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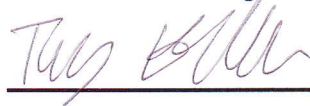
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**Abstract:**

The aim of this project has been to develop an early prototype of a system which teaches players the mathematical subject of algebra within the context of an emergent narrative to create continuation desire.

To develop this early prototype, research was conducted on the concepts of the mathematical subject algebra, transmediation, emergent narrative in interactive storytelling and virtual environments, and narrative elements such as Author-Audience Distance, Abstract-Didascallic Continuum, Intellegibility and Closure and Goal of the System.

After the implementation this early prototype was tested for continuation desire and possible improvements in the participants' skills of algebra. The results of this test show indications of both improvements in the participants' skills of algebra, but also that a high number of participants enjoyed playing the prototype and both had the desire to continue playing and to play the prototype again. The test, however, shows that the prototype still needs work to make users keep playing, and there is room for both technical and usability improvements.

# Transmediating the Mathematical Subject of Algebra



"Just a darn minute — yesterday  
you said that X equals two!"

AUTHOR:  
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MEDIALOGY  
GAMES  
MASTER THESIS, 2015/2016

# Contents

1	Introduction .....	3
2	Background .....	4
2.1	Algebra .....	4
2.2	Mathematics and Narratives .....	5
2.3	Narrative as a Tool .....	6
2.4	Transmedia .....	7
2.5	The Narrative Paradox .....	7
2.6	Combinatorial explosion .....	8
2.7	Emergent Narrative.....	9
2.8	State of the art .....	10
2.9	Narratives in Interactive Digital Media .....	14
2.10	Requirements.....	18
3	Design.....	19
3.1	Game Design .....	20
3.2	Narrative Design .....	20
3.3	World Design.....	21
3.4	Equation Design .....	22
3.5	Scripting Design.....	24
4	Implementation .....	26
4.1	World assets.....	26
4.2	Narrative .....	28
4.3	Unity Setup and Scripts.....	29
5	Method .....	41
5.1	Participant.....	41
5.2	Equipment.....	42
5.3	Approach.....	42
6	Experiment.....	43
6.1	The Engagement Sample Questionnaire .....	43
6.2	Mathematical Questionnaire .....	46
7	Results.....	47

7.1	Mathematical test results .....	47
7.2	The Engagement Sample Questionnaire .....	51
7.3	Errors and Improvements .....	55
8	Discussion.....	56
8.1	Equation system.....	56
8.2	World generation .....	56
8.3	Narrative .....	57
8.4	Experiment.....	57
8.5	Results.....	58
9	Conclusion.....	59
10	Future works .....	60
11	References .....	61
12	APPENDIX A – Pictures used for the prototype .....	64
13	APPENDIX B – Messages from CSV file .....	68
14	APPENDIX C – Equations from CSV file .....	69
15	APPENDIX D – Mathematical test results .....	70
16	APPENDIX E – Continuation Desire scatter plots .....	72
17	APPENDIX F – Google Form Questionnaire.....	74
18	APPENDIX G – Data on DVD .....	78

# 1 Introduction

It is common knowledge that many people find mathematics a challenging subject to learn and understand. That this is more than just an assumption but also an actual fact is confirmed by the guidance document for mathematics teachers in Danish high schools (Ministeriet for børn, undervisning og ligestilling, 2010a; Ministeriet for børn, undervisning og ligestilling, 2010b; Ministeriet for børn, undervisning og ligestilling, 2010c), which states that students beginning their high school education often come from very different backgrounds and with different levels of competency in mathematics and especially in the subject of algebra. There are many approaches to learning and teaching, and one of the more recent concepts is the learning through interactive applications. In this connection, many games have been developed that let the audience play their way through a particular subject, and by doing so teach the player a subject through the game and the narratives. Inspired by these kinds of games, the aim of this paper has therefore been to develop an early prototype with elements of algebra embedded within a narrative with the purpose of teaching students and others about the subject of algebra. Rather than having teaching as a main goal for the prototype, the goal has been to develop a prototype which people would feel the desire to play and continue playing. Then while playing the prototype, audience would learn elements from the subject of algebra. One way to achieve engagement is through emergent narratives, which was first introduced and discussed as a concept by Ruth Aylett in 1999 (Aylett, R., 1999). These considerations have led to the following problem statement:

“How can an early prototype be developed whose purpose is to facilitate the learning of the mathematical subject of algebra, and which is based on the theories of transmediation and emergent narrative in order to create a continuation desire?”

The first chapter presents the background research on which this paper is based. Important concepts such as transmediation, narrative elements and emergent narrative are treated in this section. Furthermore, this chapter also provides a brief outline of the subject of algebra and elaborates on the problems faced by students when trying to learn this subject.

As mentioned, this research forms the basis on which an early prototype should be implemented. The prototype should include a narrative which is designed according to the elements of transmediation and emergent narrative. The actual design and the implementation is presented in chapters 3 and 4.

To see if the implementation met the requirement of continuation desire and led to learning, a test was designed and conducted among 20 participants. The design, experiment and test results are presented in chapters 5, 6 and 7. The test showed indications of improved skills among some of the participants in the field of algebra. The test also indicated that a significant number of the participants felt a desire to continue the game experience during the game and also felt a desire to play the game again.

## 2 Background

To achieve an understanding of the subject of algebra, mathematical learning and learning through narratives, research on these subjects was conducted. In the process of researching narratives, the subject of emergent narrative was discovered and researched as well. The purpose of this research is then to understand and develop the necessary components needed for the interactive application. This background section will discuss the subject of algebra, how narratives are used as a tool for learning, and the general elements of narrative in digital culture. This results in a list of essential elements required for an emergent narrative and useful elements for creating a narrative.

### 2.1 Algebra

Algebra is the solving of equations with variables. The variables or letters, symbolize numbers and work as a placeholder for a number as it is possible to insert a number instead of the letter. Therefore, the rules of operations that normally apply to numbers can also be applied to the variables (Beck, 2009).

An example of an algebraic equation is as follows:

$$3x + 5 = 13$$

**FIGURE 1 - EXAMPLE FROM GYLDENDALS GYMNASIEMATEMATIK, ARBEJDSBOG B1**

In Denmark, basic algebra is taught in elementary school (in Danish: folkeskole) at grade 4-6. The teaching of the subject might start out at a lower level than the example shown in the figure above, but the students are still supposed to get a basic understanding of the idea behind algebra (Ministeriet for børn, undervisning og ligestilling 2015).

Although students are taught algebra in elementary schools, problems in this area have been recorded later on in the educational system, among students who decide to continue their education to the level of high school (in Danish: Gymnasium). At this level of education, students are expected to know basic algebra and even a bit more advanced algebra, but this is not the case with all students. The level of algebra, which students know at this point, can vary from student to student. This is explained in the guidance document for mathematics teachers in Danish high schools on C, B and A levels<sup>1</sup> (Ministeriet for børn, undervisning og ligestilling, 2010a; Ministeriet for børn, undervisning og ligestilling, 2010b; Ministeriet for børn, undervisning og ligestilling, 2010c). In the guidance paper, it states:

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<sup>1</sup> In the Danish high school system, mathematics is taught on three different levels with the C level being the lowest level and the A level being the highest.

*“The students in any given class will often have very different degrees of knowledge and skill; some students master the art of algebraic manipulation and equation solving, others have significant number of “blanks”, and some may even have got the impression early on in their school careers that they cannot learn mathematics. Such a heterogeneous group cannot be homogenized with a ‘brush-up-course’ in the beginning of 1.g. (red. the beginning of high school)”*

(Own translation of: Ministeriet for børn, undervisning og ligestilling, 2010a; Ministeriet for børn, undervisning og ligestilling, 2010b; Ministeriet for børn, undervisning og ligestilling, 2010c)

What this quote establishes is that even though students should by this stage of their school education have learned the topic of basic algebra at elementary school (in Danish: folkeskolen), many students still have “holes” in their knowledge about the subject. The guidance document concludes that a “brush-up-course” in the beginning of high school is not sufficient to get every student on the same level.

When looking in the textbook “Gyldendals Gymnasiematematik: Grundbog B1”, which is used to teach both C and B levels of mathematics in high schools (red. the beginning level of mathematical classes), there is no section teaching about algebra. This indicates that it is assumed by the book that the students already understand algebra at this point in their education. It is only if we look in the work book “Gyldendals Gymnasiematematik: Arbejdsbog B1”, which is used together with the previously mentioned “Gyldendals Gymnasiematematik: Grundbog B1”, that we see a small section which shows the different operations used in algebra, and this is even on a more advanced level.

It therefore seems like there is a conflict between what is expected of the students when they start in high school and the skills that students actually possess when leaving elementary school. This problem will then follow the students if they should choose to continue their education at university level studying a subject where algebraic skills are required. One of the reasons that students are having difficulties understanding algebra could be the abstract nature of the field since students have to work with letters instead of numbers, and it also seems like students struggle to see how algebra may be translated into something they can use.

A solution to teaching something which seems abstract could be to explain the subject using narratives, which will be further explored in the next subsections.

## 2.2 Mathematics and Narratives

The idea of using narratives in combination with mathematics is not a new idea and has been carried out in many variations and many media. Many of us have already experienced how a mathematical problem like  $2 + 2$  could be translated into a story by the teacher, telling us how many apples Peter would have if he already had two apples, and his friend John then gave him two more. An example of a more elaborate narrative is seen in the book “The Curious Incident of the Dog in the Night-Time” (2003) by Mark Haddon, which is about a 15-year-old autistic boy, who uses mathematics as a tool to understand the world around

him (Haddon, 2004). It is possible to understand and read the book without having a higher level of mathematical knowledge, but if the reader possesses an understanding of the mathematics in the book, it could help the reader to achieve a better understanding of the 15-year-old boy and understand the character on a deeper level.

Another book dealing with mathematics and narratives is “Lewis Carroll in Numberland”. The author Robin Wilson, who is a Professor of pure mathematics at the Open University in London, describes the mathematical side of Lewis Carroll’s life, and how his famous book “Alice in Wonderland” is filled with mathematical themes (Wilson, 2009).

When computers started to be affordable for schools, mathematical games were also introduced to students. Most of these games have mostly focused on the mathematical aspect, and the narratives included in these games were often similar to the earlier described apple metaphor. As games have become more popular, so has the amount of mathematical games with small stories. One of these games is called “Dragon Box”, which teaches the subject of algebra on different levels. This game will be described in greater details in the state of the art section as it is used as an inspiration for the prototype developed in this paper.

## 2.3 Narrative as a Tool

Narratives can be a powerful tool for teaching and learning and have been used for this purpose on many occasions. First-person victim, Ære på spil, FearNot!, Valiant Hearts, Never Alone and Ayiti: The Cost of Life are just a few examples of this. One of the reasons why narratives are a good teaching and learning tool is that they employ the strategies our brains already use for learning according to Szurmak and Thuna, which they write in their paper from 2013 (Szurmak and Thuna, 2013). Our brains will always try to find structure and sense in everything, which Bruner writes about in his book, “Act of Meaning”:

*“People do not deal with the world event by event or with text sentence by sentence. They frame events and sentences in larger structures.”*

*(Bruner, 1990)*

This could be applied to stories as well. We do not deal with a story event by event, but rather as larger structure.

In the article by Szurmak and Thuna, they state the following three elements of narratives in teaching as being particularly resonant (Szurmak and Thuna, 2013):

1. Narratives make something abstract more concrete/immediate.
2. Narratives contextualize information by creating a framework for students into which they may place new knowledge (and it thus improves their retention and understanding).



3. Narratives allow students to have more immediate emotional experiences that they can relate to (and therefore remember).

These three elements of narrative do correlate with the observations from the games mentioned earlier. Some of these games will be described in more detail in the state of the art section of this paper.

## 2.4 Transmedia

When dealing with storytelling, an author has to decide which media to tell their story through. There are many possible types of media for telling a story, and sometimes an author can even choose to tell the same story through different media, which is when the term *transmedia* becomes interesting. Transmedia or transmediated stories are stories told across multiple media, and today the most significant stories tend to flow across multiple media platforms (Jenkins, 2009). An example of this could be the Marvel superhero comics, which have been made into cinematic movies. The original stories and characters originate in comic books, but have then been transmediated into movies. The ideal transmediation is described by Jenkins in the following way:

*“each medium does what it does best — so that a story might be introduced in a film, expanded through television, novels, and comics, and its world might be explored and experienced through game play. Each franchise entry needs to be self-contained enough to enable autonomous consumption. That is, you don't need to have seen the film to enjoy the game and vice-versa.”*

*(Jenkins, 2003)*

In the traditional sense, transmediation transfers a text or story from one media to a new media. In the context of this project, the aim is to transmediate the topic of algebra to an interactive media. To do this, the field of narratives in interactive mediums needs to be researched to find tools for designing a narrative which transmediates the subject of algebra.

## 2.5 The Narrative Paradox

An issue that may occur when telling or constructing a narrative through an interactive medium is the narrative paradox. This paradox was first introduced by Ruth Aylett in 1999, and it appears when combining the concept of a free-roam interactive world with an author-controlled narrative (Aylett, 1999).

