rate compared to the current method. Or perhaps it was their thirst to continue on with the activity day after day which was a motivational factor allowing a higher absorption rate. Some things may seem obvious, but they do not need to behave that way.

Boys and girls are different, while not an absolute, each group seems to have different preferences. Boys tend to migrate towards violent games while girls steer towards social games. Seeing how Minecraft affects boys compared to girls and how their performance is related to that is intriguing and potentially an important question. While there were both boys and girls in this study, it comes down to the problem of sample size. In order to establish a very high confidence interval to establish the use of Minecraft to teach geometric principles, a higher sample size would be needed.

Viewing how this set of activities would work on students from different cultures could be very beneficial. Each culture is unique in its way, in how they express themselves or how they approach things. Some cultures are pre-dispositioned to be very sure of themselves, some to be very humble, some to be more aggressive, some to be very dedicated to their work. Each of those factors has a chance to impact the learning process of the student in

question. Knowing how each of those pre-dispositions influence the whole process would allow us to compensate for them in order to optimise everyone's material absorption and overall experience.

The tests were designed such that the questions increased in difficulty as they progressed along. Perhaps the children observed that the test questions were getting sequentially more difficult and as soon as they got stuck, if the questions would be in a random order, then perhaps the students would consider each question on a deeper level.

Some research has been done regarding how new pre-teachers would perform using Minecraft. (Meany & Pajic 2018) More research in that area is in a definite need of expansion, but also how long it would take teachers to learn to create such maps. One of the bigger reasons as to why games are not used as much in the classroom is because teachers do not have the necessary skills to make it happen. With a programming background and years of experience using Minecraft it took approximately 12 hours to create two very simple and non-glamorous looking maps. A look into the feasibility and cost to create, the amount of time involved to create modules and the amount of time that is needed to reach a proficient level of skill to become a module creator.

The current activity was regulated, the children were observed as they completed the activity, but how would it have been different if it were unregulated? Observation is a form of control which lowers intrinsic motivation. Since the children were discovering the concepts completely on their own, it would be possible to see how they would manage differently if they had received it as homework, where they would do it completely on their own at their leisure, potentially bragging to their friends about their cool homework, would they continue to explore it further even once they would finish their required task or would they completely forget and just like any other homework would not get finished? These are all interesting areas to explore to try to maximise autonomy even more.

One thing that would have been much more appreciated if done differently is if there would have been more order and consistency. It was originally intended to give the children some instructions as they received the tablets. Due to technical difficulties, an auto-update the night prior, each tablet had to be fixed which caused a queue. Due to the activity having started, along with the children's eagerness to begin, coupled with the fact that it supports

the Self-Determination theory in giving more autonomy, it was decided to allow them to begin and not force them to wait if they chose not to. The second group was going to be a control group for a chaotic versus a non-chaotic start, but the skill level discrepancy was too great that it was chosen to instead compare differing skill levels. It would be interesting to see if having a chaotic start is actually a benefit or a detriment, it could be a benefit for active students and a detriment for passive students.

The entire process was an individual activity. How would the learning process go if the activities were done in small groups such as in pairs? Relatedness is the third need that is satisfied in order to maintain intrinsic motivation. By working together not only is there a stronger satisfaction for relatedness, but you also apply Vygotsky's zone of closest proximity on an additional level. There could be comparisons for various group sizes, find ways where teamwork would not just be necessary, but also required. Theoretically reaching even higher levels of competence, relatedness and even autonomy.

It would be intriguing to see if motivation would go up even more if this activity was gamified. Gamification is taking principles of gaming and applying them to other activities. What would happen if we applied the principles of gaming as a layer on top of the game itself? There could be custom achievements that others can see when you complete a section, there is nothing that prevents from one map having duplicated sections, or even instances of them and allowing more participants at once each doing their thing. This would connect students even more, again raising the relatedness need satisfaction.