In her paper, Ruth Aylett addresses the issue of moving and preserving the original narrative when moving the characters from television to a virtual environment. In television, the audience is passively experiencing the narrative through the television and has no say in the course of the narrative and no way to interact with it. The narrative is pre-scripted by the author, and the audience can only experience the

narrative through fixed angles, which has been decided by the author. When moving a narrative directly from television into an interactive virtual environment, two problems may occur, according to Aylett:

The first issue occurs when the author tries to keep a predefined narrative by creating multiple interactive choices in the narrative. This could lead to what is defined as the combinatorial explosion, which will be further elaborated later in this paper (Aylett, 1999).

The second issue deals with the degree to which the audience can interact and participate in the narrative, rather than just being a passive audience with no interaction whatsoever. This issue is also an example of what is known as the narrative paradox (Aylett, 1999).

Aylett argues that by using a design method which she defines as emergent narrative, virtual actors, meaning characters in an interactive virtual environment, can allow the player to experience narratives depending on his behaviour and choices with the virtual environment and these characters.

Since this article, Aylett and other researchers have gone further in exploring this concept of emerging narratives, and tried to understand how to create it with the use of artificial intelligence, embedded narrative design, game design or other elements.

It is therefore important to understand the difference between a pre-scripted narrative and the free-roaming narrative in an interactive and virtual environment when designing the interactive application for this thesis.

## 2.6 Combinatorial explosion

When working with non-linear narrative structures or extended content development, an issue called the combinatorial explosion can occur. In a non-linear structures narrative, the author would in order to construct a rich narrative with depth want to create many events and encounters with characters. This can end up in an exponential increasing amount of content for the author to create as they try to create more depth to the story. It is therefore the author's job to avoid this issue and to limit the amount of events and encounters.

A simple explanation of the combinatorial explosion is that it is the behaviour of a rapidly growing amount of events, which is a result of the combinatorial considerations (Johnson and Christensen, 2012). The combinatorial explosion is a common problem when developing an interactive application and narrative. It is therefore important that both narrative and content should be designed to minimize it (Johnson and Christensen, 2012).

The combinatorial explosion is therefore very important to include in the considerations when designing the interactive application for this project, and a solution to this problem needs to be researched in order to avoid it.

## 2.7 Emergent Narrative

Because of the two previously mentioned issues, the narrative paradox and the combinatorial explosion, the concept of Emergent Narrative should be researched as it has been recognized as a tool to solve these issues. In Aylett's paper, she addresses the issue mentioned earlier of the paradox when trying to combine pre-scripted characters and the freedom offered by a virtual environment (Aylett, 1999). The results of her paper showed that by combining emergent narrative and the creation of social presence, a relatively unexplored approach occurred for adapting narrative to the particular characteristic of virtual environments (Aylett, 1999).

Later on, in cooperation with Sandy Louchart, Aylett and Louchart explain emergent narrative as:

*"...Rather than 'a' story, we see a web of stories, each constructed by a character from the experience of their own participation. Moreover we see participation as quite unlike spectating, being both situated rather than detached, and active rather than passive, with all the cognitive load this brings with it..."*  
(Aylett, 2006)

In interactive applications, media and games, emergent narrative is most commonly seen with the use of artificial intelligent agents, rule-based interactions and interactions between other players or intelligent agents. To get a better understanding of emergent narrative and how to achieve it, I analyze different games which I consider to have achieved this kind of narrative.

In their research, Aylett and Louchart look into emergent narrative through observations of RPG, LRP, Conflicting RPG and Interactive theatre (Aylett and Louchart, 2004). Through their observations, Aylett and Louchart develop a list of requirements to achieve emergent narrative as seen below:

<b>Environment Requirements</b>	<b>Source</b>
A restrictive environment	(3)
Environment designed for interaction	(1,3)
Stimulating environment / idea of discovery	(1)
The environment justifies the full range of activities engendered by the characters	(4)
<b>Narrative Requirements</b>	<b>Source</b>
Character-based narrative structure	(1,3,4)
Real-time interactions	(5)
Randomization (character / locations / behaviors / personality/ events)	(5)
Causes and consequences logical sequencing	(1, 3)
Each performance is a unique experience	(1, 3, 4)
Use of flexible high-level hypothetical plot line	(1, 3)
Narrative control embodied in actors	(2, 4)
Time pressure	(3)
Actors and non-actors in the same environment	(2, 4)
Narrative emerges from character interaction	(1, 3, 4)
One main objective for the party	(3)
The narrative must be prevented to disintegrate into anarchy	(3)
Dynamic created by internal conflict (will / counter-will - plot/ sub-plot)	(3)
<b>Character Requirements</b>	<b>Source</b>
Character designed in function of other characters	(3)
Character possesses conflicting objectives within other characters	(3)
Character must be colorful (extraordinary skills, dramatic personalities)	(3)
Characters fill the dramatic space appropriately	(3)
Character respond to the environment interestingly	(3)
Characters present interesting sub-plots	(3)
For each idea, the character has a concrete will	(4)
Interactive characters takes on the responsibilities of the dramatist	(4)
Characterization is the dramatic engines	(4)
Each character must have a passionate desire that motivates it	(4)
<b>RPG (1) LARPG (2) Conflicting RPG (3) Interactive theatre (4) VR (5)</b>	

**FIGURE 2 - EMERGENT NARRATIVE REQUIREMENTS (AYLETT AND LOUCHART, 2004)**

However, Aylett and Louchart state in the paper that this list is not obligatory to achieving emergent narrative, and that it would be difficult to implement every component on the list into one single application (Aylett and Louchart, 2004). This list could be a very useful tool to achieve emergent narrative and some of the components from the list should be considered when implementing the prototype.

## 2.8 State of the art

To understand both the subject of teaching through games and emergent narrative, I have analyzed games which were recognized as being either emergent narrative or to have had the purpose of teaching the player a subject through the game. The reason for this section is also to get an idea of which games already exist, but also to get a wider understanding of how to teach through games, and to establish which elements can contribute towards achieving emergent narrative games. This understanding becomes important later on when designing the prototype for this project. First, games which are considered to

contain emergent narrative (Mirror Moon EP, MineCraft) are looked at, then games with both emergent narrative and teaching elements (MinecraftEDU, First Person Victim), and in the end games which have teaching elements in them (Never Alone, Valiant Heart, DragonBox).

### 2.8.1 Mirror Moon EP

The game Mirror Moon EP is set in outer space and is an exploration and puzzle solving game with a very mysterious setting. The game is very abstract and the graphics/style is very simplistic. In the game, the player travels around to different planets and explores them, while trying to solve the puzzle that the planet offers. Again, this is very abstract and in the beginning it is very hard to figure out what to make of it and what the “puzzle” really is. When you as the player start to realize the mechanics of the game, you realize that the moon of the planet you are walking on is a “mirror” of the planet. As you get a tool gun, you can then shoot or mark points on the moon to help yourself navigate around the planet and to find landmarks and puzzles. The story of the game is not clear, and it is entirely up to the player to interpret the story for themselves. The game achieves emergent narrative because of its abstractness and lack of clear storytelling. This is a great way to achieve emergent narrative without the use of an Artificial Intelligence, but there is a risk that the audience will not get a narrative experience at all.

### 2.8.2 Minecraft

In Minecraft the player can build structures, fight enemies and be creative whether that involves destroying landscapes or building monuments. The game has no other goal than the one the player sets for themselves, which could be the element that helps create emergent narrative. The elements mentioned above and the purpose of surviving give the user total freedom to make his own rules, build the society and create their own narratives while playing the game. Even though the player cannot die from starvation, he will lose almost all his health if he does not eat. This survival element in the game is seen in many open world games and constitutes a whole genre in itself. The survival aspect is a smart element as it forces the player to explore the world in order to survive. The game is a multiplayer game, and the player has the option of playing by themselves or to join big community servers with an unlimited amount of players. The creators of Minecraft keep updating the game and add new content that enables players to create new structures, which helps to make the world richer. When a world in Minecraft is created, it is randomly generated with the use of algorithms that make sure that the world has different types of environment areas (winter, jungle, woods, etc.) and includes caves, dungeons and different resources. This makes each world unique and ensures that each time you make a new world, you will have a completely new world to explore. Whether users play alone or with other players, Minecraft gives the freedom and offers events and game mechanics that allow the players to experience emergent narratives. There are specific servers like Massivecraft (“Factions RPG Minecraft Server - MassiveCraft”, 2015), who modify their server so that the game includes roleplaying and much more. This gives the players an opportunity to make detailed characters and live out those characters’ lives. There are many servers like

this in the Minecraft community. There are communities for those who share events and experiences, and these players write stories as they play the game. These communities of players then go on to share their individual stories on fan fiction sites and Minecraft forums (“Minecraft Forum - Minecraft Forum”, 2015), which really shows that Minecraft achieves emergent narrative.

### 2.8.3 MinecraftEDU

MinecraftEDU is a modified version of the previously described game Minecraft. The idea behind MinecraftEDU is to allow teachers to use the game as a tool for teaching different topics. In the game the teacher assumes an administrator role, which means that he has more rights than the students. The teacher can design a specific area and decide the purpose of the area, including how the students are going to use it. Some of the exclusive blocks that the teacher is allowed to place is for example blocks which the students cannot walk past. This can help the teacher constrain the boundaries of an area to prevent the students from wandering off. They can also restrict which area the students are allowed to build on and with which blocks they are able to build. This way the teacher gets total control and is able to determine what the students are allowed to do and in which area they are allowed to do it. This way MinecraftEDU offers teachers the freedom to design and construct their own teaching progress (“MinecraftEdu - About” 2015).

### 2.8.4 First Person Victim

In First Person Victim, the user plays as a victim in a warzone. First Person Victim was developed to create an awareness of the consequences of being a civilian in wartime. The subject or themes are communicated to the user through tragedy, and instead of letting the user play as the person with a gun, as is common in First Person Shooter games, the roles have been switched around to let the user play as the person on the other side of the gun. First Person Victim faces the user with ethical choices, and the user experiences a realistic war scenario with an unpleasant atmosphere and encounters. The game experience uses an “Interactive Dramatic Experience Model”, which makes sure that different events of the narrative occur, a help to achieve emergent narrative. This game not only teaches the players about the subject of being a victim, but also offers each player their own experience with the game. The idea of using some kind of event manager to make the player experience more unique for each player is a good idea for achieving emergent narrative, and should be taken into consideration when designing the prototype for this project.

### 2.8.5 Never Alone

Never Alone is a basic platforming game with puzzle elements. In this game, the player can either play alone or in cooperation with another player by controlling a girl and an arctic fox. What makes this game different is that it is made in cooperation with Alaskan native storytellers and elders to unfold the traditional folklore and culture of the Iñupiat people (“Never Alone - Game”, 2015). In the game, the player

encounters spirits based on traditional folklore of the Iñupiat culture. The player is then able to control these spirits through the arctic fox. The setting in the game is the harsh landscapes of the Arctic, and the game is aesthetically beautiful, which helps draw the player into the universe. By completing the levels, the player unlocks achievements, which in this game are videos that tell more about the culture through interviews with elders and show the arctic landscapes. This way of teaching only works for players who are interested in learning more about the subject or that see it as a reward to win these video clips, while other players would not want to watch the videos and are more interested in only playing the game and would thereby only learn the story which was told through the gameplay and environment.

This is an example of a game that teaches the player about a subject by making the game revolve around the subject. It offers the players who are even more interested in the subject to learn more by watching the videos, while they lose the players who are not interested in watching these videos and who are only interested in the interaction with the story.

#### 2.8.6 Valiant Hearts

Valiant hearts is a puzzle-based game where the player takes control of multiple characters over the course of the First World War. The game is a 2D game in which the user is playing the story as different characters with different backgrounds, who are all involved in the war. Through the game, the user experiences being in the middle of combat, seeing their fellow soldiers die next to them while running for the enemy lines, but they also get to experience the stories which occur in cities that are being occupied by the enemy. By playing the game, the player gets a sense of what happened during the First World War. Through each different level the player is offered the choice of looking into background information which tells details about World War I, and by collecting items through the different levels the player also gets insights into the way that people lived. These items can be equipment which soldiers possessed and even letters from real people, which were written to loved ones during the war. This way the game teaches the player about World War I, but also offers the player more information through articles, pictures and items. This is just one of the examples of how one can teach through games and make the user decide if they just want to enjoy the story in the game or also learn more about the subject on which the game is based.

#### 2.8.7 DragonBox

DragonBox is a tablet game whose purpose is to teach algebra through puzzles and therefore has a particular relevance in connection with this thesis. The game starts out by telling the player that there are two sides on the board, which is visualized as a book. It then explains that to complete a level, the player has to isolate the tile showing a magic box on one of the sides. There are many other tiles than the magic box tiles, which show different imaginary animals. The game teaches the player that for each animal, there is a night and a day version and by combining them, they cancel each other out. For each level the player is taught something new, such as division, and each new lesson teaches the player a new step about algebra. As the game progresses, the tiles sometimes change from showing imaginary animals to showing

dice numbers, and the magic box is changed to the letter x. The game keeps changing small things like this until the player in the end is working with numbers and variables such as a, b and c. By starting out with teaching the player the different rules of algebra and how to perform different mathematical operations using imaginary animals instead of numbers, the player does not realize that they are doing these mathematical operations and is simply thinking that they are playing a puzzle game. However, as the game progresses, the player starts to realize that they are actually doing algebra and sees that they are actually able to solve equations. DragonBox uses the principle of engagement to help the player feel the desire for progress and learning. The company behind DragonBox states that tests have shown that there is a high level of transfer to pencil and paper, and their site is filled with quotes from parents, teachers and companies saying that this game has helped their children or themselves to understand algebra ("Dragonbox - About Us", 2015).

The way this game uses metaphors such as imaginary animals instead of numbers is an excellent way to teach the user how to think in mathematical operations without them realizing it. By slowly changing the visuals on the tiles, the user is then slowly getting used to performing these operations in more formal terms. This approach can therefore be useful when designing the prototype for this project.

## 2.9 Narratives in Interactive Digital Media

When narratives are transmediated into the world of interactive digital media, many issues arise and many things change for the narratives. In an interactive digital media, the relationship between author and audience can change drastically as the audience is no longer passive, but can take on an active role in the narrative and have the opportunity to influence it. To create an interactive application, it is therefore important to analyze and understand the building blocks that are used to form an interactive application. It is for this reason that this section looks into these building blocks and investigates the topics of Author-Audience Distance (AAD), Abstract-Didascalical Continuum, Narrative Intelligibility and Narrative Closure as well as Goals of the System.

### 2.9.1 Author-Audience Distance

For every story told, there will be an author and an audience. It is for this reason the term Author-Audience Distance (AAD) was coined. The term describes the interpretation gap between the designer and the receiver of the story and can be understood as the distance between the sender and receiver depending on the context of communicating the story (Bruni and Baceviciute, 2013).

This gap is both seen in connection with written stories from a book, a movie and even in an interactive application. However, when working with an interactive virtual environment, the audience has more freedom to experience the story at their own desire, and the audience can directly interact with the narrative in contrast to a written text or a movie. This leads to a higher potential of the audience to change the intention in the narrative communication process (Bruni and Baceviciute, 2013).



It is for this reason that it is interesting and important to consider the AAD when working with narratives, both in creating the narrative, but also in how to contextualize it. This will be further elaborated when describing the Abstract-Didascalical continuum in the next section.

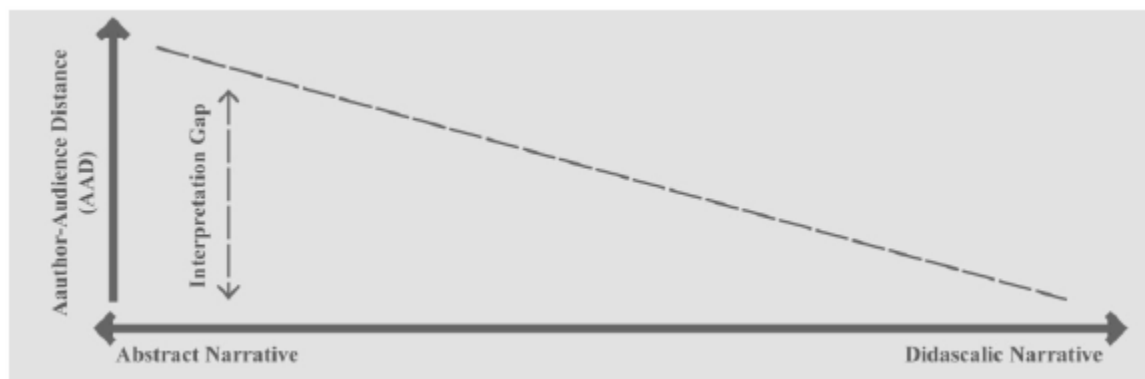
### 2.9.2 Abstract-Didascalical Continuum

It is because of the AAD that Bruni and Baceviciute came up with the term Abstract-Didascalical Continuum, to determine how abstract or described the narrative is intended to be by the author.

Here, abstract refers to all forms of content with none or only little use of pictorial, figurative or explicit representation, but with potential to create some degree of narrativity (Bruni and Baceviciute, 2013).

Didascalical refers to the opposite of abstract where the content has a high level of pictorial, descriptive, explicit, concrete, figurative or narrative representational power, and the potential of creating narrativity is much higher (Bruni and Baceviciute, 2013).

In their research, Bruni and Baceviciute made a graph showing the AAD as a function of the Abstract-Didascalical continuum to improve the understanding of the Abstract-Didascalical continuum. This graph can be seen in the figure below:



**FIGURE 3 - VISUALIZATION OF AUTHOR-AUDIENCE DISTANCE AS A FUNCTION OF THE ABSTRACT-DIDASCALICAL CONTINUUM (BRUNI AND BACEVICIUTE, 2013).**

The Abstract-Didascalical Continuum can be used as a tool for analyzing interactive applications. When using this tool to analyze the interactive applications stated in the state of the art section, it is observed that some of the games achieve being emergent narratives through being abstract, and others achieve it by offering freedom to the player, based on certain mechanics. This abstractness allows the audience to interpret the narrative more freely. Because the narrative in the interactive application is so abstract, there is no clear story, which results in many unfilled holes in the narrative that only the audience can fill themselves. An example of this is the Mirror Moon EP game. This game is very abstract in its goals and

story, and some would even argue that the game is not even supposed to have a story. However, the mystic and exploration aspect of the game makes it very intriguing and leaves room for the audience to interpret their own story.

The other games which have been described in the state of the art section, such as First Person Victim, Valiant Heart, Never Alone, Minecraft and Minecraft, are further to the Didascalical Side of the continuum. The ones that are categorized as achieving emergent narrative use player-to-player interaction or rule-based emergence, and most of these games also offer the player freedom to walk around and experience their own unique story. The rest of the didascalical games are the ones which are considered to have elements of learning in them. This makes sense since the narrative in these games is also the subject which is being taught, and it would therefore be important that the narrative that is communicated to the audience is the same as the narrative which is intended by the author.

### 2.9.3 Narrative Intelligibility and Narrative Closure

Bruni and Baceviciute do not only consider narratives as a communication act, but also as a human cognition mode for organizing experiences. They go on to say that even in the case of a person who is alone in generating their internal narrative, there is still a communication act, which is called “auto-communication” (Lotman, 1977; Lotman, 1990).

In the paper, Bruni and Baceviciute divide the narrative process into two processes of meaning generation, interpretation and reception in communication act between the author and the audience (Bruni and Baceviciute, 2013). These two processes are referred to as narrative Intelligibility and narrative Closure.

#### Narrative Intelligibility

The Narrative Intelligibility is the process where the audience perceives and generates a narrative that is close to the one that was intended, desired or expected by the author (Bruni and Baceviciute, 2013). In other words, the term is used to describe how close the understanding and the narrative generated by the audience is to what the author had in mind.

#### Narrative Closure

The Narrative Closure is the process in which the audience generates and constructs an internal narrative on their own. This does not necessarily have to be related to the same narrative that is intended by the author. Consequently, the concept of narrative closure refers to whether or not the audience feels like they have experienced a narrative from the communication act (Bruni and Baceviciute, 2013).

It could therefore be stated that a narrative with high-level narrative intelligibility would result in narrative closure, but would not necessarily go the other way. The audience could experience a high level of narrative closure, meaning they generated a narrative on their own, but this was not the narrative intended by the author, meaning that there would be a low level of narrative intelligibility.

### 2.9.4 Goal of the System

In the paper by Bruni and Baceviciute, they introduce the terms *goal of the system* and *goal of the narrative*. These two terms have the purpose of dividing the experience into the system and the narrative. Bruni and Baceviciute state that every narrative in digital interactive systems has subliminal intentions to be perceived by the audience, even though the communicated content may not be the same as the goal of the system (Bruni and Baceviciute, 2013).

In the paper, they state that in order to consider intelligibility and closure, the intentions of the goals of the system should be integrated into these considerations. This means that there should be an explicit or implicit goal of the system:

“...if one wants to use digital, interactive, and narrative-based technology for communicational, pedagogical, educational, didactic, therapeutic or artistic purposes, for instance, there must be a more or less explicit or implicit normative goal in the whole endeavor. On the other hand, some developments in interactive narrative, storytelling, and drama have focused on the generation of engagement by attempting to empower the interacting subject in the composition of the narrative, emphasizing more the experience of narrative closure than that of intelligibility of a particular thesis.”  
(Bruni and Baceviciute, 2013).

To discuss this subject, it is therefore important to distinguish between if the perceiver of the experience is experiencing the system or experiencing the narrative that is mediated. The author or designer has to define the terms closure and intelligibility at two different levels: the level of the system and the level of the embedded narrative.

#### System level

At the system level the perceiver experiences intelligibility as decisive interaction in connection with the goals of the system, meaning that the intelligibility determines the AAD at the system level. Here closure is experienced as decisive interaction, but its result can differ depending on the author's/designer's goals of the system (Bruni and Baceviciute, 2013).

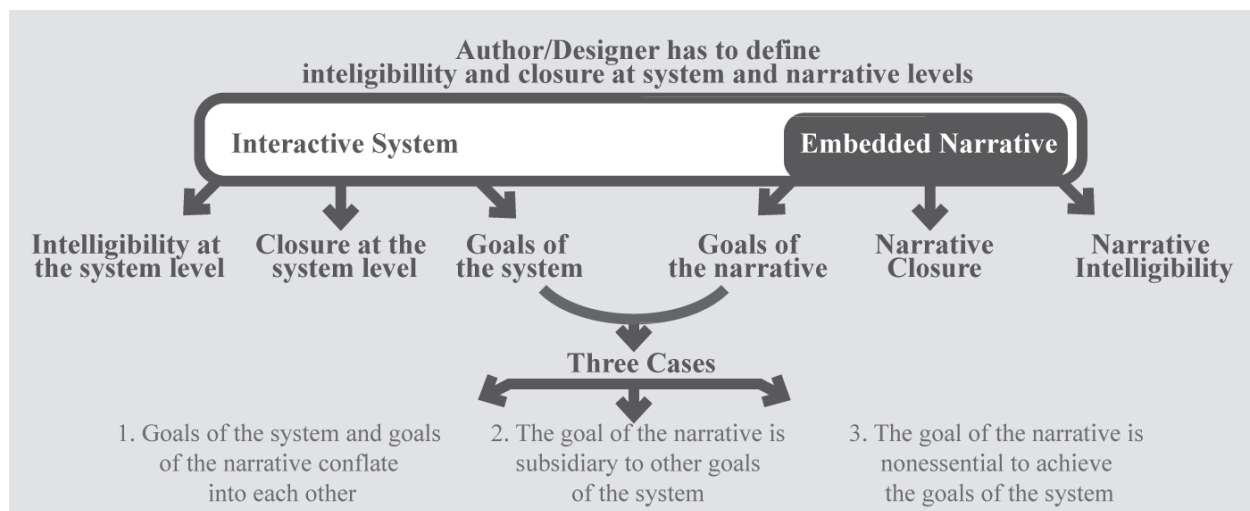
#### Embedded narrative level

At the embedded narrative level a high level of intelligibility will also entail a short AAD, but in this case, the audience will have a good understanding of the narrative as intended by the author/designer. At the same time if the narrative is also well integrated to the goal of the system, the audience will get the experience of intelligibility at the system level. Closure at the embedded narrative level results in a good sense of having experienced the narrative, but does not necessarily match with the author's/designer's intended interpretation (Bruni and Baceviciute, 2013).

Seen from a design point of view, the level of desire related to narrative intelligibility and/or closure depends on the goal of the system, and sometimes the intelligibility and closure are not normative values on their own. Based on these considerations, Bruni and Baceviciute present three cases in which the goals of the system and the goals of the narrative are interrelated.

1. In the first case, the goal of the system is to mediate the embedded narrative, and the goals of the system and the goals of the narrative merge, meaning that the goal of the system is to achieve some narrative intelligibility and/or closure (Bruni and Baceviciute, 2013).
2. In the second case, the embedded narrative is just a resource to achieve the goal of the system. The role of the embedded narrative and the intelligibility and/or closure which is a result of this, is only a step to the other goals of the system. If it is needed by the system to have a narrative which is open to interpretation (have a large AAD), which results in an abstract narrative, the audience can still get an overall sense of intelligibility and/or closure, by achieving the goal of the system, even with low level of narrative intelligibility and/or closure. Examples of this is seen in interactive narrative applications which are categorized as edutainment, persuasion, therapy or entertainment (Bruni and Baceviciute, 2013).
3. In the third case, the narrative is only used as an accessory to the system and is nonessential for achieving the goal of the system. Examples of this is seen in First Person Shooter games, where the narratives are presented in cut scenes and are not central to the goals of the system (Bruni and Baceviciute, 2013).

To give an overview of the three cases Bruni and Baceviciute present the following figure in their paper:



**FIGURE 4 - TWO LEVELS OF GOALS, AAD, INTELLIGIBILITY AND CLOSURE.**

The intended purpose of the framework of the goals of the system is to help authors make design choices and to be able to specify the intention of an interactive application which contains a narrative where the content has been designed by the author (Bruni and Baceviciute, 2013).