Perhaps there are better games to be used for this or worse, but better at a particular task. Games like Lego World are massively influenced by and try to imitate Minecraft in many ways. Lego can be more relatable because many of us have experienced it as children, but it is uncertain if Lego World has actual cubes. Would this game work better or worse? Perhaps trying a game like Eco, a game that is also being tested with as a teaching tool, a continuation and expansion of the ideas that Minecraft was built upon. Can this help us become all that much more interested in learning new things? (Avard, 2022)

A different default setup can be used. There were no general instructions mentioned as the students opted directly for self exploration as opposed to waiting for instructions. While there were instructions written on an in-game blackboard, some may ignore it. This would

mean that unless it would have crossed their mind, less options would have been at their disposal. Would this quality of life option make a difference in the overall opportunity that a student has in this learning module?

Other than motivation, what specific benefits are gained via Minecraft. Studies have worked on categorising games genres and their specific benefits. However, just like vegetables are generally good to eat, each one will have different benefits to itself. The same would apply to video games, some games cross over multiple genres and then they can also be used in a variety of different ways. It would be very useful to be able to quantify the benefits in order to be able to use this information better in future policy decision making.

It would be interesting to compare the absorption rate between using Minecraft and some form of physical cubes which snap together. One would be an environment which they can touch and feel while the other is seen and experienced. Minecraft being digital has more options as to how to approach the problem, physical ones have less of them, but by physically manipulating the blocks, it creates different connections as opposed to visual only. Both of them are tools, but one of the two is a game, the other is just a bunch of blocks attached together. Both have advantages, but which of them is predominant and what relation do they have together?

This study was to see how it would work with geometry. Being a cube game, it seems like mathematical topics can be relatively successfully taught using Minecraft. Minecraft Educational edition does have built-in programming capabilities as well as built-in chemistry crafting aspects. Minecraft is a sandbox game, the creative options are near endless, but how well would they work with other subjects, like languages, history and other arts and sciences. Microsoft creates and publishes free modules to be used with Minecraft Educational edition, how effective are they and can they be optimised?

While the tests did supply us with information which was then processed and allowed us to get information. Having a longer and more detailed test would have given us a lot more insight into how well they were advancing. There could be several maps or tiers within the maps. The students can begin at different points based on how well they perform on the entrance test. Then additionally the students can begin at different parts of the exit test based on the knowledge they have previously learned. This way of dividing the children based on

tiers would allow them all to progress based on their own pace, more importantly, to make sure that they students who managed to catch on quickly do not get bored due to the lack of a challenge.

All of these are different ways that this experiment and study can be modified. Some of these changes are small, some of these are enormous. Every little change will affect the system in some way or another. The more information we know, the better decisions we can make regarding the use of Minecraft and how to best apply it in the classroom setting. This list is by no means exhaustive and will only grow as more studies are made and our eyes are opened to the potential wonders of Minecraft in the classroom setting.

4 Conclusion

This study shows that children not only have the capability to learn material sooner than the current curriculum, but that they can also discover these concepts on their own using specifically tailored Minecraft maps. This study also shows that after only a few hours of self exploration with the concept of area will give students the confidence necessary to go from ignoring it to attempting it. The response from the students was overwhelmingly positive, none realised the lesson was over when it was. Minecraft really captured their attention and helped them not just focus but also remain interested and engaged far beyond regular engagement levels. The goal to see the viability of using Minecraft in the classroom setting has been met.

This study was completed with a relatively small sample size of 15 children. This amount is far too small to make a generalisation of any kind. However, this does demonstrate a proof of concept and further research would be needed to get quantifiable results. Geometry has shown to work, other beginner or intermediate mathematical concepts could also work, but how well? What about advanced mathematics? Can you teach non-cubic geometry using Minecraft? How about calculus? Minecraft does possess a coordinate system; how effective would it be to teach vectors? Chemistry and programming are included inside Minecraft, but how about other subjects? Many more studies will need to be made and in many dimensions. The more data that is gathered, the more we can map it out in order to find trends. Eventually sufficient data can be gathered to start making policy changes.

With the higher demand of digital literature that the European parliament is requiring, more material needs to be taught in the same amount of time. This study shows that Minecraft not only can cover teaching mathematics but has the chance to also double up as a computer class all while keeping the students highly engaged and motivated to continue. This would not only alleviate overall stress, but also make education more efficient all while keeping it very enjoyable for everyone.

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7 List of appendices

Appendix A: Tables of results from the entrance and exit tests

Appendix B: Tests used

Appendix C: Worksheets Used

Appendix D: Images of the individual questions from the maps

Appendix E: Examples of calculations