## 2.10 Requirements

Based on the background research, I have made a requirements list as a way to organize what was needed for the prototype to work, and this list has also been used as a checklist for the design and implementation

face of the project. The goal of this list is to have a “need-to-have” list that should be the minimum requirements for the prototype:

- Basic algebra solving system.
  - Equation with one unknown variable.
  - Calculations with mathematical expressions that contain the same variable (in Danish: ensbenævnte led).
- Different levels of algebra problems to solve.
- “Open” world for the player to explore, but also a world that is restricted on some level.
- Some events should happen to trigger a narrative element.
- A simple drama manager should trigger these events
- An overall objective for the game.

A list of “nice-to-have” was also drafted, which is a list of all the requirements that would be implemented if time permitted:

- More basic algebra solving.
  - Equations with parentheses.
  - Equations with fractions.
- The environment changes according to actions.
- Many different events should be triggered.

### 3 Design

Based on the background and the state of the art research from the previous section, a prototype was developed using this information. This section will describe how the research was used to develop this prototype. Based on the previous research, it was decided that algebra would be an interesting subject to work with since it is a subject that many students have difficulties understanding. Although it could be interesting to design the prototype so it could be used in a classroom, this was not the explicit intention with this particular prototype. The reason for this decision is that such a teaching tool would have to be highly customizable to be used in several classrooms, and this would not be possible to achieve in the timespan which is set for this project. Instead the aim with the prototype has been to give students a desire to play the prototype on their own outside the classroom. In the state of the art section, it was discovered that the game Dragonbox is a very good tool for learning algebra, and this game is therefore used as an inspiration for the prototype’s inclusion of mathematical elements. The framework provided by Bruni and Baceviciute will be used when considering which role the narrative should have in the prototype, how to design the narrative, and how big of a role the narrative should have on the audience. To help achieve emergent narrative, the requirements list for emergent narrative by Aylett and Louchart will also be used to design the prototype.

The following section will describe how the background research was used for designing the interactive application prototype and which considerations were made.

### 3.1 Game Design

To fit the time schedule set for this project the game's design should be as simple as possible and should aim to reach the requirement goals with as few resources as possible. The game design should offer some degree of interaction for the player. To avoid the combinatorial explosion, the prototype should include some kind of speechless creatures with a simple AI which the player should be able to interact with. It was decided that the game should be a first-person game, as this would help players get the feeling of being inside the game. This would also save us the whole process of creating a believable character for the player to control and would also minimize the work related to camera controls which would have to be more complicated for controlling a game in third person.

### 3.2 Narrative Design

The narratives tools by Burni and Baceviciute were used to help make decisions regarding the construction of the narrative. Elements such as Author-Audience Distance, Abstract-Didascallic Contenuum, Narrative Intelligibility and Narrative Closure, and the Goal of the System were taken into consideration when constructing the narrative.

To help create emergent narrative and at the same time keep the workload on content for the narrative low, it was decided to create a narrative which is in the abstract section of the Abstract-Didascallic Continuum, which will create a higher AAD. By making the narrative abstract, the aim is to achieve emergent narrative the same way Mirror Moon EP does, and by doing so create a higher level of freedom for audience to interpret the narrative. By doing so the audience should experience their own unique story, but it should also be a way of intriguing them to feel the desire to explore the game world and narrative.

It is for the same reason that the aim of the prototype is not necessarily to obtain a high level of narrative intelligibility, but some level of narrative closure is desirable. The reason for this decision is that it is not very important for the player to have the same understanding of the narrative as was intended by the author, but it is important that the audience feels that they have experienced a story from the prototype, which should help the learning process. It could be argued that since part of the goal of this prototype is to facilitate mathematical learning, the narrative should only serve the purpose of making the prototype engaging. Therefore, the purpose of the narrative is most of all to keep the audience entertained and intrigued so they will continue playing the game and in so doing continue solving the equations and hopefully achieve learning.

To help considering the levels of intelligibility and closure, the three cases of relation between goals of the system and goals of the narrative stated in Bruni and Baceviciutes paper were used. Here the second

case in which the narrative is used as a resource to achieve the goal of the system was considered the most suitable choice. The reason for this choice was that the narrative in our system should be used as a way of teaching the mathematical subject. Even though the narrative is still a big part of the system, it should still only be a tool for achieving the system goal of teaching mathematics.

The narrative for the prototype should be split in two sections, which serve two purposes for the prototype. The first section should include elements of a narrative which is connected to the mathematical elements of the game and should have the purpose of connecting the algebraic system to the narrative. These parts should focus on explaining the algebra system, and therefore do not have to be very descriptive about the world narrative. The second section should only be narrative elements which serve the purpose of adding to the world story, and these should give more information about what is happening in the world. These parts have to be more elaborate and focus on adding to the narrative experience instead of explaining the mathematical aspect of the prototype.

Based on the list of emergent narrative requirements by Aylett and Louchart, additional elements for achieving emergent narrative could be added to the prototype. Aylett and Louchart mention “One main objective for the party” as one of these elements. This element could be added to the prototype by introducing a plot in the narrative, which tells the player to solve ten puzzles in order to save the world. By doing so, the player is given an objective. This could also help to restrict the amount of time the participants later in experiment will use on playing the prototype.

### 3.3 World Design

Based on the research described in the background section, it was discovered that many emergent narrative games have some degree of open world for the player to feel free to experience and explore in whatever way they want to. By looking at games such as Minecraft, which has a randomly generated open world, and First Person Victim, which has branches of pathways, which create the illusion of an open environment, it was decided that it would be interesting to create a false open world. A false open world should be understood as referring to a world which seems open to the audience and gives them the illusion of being able to walk wherever they want, but is actually restricted in some degree. This decision was also based on the list of emergent narrative requirements by Aylett and Louchart. The components from the list, which the prototype aims to achieve should be: “A restrictive environment”, “Stimulating environment / idea of discovery”.

Such a world should let the player walk in any direction they want, but the world will consist of fixed environment squares, which will be placed according to different factors. An example of such an environment square could be a square with a house on it or a square filled with trees. With reference to setting, it was decided to situate the world in a mystic forest where different tiles would keep repeating, and this would add to the experience of the player feeling lost in a mystical and magical forest.

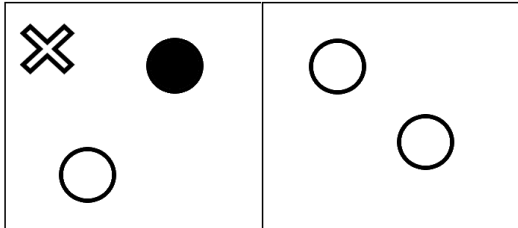
The world should generate around the player as he walks through it, but still remember the location of the already generated squares. In this way, the world will generate randomly as the player progresses

through it, so the player gets the feeling of an endless world. The player should be able to walk back to previous squares. This would also help achieve the “Randomization (character / locations / behaviors / personality / events)” element from the emergent narrative requirements list.

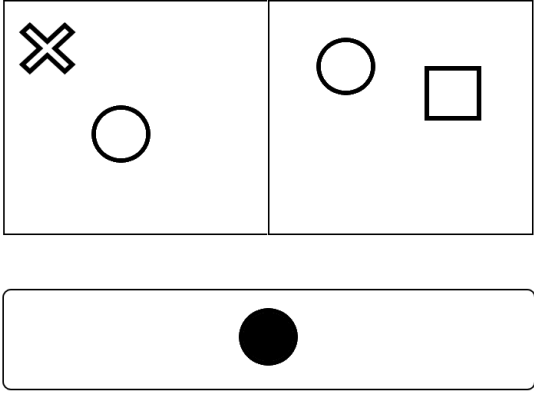
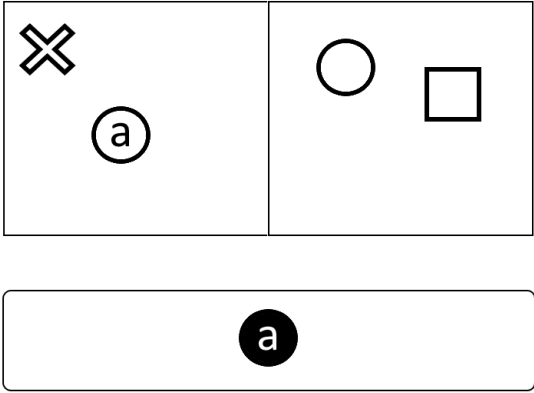
To add more content to the world and the narrative, a simple non-human AI should inhabit the world, and should help achieving emergent narrative by letting the player interact with them. To fit the non-human creatures into the game world and the narrative, they should be visualized as boxes and spheres, in order to add to the mystic and abstract environment.

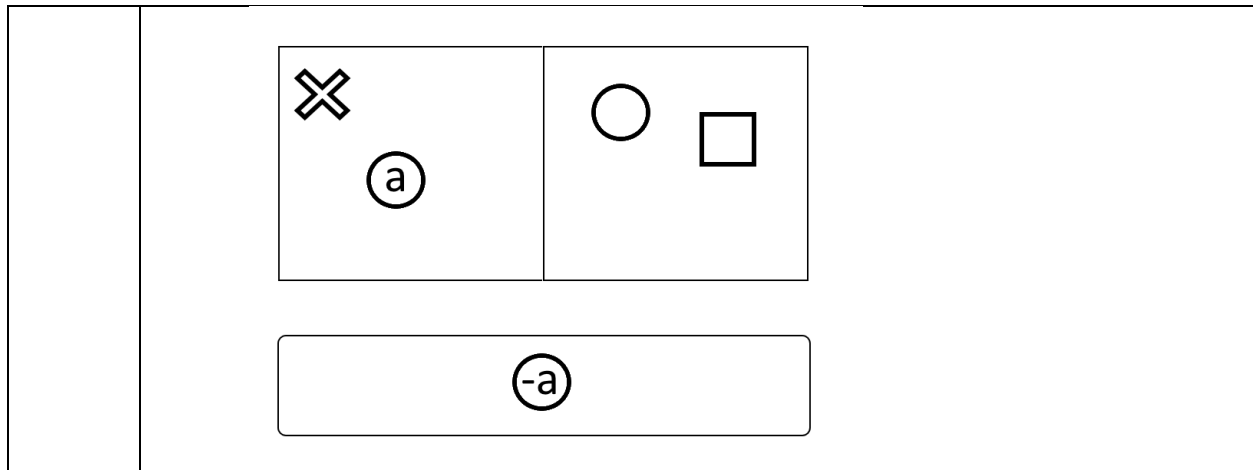
### 3.4 Equation Design

For the design of the mathematical element of algebra, the game DragonBox was used as an inspiration, as it employs some clever mechanics to teach maths, using blocks and then slowly changing these blocks into variables. Based on an analysis of Dragonbox and how it teaches the subject of algebra, a list of features was written down and used in the design of the prototype. Instead of using different dragon drawings on the blocks, the illustrations should be connected to the non-human AI creatures from the game world. The reason for this is going to be explained later in this section. Just like in DragonBox, the blocks should have two versions which symbolize if they are positive or negative values. The prototype equation system is divided into different levels of difficulties. The figure below shows these different levels and lists what each level should contain:

<b>Level 1</b>	<ul style="list-style-type: none"> <li>• Only blocks with symbols are shown (e.g. circles and squares).</li> <li>• The player should be able to solve the equation with the blocks showing on the screen. This means that it should not be possible for the player to drag new blocks into the equation from outside the equation.</li> </ul> <div data-bbox="457 1304 971 1530">  </div>
<b>Level 2</b>	<ul style="list-style-type: none"> <li>• Only blocks with symbols are shown (e.g. circles and squares).</li> <li>• The player should at this level be able to drag new blocks in from outside of the equation.</li> </ul>



	
<b>Level 3</b>	<ul style="list-style-type: none"> <li>There will at this level be shown squares with the letter 'a' inside of them, but the negative version of this block will still have a black coloured background with the letter 'a' inside.</li> <li>The player should still be able to drag new blocks in from outside of the equation.</li> </ul> 
<b>Level 4</b>	<ul style="list-style-type: none"> <li>At this level the variable blocks should now have the negative block shown with a white background and should now have '-a' written on them instead of the letter 'a' with a black background.</li> <li>The player should still be able to drag new blocks in from outside the equation.</li> </ul>



**FIGURE 5 - TABLE OF THE DIFFERENT LEVELS OF EQUATIONS**

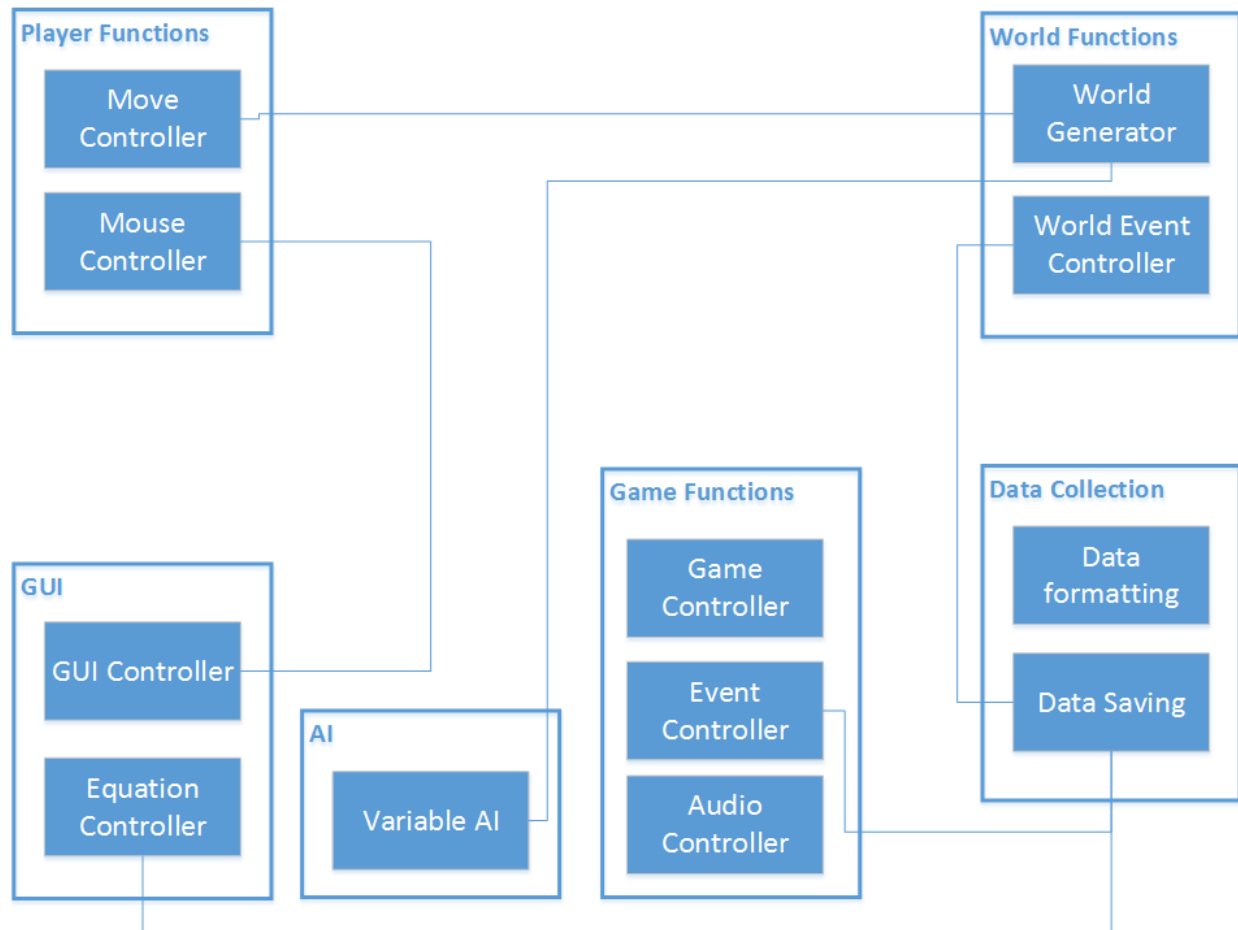
To help players understand the equation system, there should be notes around the world which will help the player to understand how the equation mechanics work. These messages should help merging the equation system and the world narrative together as mentioned earlier. By connecting the equation system to the notes, this should create a reason for the players to walk around the world and try to find these notes for them to understand the equations system and then progress in the equation system.

As mentioned earlier in this section, the blocks should be visualized as squares and circles. The reason for this decision is that the visualization on the blocks should be connected to the game world as well. The squares and circles will be visualized in the game world as boxes and spheres, and should act as some kind of creature. The boxes and spheres will be merged with the narrative to connect all these elements of the narrative world together. The reason for choosing squares and circles was to add to the abstractness of the narrative, but also to keep it simple as there was not much time for creating 3D models and creating convincing animals for this prototype.

To complete the connection between the open world and the equation system, the box and sphere animals should apply the same rules as on the equation system, meaning that there should be a positive and negative version of the shapes, and that they should disappear when they touch each other.

### 3.5 Scripting Design

To get an overview of the prototype structure, a UML class diagram was drawn based on the principles of the book "Object-Oriented Software Engineering: Using UML, Patterns, and Java". The class diagram shows all the different classes which are expected to be implemented in the prototype. These scripts are shown without details, and the purpose of this diagram is to show the connection between the scripts and most importantly, which scripts are needed. A further description of the scripts and their functionality is going to be elaborated in the Implementation section of this paper.



**FIGURE 6 - CLASS DIAGRAM OF THE PROTOTYPE**

To give an overview of what was needed for the implementation of the prototype, containers were first set as a way of categorizing the bigger groups of functionality which the prototype should include. The first overall containers that came to mind was the Player Functions, Game Functions and Graphical User Interface (GUI), which were essential for the prototype. The users should be able to control their character in the game and should be able to move and look around. Game Functions were also very essential as they should control the functionality of the game, such as starting it correctly, switch between different scenes and so on. To communicate certain information to the screen, it would be necessary to have some sort of GUI in the prototype as well. As previously described in the World Design section, the world should be randomly generated around the player. This is why we would need a World Functions category, which includes the world generator for generating the world around the player, and a world event controller which should control different events in the world.

To help achieve emergent narrative, an element of interaction between the player and the world was needed. An idea for this was to transform the squares and circles from the equation system into an animal-like creature in the real 3D world. These Variable animals, as I have chosen to call them, should be placed on a specific world tile and should include a simple Artificial Intelligence (AI), which will jump up in the air

when the player is far away to attract their attention. When the player approaches the Variable animals, they should switch to another state, which will allow them to move around, and if opposite Variable animals are close to each other, they should start to move towards one another other. When colliding, they should disappear just like in the equation system.

For testing purposes, the prototype should also include a data collection part. The data collection should collect interesting data such as a record of different events that happen in the game, but it should also be able to save this data both locally and upload to a server, which will make it easier to run tests as it will be possible to send the prototype out to people and thereby enable them to play the game from their own homes. The data collection should also include collection data from the experiment questionnaire, which will be described later.

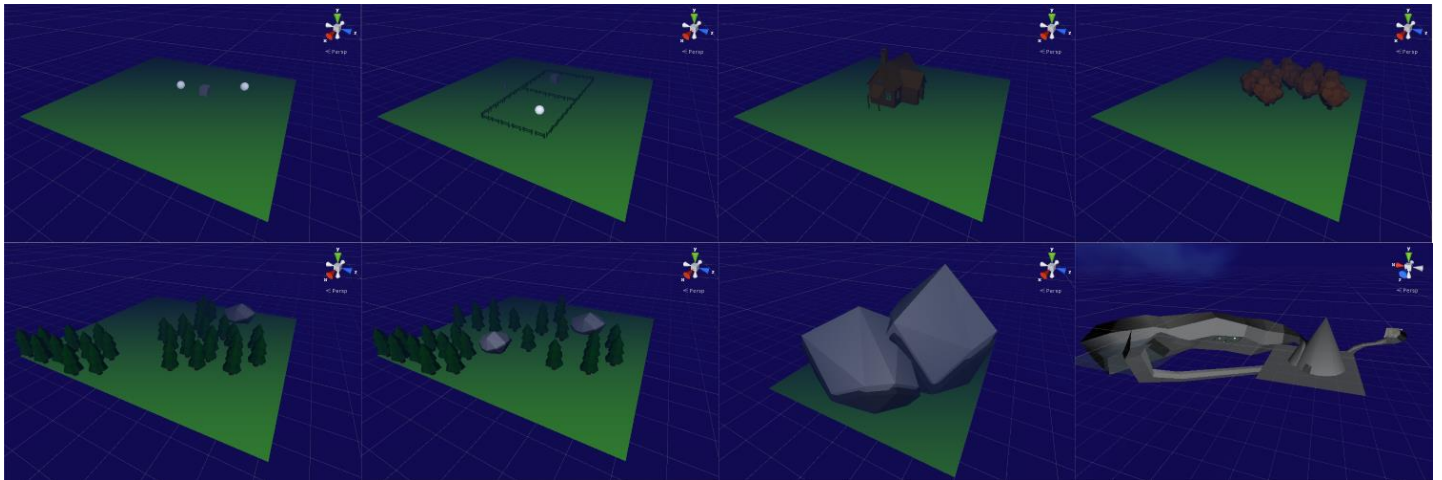
## 4 Implementation

In order to explain the functionality of the system, an elaborate description of the scripts and environment can be seen in this section. The interactive application which has been implemented for the purpose of this project is an early prototype to show how mathematical subjects like algebra could be merged with narratives to create an application which is not necessarily used as a learning tool in schools, but rather as something an audience would feel the desire to play and feel engaged to also play outside of school. This early prototype includes algebra, and by having the audience play through the prototype, they should get more familiarized with the subject. This is of course the goal of the finished interactive game, and this early prototype is only at the beginning of reaching that final goal.

For the purpose of implementing the prototype, Unity3D 5.2.2f1 was used. The reason for this choice is that I have previous experience with Unity3D, and that the program is very useful for quickly implementing a prototype project. By using the UML class diagram from Figure 6 as a starting point, the prototype was implemented, and this section will describe the essential scripts and their functionality, as well as the assets used for building the environment.

### 4.1 World assets

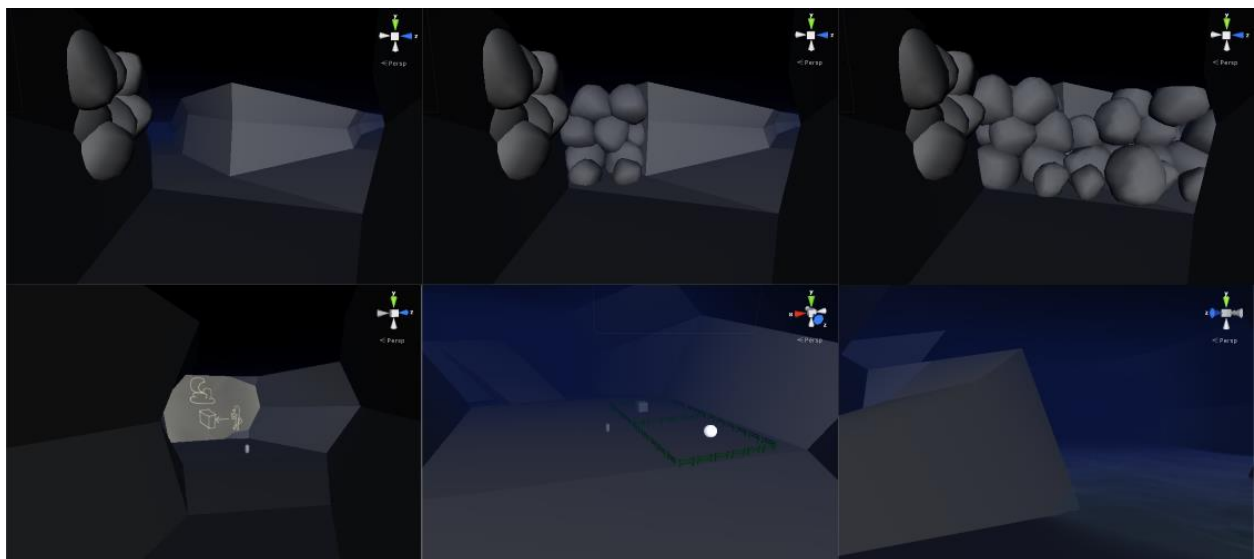
For the implementation of the prototype, multiple world planes were developed to populate the world through the world generator. The different planes can be seen on the Figure below:



**FIGURE 7 - PLANES FROM TOP LEFT TO BOTTOM RIGHT: VARIABLE**

**ANIMALS PLANE, EQUATION PLANE, HOUSE PLANE, FOREST PLANE 1, FOREST PLANE 2, FOREST PLANE 3, FOREST PLANE 4, MOUNTAIN PLANE.**

The green ground planes, which were used for all the world planes except for the mountain plane, were made in Unity. The same applies to the spheres and cubes that were used for the Variable animals. The trees were found in an asset pack called “Handpainted Forest Environment Free Sample” and the skybox was in an asset pack called “Fantasy skybox FREE”, both found in the Unity Asset store. The House including interior, the fence on the Equation plane, and the mountain plane with all the rocks, were all created in Maya2015. As seen on the figure below, the mountain plane is a bit more detailed than the other planes as I wanted the cave in the mountain to add to the illusion of even more possible things to explore.



**FIGURE 8 - EXAMPLES OF INSIDE THE MOUNTAIN, FROM TOP LEFT TO BOTTOM RIGHT: ENTRANCE, ENTRANCE WITH STONE BLOCK 1, ENTRANCE WITH STONE BLOCK 2, THE RIGHT PATH, THE LEFT PATH 1, AND THE LEFT PATH 2.**

As seen on the figure, there are two paths to choose in the cave of the mountain. When walking down one of the paths, the stones seen on “entrance with stone block 1 and 2”, will block the other path, and thereby prevent the player from walking down both paths. This was added in order for the player to feel like their choice of path has consequences.

To add more content to the messages, which will be described in the next section, different drawings were made. These drawings were drawn on paper and then scanned in to the computer where the image manipulation application GIMP was used to modify the drawings to add a dark effect to them and make them look clearer. The drawings can be seen in the figure below:

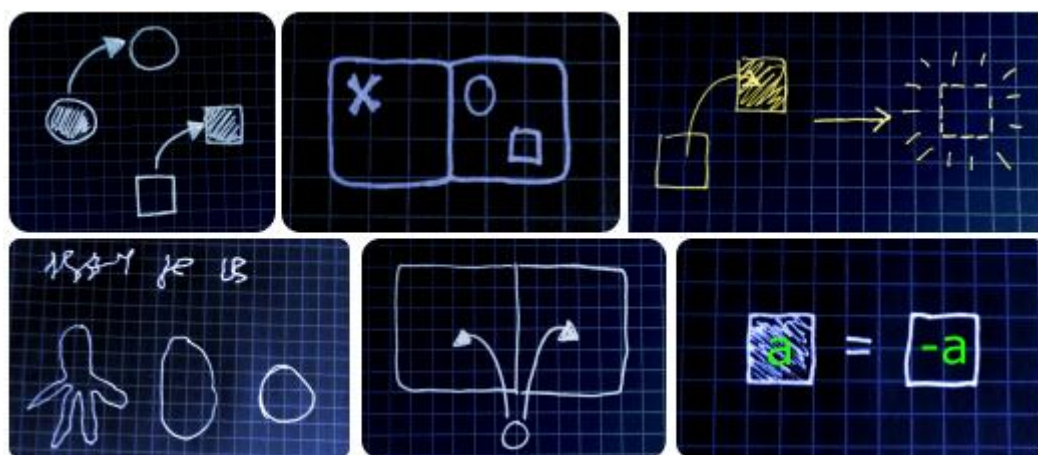


FIGURE 9 - DRAWINGS MADE FOR IN GAME MESSAGES

The images were used both to explain the mathematical elements of the equation system in the game, but also to elaborate and add content to the narrative. The messages which make use of the drawings can be seen in APPENDIX B – Messages from CSV file.

These and the rest of the images used for the prototype can be seen in APPENDIX A – Pictures used for the prototype.

## 4.2 Narrative

Based on the considerations outlined in the Narrative Design section, a narrative is constructed within the prototype through the use of different messages, which will show up at different locations in the game world. To create an overall setting and a goal for the game, the game is provided with an overall story in which “the darkness” has taken over the lands. To rescue the land, the player will have to release the animals in the land by solving the equations. This narrative is told by a stranger, possibly the player himself (this is how it was intended by the writer of the narrative). The stranger is trying to understand how the world works after “the darkness” has overshadowed the lands. “The darkness” has made the people of the land change into the simple shaped creatures, the spheres and the squares. Some of these spheres

and squares have then been captured and the only way for the player to save them is to solve the equations that will release their souls. In the narrative the stranger starts to turn himself, and in the last messages it is not possible for the player to understand what the stranger is writing to him. The messages have been written so they only give a small amount of information about the story. The reason for this is so the player will have to try to make up the missing information and thereby make up his or her own story. The messages are also used to explain the mechanics of the equation system to the player. An example of this can be seen in the message below, which explains that opposite shapes cancel each other:

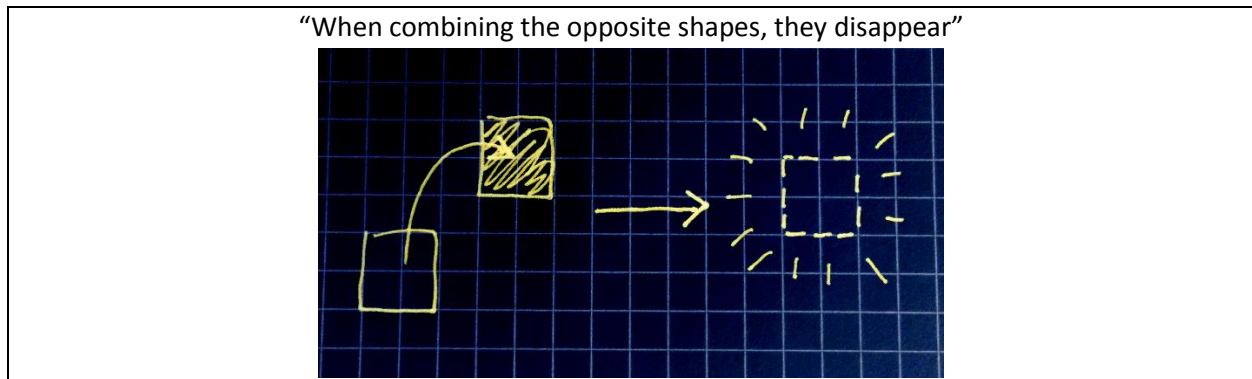


FIGURE 10 - EXAMPLE OF A MESSAGE, BASED ON MESSAGE NUMBER 7

16 different messages were written for this prototype, which are either a description of the story or a message like the example above, which explains the mechanics of the equation system and the game world. The 16 messages can be seen in APPENDIX B – Messages from CSV file.

## 4.3 Unity Setup and Scripts

In order to give an understanding of how the prototype works, this section will describe some of the essential scripts and structure in Unity that are essential to the prototype. As mentioned before, the prototype was developed using Unity3D 5.2.2f1 and the scripts were written in C#.

### 4.3.1 Player Functions

The player functions consist of one simple, but also very important script, the *Move.cs* script. This script is responsible for allowing the audience to control the character in the game world. The script uses Unity's built in axis control, which responds to mouse movement, when moving up, down, left and right. It also responds to the keys W, A, S and D, which allow the user to move the character around in the game world. The mouse allows the audience to rotate the camera. The *Move.cs* script restricts the mouse up and down panning to 60 degrees, for the reason of preventing the audience from trying to move the mouse further down, which would result in the camera continuing to rotate. It would be similar to how the human head is not able to move further down than to what our necks could support. The *Move.cs* script was placed on a capsule object, which had a camera placed on it and worked as the player object.

### 4.3.2 Game Functions

The scripts that are within the game functions group, are the scripts that create the flow of the game, and these are the ones that have main control of what is happening in the prototype.

#### Game Controller

The *GameController.cs* script is the main script of the prototype. It is this script that contains all the script events that happen in the game. It is also this script that makes sure that the equation system is started, ended and deactivated properly. The *GameController.cs* script also makes sure that the player is not able to move when he for example is in the equation system, reading a message, or is filling out a test formula.

#### Audio Controller

The *AudioController.cs* script is also one of the Game functions. The script adds the functionality of playing audio in the game. It is a very simple script which is implemented so it is easy to add new sounds to the prototype if needed. The script listens to different script events and plays a specific sound when the event happens, such as when a message capsule appears or when an equation is solved. The *AudioController.cs* script can also be used by other scripts and can play audio both at a specific location or just a 2D audio.

#### Message Translator

To be able to easily add and edit messages into the system, a message system was implemented, and the script that was responsible for translating the message structure into the game was the *MessageTranslator.cs* script. All the messages that are used in the game were written in a single Comma-Separated Values (CSV) file. The structure of a single message is: **{Header},{Message}**. A message can also include one image which would be included in the message text **{Message}** by adding the following text at the end: **(img){Image file name in the Resources Folder}(/img)**. By adding this text in the end of the message string and replacing the middle part with the name of the image file, which would have to be placed in the **Resources** folder in the Unity project, an image will show in the message window. The Message window can be seen later in the GUI section, and the CSV text for the messages can be seen in APPENDIX B – Messages from CSV file.

The *MessageTranslator.cs* loops through each line of the CSV file and has a dictionary for Header, Message, and Image. For each line in the CSV file, the script then performs some string analysis and adds the Header, Message, and Image to the three dictionaries, which share an index so the three values are connected. With the three dictionaries, it is easy for the *MessageTranslator.cs* script to share information with other scripts to get all the information for a specific message.

### 4.3.3 World Functions

The world functions mainly consists of two scripts, the *WorldGenerator.cs* and *WorldEventSystem.cs* script, but also has other smaller objects and scripts which the two main scripts make use of.



## WorldGenerator

The *WorldGenerator.cs* script is one of the more complex and essential scripts for the prototype. The purpose of this script is to generate the world around the player and keep the information about the part of the world which has already been generated. The *WorldGenerator.cs* makes use of its own *Plane* class. Each plane has a set of information about the plane, which is the maximum amount of planes instantiated<sup>2</sup> at a time, the probability of the plane to be generated, which type of plane it is, and what the game object of the plane is. To add new planes more easily to the system, a Unity Editor Script was implemented to make the information about the planes show correctly. On the figure below is seen the difference before and after applying this Unity Editor script:

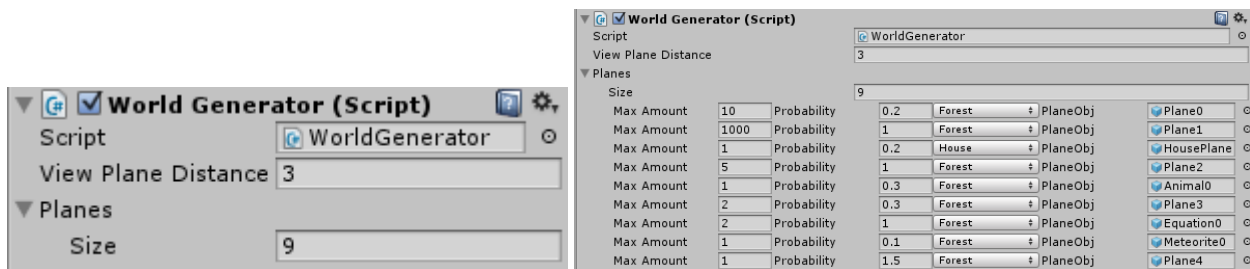


FIGURE 11 - THE DIFFERENCE BEFORE (LEFT) AND AFTER (RIGHT) ADDING THE PLANE UNITY EDITOR SCRIPT

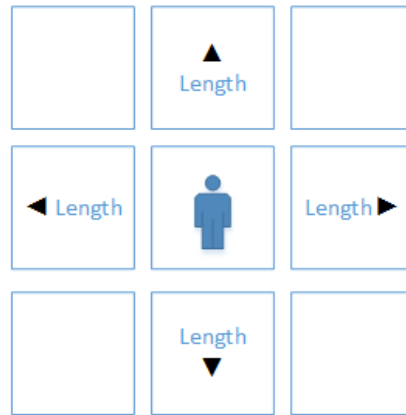
The reason for implementing this part of the *WorldGenerator.cs* is to make it easier for future implementation and adding new content to the early prototype.

Without going into too many details about how the *WorldGenerator.cs* works, the essential way it creates the world is by having a big 1000x1000 two-dimensional grid of integer values. This grid contains which plane is at a specific position. To keep track of the position in the two dimensional grid and the position of the planes in the game world coordinates, a method was implemented to translate the position between game world coordinates and grid coordinates. In this way, it was possible to take the player's position in the game world and figure out which plane from the two dimensional grid he or she was positioned at.

Here, a small and simplistic procedural world generator was implemented by instantiating and destroying planes around the player as he moves through the game world. Here the *WorldGenerator.cs* has a changeable value, which decides how many planes should be instantiated around the player. An illustration of this can be seen on the figure below:

---

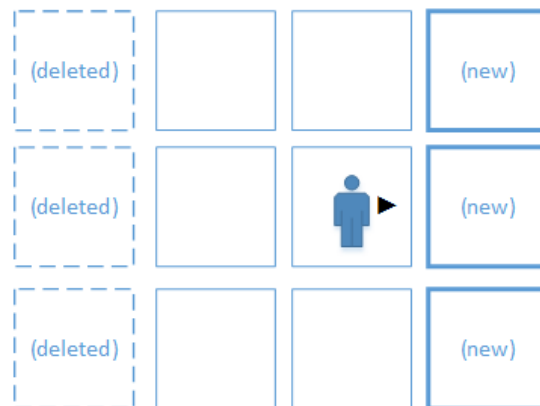
<sup>2</sup> This is a term used in Unity to express that a particular object is placed in the game world.



**FIGURE 12 - ILLUSTRATION OF THE WORLD GENERATOR INSTANTIATING PLANES AROUND THE PLAYER.**

On the illustration, the value for the length is the changeable value mentioned before. The illustration shows how the *WorldGenerator.cs* would instantiate the planes if the value were set to 1, and hereby making a 3 x 3 grid. If the value had been 3, which is the value used in the prototype, the *WorldGenerator.cs* would instantiate a 7 x 7 grid, since 3 planes would be instantiated in every direction from the player's position.

When the player starts to move around the world, the *WorldGenerator.cs* will then remove the unused planes behind the player and instantiate new planes in front of him as seen on the figure below where the player is moving towards the right:



**FIGURE 13 - THE WORLDGENERATOR REMOVING AND INSTANTIATING NEW PLANES AS THE PLAYER MOVES.**

In this illustration the player is moving to the right, and the *WorldGenerator.cs* then removes the planes in the opposite direction and instantiates new planes in front of him. With a view distance value of 3 like the one used in the prototype, it will not be as noticeable for the player that the planes are being removed and instantiated around him, but to make it even less noticeable, fog is added to the world to blur the long distance view. The fog is at the same time chosen to add to the mysterious forest setting which was chosen for the prototype.

As mentioned before, each plane holds different information such as the maximum numbers of planes at the same time, and the probability of the plane to be instantiated. These values are used by the *WorldGenerator.cs* when the script adds new planes to the world. The way the *WorldGenerator.cs* adds new planes to the world is by first checking if the new plane coordinates have been instantiated before. The reason for this is to make sure that if the player has already been in an area, this area should look the same and thereby make sure that the player would be able to go back to a previously visited area. If the plane coordinates have already been instantiated before, the *WorldGenerator.cs* just instantiates the same plane as last time, but if the new plane coordinates have not been instantiated before, meaning that the player has not been in this area before, the *WorldGenerator.cs* then randomly chooses a new plane according to the probability of a certain plane to be instantiated. Before the *WorldGenerator.cs* even considers a plane to be the new plane to instantiate, it sees if the max amount of this plane has already been instantiated in the view distance area. This was implemented to make sure that a certain plane would not appear multiple times in the same viewable area.

The *WorldGenerator.cs* script will also keep track of the player's locations and log this data. The reason for this is to make sure that the player will not just walk around endlessly without anything happening. To make sure that something will happen, the script will see if the player has walked around on forest planes for a certain amount of time in a row. If so, the script will trigger a *message event*, which will instantiate a message capsule near the player's location. More on events will be described in the next subsection. By having this functionality, the *WorldGenerator.cs* will act as a simple drama manager along with the *WorldEventsSystem.cs* script.

### World Events

The *WorldEventsSystem.cs* was designed as a system that should allow the prototype to trigger events in the game world. The script includes the event of instantiating a letter in the game world and trigger a meteorite event. Sadly, the meteorite event was not completely finished and was therefore not included in the prototype which was tested. The letter event will instantiate a letter capsule close to the player's current location and makes use of the *MessageTranslator.cs* script to parse the message content. Each world plane will include a location on the plane which is reserved for the letter capsule. The reason for this is to make sure that the letter capsule will not instantiate inside of an object on the plane and thereby not be accessible to the player. The message capsules will then include a message trigger, which will be explained later.

### Local Events

The *LocalEventTrigger.cs* is a script with the purpose of creating local events on different locations. The script needs to be attached to a trigger box, and when the player enters the trigger box, the script will activate and deactivate the desired objects and play a sound if needed. In the prototype there is only one place where this local event trigger is placed, which is in the caves. Here the player is able to go right or left at two different passages. For each of the passages there is placed a trigger box and each trigger box will block the opposite passage, meaning that the player will not be able to access the other passage. The idea is to have multiple of these local event triggers, and the script is designed to be used in other scenarios, meaning that it could be used in further developments of the prototype.

### Message trigger

The message trigger is used in two scenarios: when reading a letter capsule and when activating an equation. As previously mentioned, message events will instantiate a letter capsule near the player. These letter capsules have a message trigger script on them as well as a trigger box, which will make it possible for the player to read the message when entering the trigger box. Similarly, the equation planes have a message trigger in front of the fences, which will trigger an equation when the player walks up to it.

#### 4.3.4 GUI

To communicate information to the audience, a Graphic User Interface (GUI) was implemented using the Unity Canvas and different scripts. To control the GUI a script called *GUIController.cs* was implemented. This script is in charge of showing and hiding the relevant Panels, panels such as the Equation Panel, Equation Indicator, UI Message Panel, Letter Panel, Test Panel, and Debug Panel. The *GUIController.cs* script is also in charge of showing and hiding the mouse cursor, which will be relevant when showing a message or the equation panel. A figure showing the different panels can be seen below:

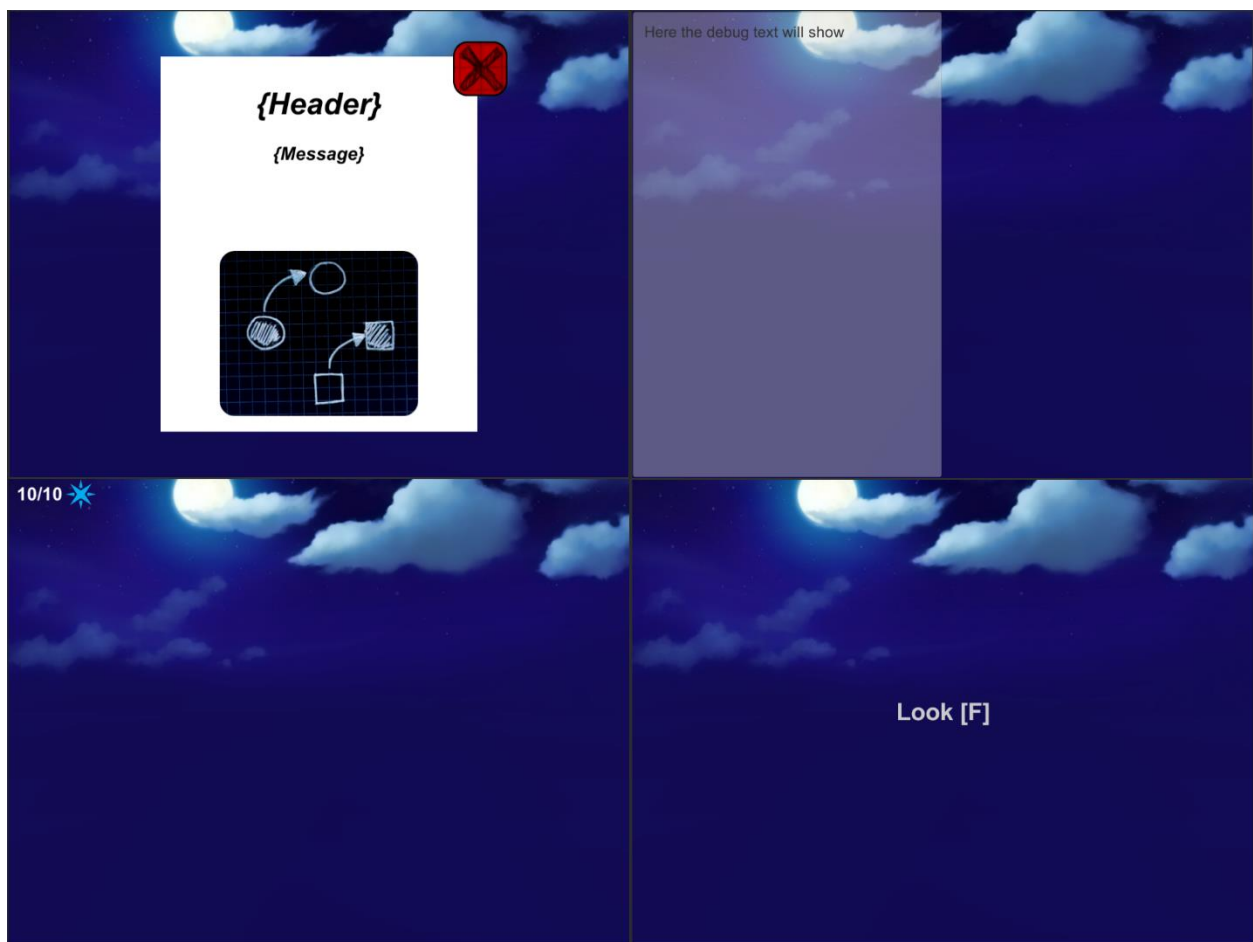


FIGURE 14 - GUI PANELS UPPER LEFT TO DOWN RIGHT: MESSAGE PANEL, DEBUG PANEL, EQUATION INDICATOR, AND UI MESSAGE PANEL.

### Equation Indicator

The equation indicator was implemented to communicate some feedback to the player and make it possible for them to see how many out of the 10 equations they have solved.

### UI Message panel

The UI Message panel contains a text area centred on the screen, and the role for this panel is to communicate different mechanical messages to the player. A UI message could be “Look [F]” or “Read [F]” which would communicate to the player that he or she should press the F key to do the action. This UI message will show whenever an action is available for interacting with an object in the game world.

### Letter panel

The letter panel, which has also been mentioned earlier, can communicate a letter message to the player and consists of the text fields {Header} and {Message}. These text fields will be replaced with the real header and message text. If there is an image in the message, this will show below the message text, but if there is no image, there will just be more room for the message text.

### Test panel

For testing purposes, a testing questionnaire panel was created, which includes different input fields and clickable toggles. These questions will be explained later in the Experiment section of this paper. Below is seen a figure showing the testing panel:

The figure displays two versions of a 'Test Questions' panel. The left panel is the normal testing panel, featuring a title 'Test Questions' and a series of questions (Q1-Q6) with input fields and a 'Do you want to continue playing?' prompt with 'YES' and 'NO' buttons. The right panel shows the same interface but with a large warning message overlay: 'Please answer all the questions before clicking YES/NO'. The warning message includes a red exclamation mark and an 'OK' button. The 'Do you want to continue playing?' prompt is still visible at the bottom.

**FIGURE 15 - VISUALIZATION OF THE TEST PANEL LEFT TO RIGHT: TESTING PANEL, TESTING PANEL WARNING.**

In the figure to the left is shown the normal testing panel, but if the player clicks on either the ‘YES’ or ‘NO’ button without filling out the fields, he or she will be confronted with the warning message shown on the right in the figure. It will later in this section be described how the test panel collects the data from the input fields and how the data is saved.

### Debug panel

During the implementation of the prototype, White Box unit tests were performed during every new functionality implementation. For this purpose it would sometimes be necessary to get debug messages written in a debug panel for when testing the prototype outside the Unity Editor.

### 4.3.5 Equation Controller

The *EquationController.cs* is one of the most essential scripts in the prototype as it adds the mathematical element of algebra to the prototype. The final layout for the equation system ended up looking a lot like the one from the design section, as is seen below:

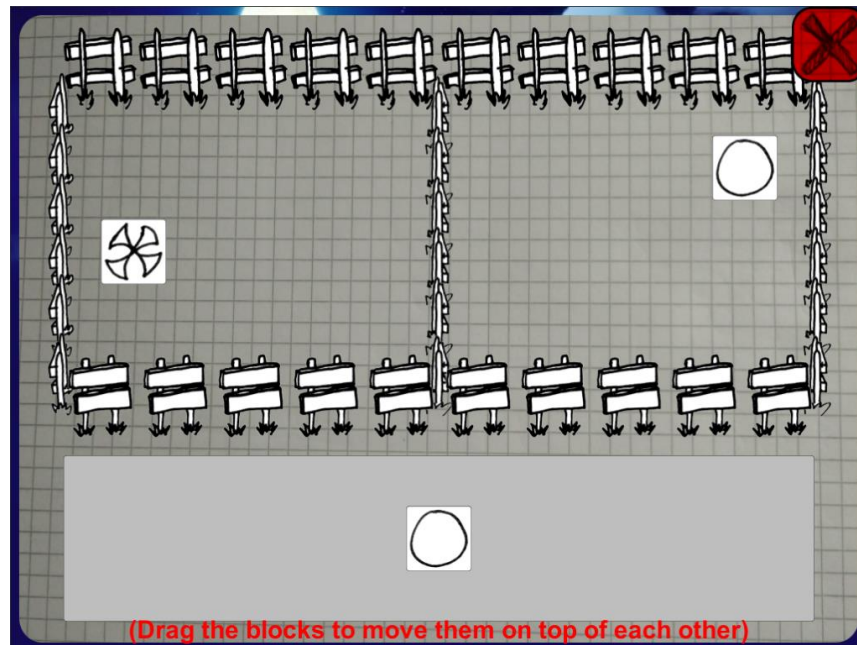


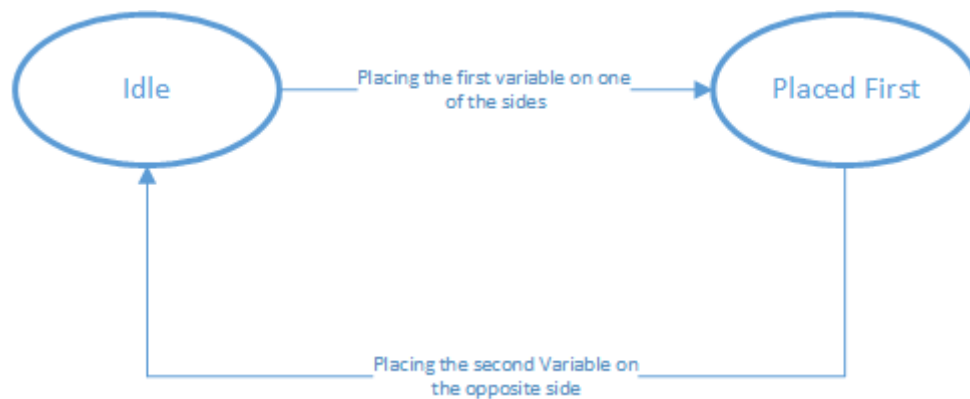
FIGURE 16 - SNIPPET OF THE EQUATION PANEL.

The design of the equation system was chosen to look like the fences that are on the equation planes in the game world, but in a style of pen and paper to resemble the paper a person would normally write mathematical equations on. The equation system is complicated and has a lot of functionality, which resulted in it being split up into two sub classes, the *EquationController* and the *EquationController\_Level*.

### Equation Controller

The equation controller contains the main mechanics of the equation system. This includes different states and many methods. First of all, the script makes sure that it is not possible to drag the variables on the right and left outside their own side area. The script also makes it possible for the variables to be dragged, and if the player drags a variable on top of another variable, it will check to see if they will cancel each other out. If this is the case, the two variables will be destroyed, but if the dragging move is not valid, the variable that has been dragged will move back to its original position. When the player encounters an equation on a higher level, meaning that he or she is able to drag a variable in to the equation from outside

of the equation, the states come into play. The rule of equations is that if you add to one side of the equation, you would also have to add to the other side. This rule is fulfilled by using two different states. A figure of the state machine can be seen on the figure below:



**FIGURE 17 - EQUATIONCONTROLLER STATE MACHINE**

The first state is the Idle state. The machine is in this state when the player is dragging around variables, which are inside the left or right areas. The machine only changes state if the player starts to drag a variable into one of the areas in the equation from outside of the equation. If the player drags a variable into either the left or right side of the equation, the state changes to the PlacedFirst state. Here the system will lock every other kind of movement for the player, except if he or she drags the same variable from outside the equation onto the opposite side of the previously placed variable. If the player does so, the state machine will then go back to the Idle state, and the player is now able to proceed with moving variables around again.

The last function of the Equation Controller is to check when an equation has been solved. Every time a player cancels two variables out with each other, the Equation Controller checks if the x on the left side is isolated. If this is the case, the Equation Controller then shows a small animation of the x bouncing while playing a sound to indicate that the player has isolated x. After the animation has played for a short while, the Equation Controller then closes down the equation panel.

### Equation Controller Level

The equation controller level part of the equation system was implemented with the following purposes: Keeping track of the equation level the player is currently in, reading the equations from a CSV file, and choosing the right equation for the current level of the player. Much like the message translator, the equation controller level script reads all the possible equations from a CSV file. Similar to the messages CSV file, the equations CSV file has a certain structure which is translated into equations by the equation controller level script. Each line in the CSV file is a new equation which has the following structure: **{level of equation},{list of variables with information}**. The level of equation value will be an integer with a value between 1 and 4. The list of variables can be as long as five variables on each side of the equation. There are two types of variables: a “normal” variable, which is placed on either the left or the right side of the equation, and a button variable, which is the variables in the bottom that can be dragged into the

equation. To determine between the two types, the first value in any variable structure line is the type name, which would be “var” for a normal variable, and “butt” for a button variable. The structure of the two types of variables can be seen on the figure below:

Normal Variable	var;{type};{sign};{area}
Button Variable	butt;{type};{isClickable};{sign}

The type of a variable is whether it is a circle, square and so on. The sign of the variable is whether it is positive or negative, and is set by writing true or false. The area of a variable determines on which side of the equation the variable is placed and is set by writing either LeftSide or RightSide. The isClickable value determines if the button is clickable, meaning if the player is able to click the button to make it switch sign of the button variable. The last mentioned value did not get to be used in any of the equations for the prototype, even though the functionality behind it worked. The reason for this is that there were already a lot of functionalities for the player to learn in the equation system, and it was therefore saved for future expansion of the prototype.

In this way the equation controller level is then able to load equations from a CSV file. The CSV file with the equations used for the prototype can be seen in APPENDIX C – Equations from CSV file. The script stores the equations into lists, categorized by their level. Whenever a player walks over to an equation plane and starts an equation, the equation controller level picks a random equation based on a certain level and instantiates it into the equation panel with all the right variables.

To create progress through the prototype, the player will advance in equation level after solving a certain number of equations. The number of equations to solve in order to advance to the next equation level are as follows:

	Level 1	Level 2	Level 3	Level 4
Number of equations to solve before advancing to next level	2	2	3	∞

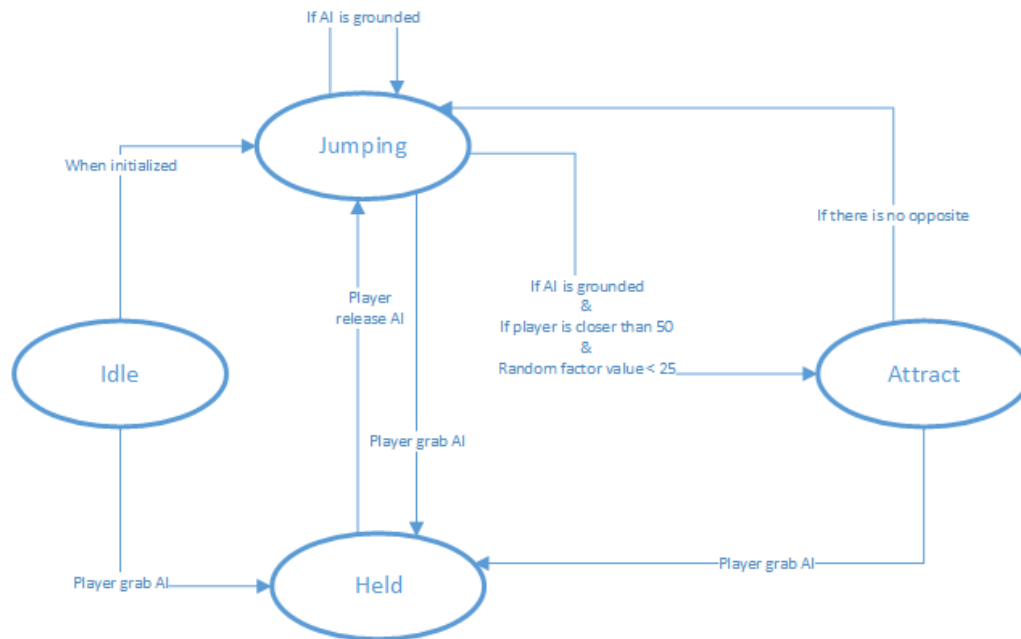
The reason why the level 4 is infinite is that the prototype was designed to only go to 10 solved equations, and a level 5 equation type was not included.

#### 4.3.6 Artificial Intelligence (AI)

To add interaction and add to the narrative, the Variable Animals were added to the prototype. The Variable Animals have a simple AI script on them, named *VariableAnimal.cs*. This script includes the state machine and the functionality for the different states. The Variable Animals have four different states:



Idle state, Jumping state, Attract state, and Held state. A figure of the state machine can be seen below to get a better overview of the AI:



**FIGURE 18 - STATE MACHINE DIAGRAM OF THE VARIABLE ANIMALS.**

The Idle and Held states are very similar states, as they both make the AI stop doing anything. The difference between them is that the Idle state is an initial state for the AI, and the Held state is used when the player is holding the Variable Animal. At any time the player is able to grab the animal, and therefore every state can be stopped and go to the Held state. After the AI has initialized in the Idle state, it moves to the Jumping state. In the Jumping state, the AI jumps up into the air and waits until it is on the ground again, after which this is repeated. The AI changes to the Attract state if all of the following criteria are met: the AI is grounded, the player is closer than 50 units and a random factor value is valid. The random factor is a value which is being randomly set to an integer between 0 and 100. If the random factor is below 25, the criteria is fulfilled. If all of these criteria are true, then the AI goes into the Attract state. In the Attract state, the Variable Animal searches for another Variable Animal with the opposite sign, e.g. if the Variable Animal that is in the Attract state is positive and the type of a sphere, it is searching to see if there is another Variable Animal of the same type, but which is negative instead of positive. If there is no opposite Variable Animal in the area, the AI goes back to the Jumping state. If there is an opposite Variable Animal, the Variable Animal starts moving towards the opposite Variable Animal. Besides the four states, the AI checks if the Variable Animal is colliding with an opposite Variable Animal. If two opposite Variable Animal collide, the AI communicates this message to the *GameController* script, and then destroys both the colliding Variable Animals.

### 4.3.7 Data Collection

The data collection for the prototype turned out to be implemented in a slightly different way than suggested by the initial UML class diagram, seen in the Design section. The data collection was split into two parts: an in-game data collection part, and a test data collection part. These two parts will be described below.

#### In-game data collection

The in-game data collection part was implemented in a script called *DataCollector.cs*, which has two purposes: Formatting the data into a string and saving the data string. The script listens to different script events, such as when an equation ends, when a message is read, and when these events occur, it will structure a data line. This data line will then be added to the overall data string and afterwards be saved to a file. A code snippet example of this can be seen in the figure below:

```
private void OnReadMessage(int letterIndex, string header, string message)
{
    dataString += FormatDataToString("ReadMessage", "ReadMessage {letterIndex}, {Header}, {Message}", letterIndex.ToString(), header, message);
    SaveFile();
}
```

**FIGURE 19 - CODE SNIPPING FROM THE "DATACOLLECTOR" SCRIPT, SHOWING REACTION TO READ MESSAGE EVENT.**

The *FormatDataToString* method that was used here is a universal method which is used by all the event listener methods to structure a string. The string that is structured will always log the time of the event, the name of the event and the description of the event.

After the string is added to the overall data string, the file is saved. The saving was initially saved to a local file on the computer, but later on it was decided to add the functionality of uploading the save file to an FTP server.

#### Test data collection

For collecting test data from the prototype, which will also be described later in this paper, the previously mentioned TestPanel was implemented, as seen in Figure 15. The script behind this TestPanel is called *TestPanel.cs*. This script has the functionality to check through all the data fields on the panel, and if the audience presses either the yes or no button before filling out all the fields, it will show a warning box, telling the audience to please fill out all the answering fields before continuing. If all the answer fields are completed, the data is converted into a string as seen in the figure below, and similar to the *DataCollector.cs* script, it saves the file locally and uploads them to the FTP server.

```

private void CollectDataToString(string buttonAnswer)
{
    int answerQ1 = -3;
    for (int i = 0; i < toggles.Length; i++)
    {
        if (toggles[i].isOn)
        {
            answerQ1 += i;
            break;
        }
    }

    dataString += string.Format("{8:hh:mm:ss},{0},{1},{2},{3},{4},{5},{6}{7}",
        answerQ1,
        inputfields[0].text,
        inputfields[1].text,
        inputfields[2].text,
        inputfields[3].text,
        inputfields[4].text,
        buttonAnswer,
        Environment.NewLine,
        DateTime.Now);
}

```

**FIGURE 20 - THE DATA CONVERTER METHOD, WHICH COLLECTS THE ANSWERS FROM THE TEST PANEL AND CONVERTS THEM INTO A STRING.**

If the reader would like to try the prototype which has just been described, instructions may be found in APPENDIX G – Data on DVD.

## 5 Method

In this section, the method for the testing of the prototype is documented.

### 5.1 Participant

The experiment was conducted with no inclusion or exclusion criteria for the participants.

The number of participants in the experiment consisted of 20 people (n=20). The participants included sixteen males (76%) and five females (24%). The ages of the participants ranged from 23 to 35 years, making the average age 28.25 years. The participants played on the range of 0 to 30 hours per week, and with the average of 6.5 hours per week. One test was conducted in the setting of the test conductor's home (4 participants), and another was conducted at the testers' own homes (16 participants). The participants were not chosen by the author of the paper, but were the ones who responded to the Facebook posts.

Before the official experiment, repeated white box unite tests of the system were conducted, and a small pilot test with 3 people (n=3) was conducted to check for the most superficial errors in the prototype and to make the interface more user-friendly for the audience.

## 5.2 Equipment

Since the experiment was mostly conducted in the homes of the test participants themselves, the computers which were used for the experiment were the participants' own computers. In addition to their own computers, the test participants were asked to use a headset for the experiment. Additionally, they were told that it was recommended to use a mouse, in case they were testing the prototype on their laptop, but this was not a requirement since this would only make the experience easier, but not change the mechanics in the game.

A group of 3 participants were after the experiment asked to elaborate on their experience of the game. For this an OnePlus One android smartphone was used as a Dictaphone to record the conversation.

## 5.3 Approach

The experiment and prototype were designed to be playable without the presence and guidance of the the test conductor. A message was posted on the conductor's Facebook wall and on the wall of the Facebook groups GameDev Show and Test and Indie Game Developers. The Facebook post carried the following message:

*"In connection with my master thesis, I have developed a prototype of a game where I try to connect storytelling and mathematical elements. It would be a great help to me if you could help me test this prototype on the following link:*

*<https://docs.google.com/.../1UqLMBvibvFGGQyXOSDtolp.../viewform...>*

*The test can take around 15-30 minutes (but you decide how long you want to play the prototype) and the prototype will only run on a pc running windows."*

The participants would then be following the instructions given in the Google Form, which would first introduce the experiment on the first page. After answering a series of questions, the form would instruct the participants to download the prototype and play it with specific settings.

Participants were recommended by the Google Form to use headset and a mouse while playing the prototype. For best performance, participants were advised to set the quality settings to fast and keep the resolution to 1024x768.

In the prototype the participants were instructed by the narrator to solve 10 equations, and they were furthermore told that the narrator had left notes all over the land to help the participant. After the participant had solved the 10 equations or chosen not to continue during the play through, the participant would be instructed to go back to the Google Form and finish the questionnaire.

The Google Form can be seen in APPENDIX F – Google Form Questionnaire.

In addition to the participants who took the test from their own homes, four of the participants were tested in the presence of the conductor in order to get further information and to ask more specific questions after the experiment. Here the participants were asked to follow the link the same way that the Facebook participants would, while the conductor of the experiment would observe the participants'

actions without interfering. After the participants had finished the Google Form, the participants were asked if they wanted to do a debriefing interview. The debriefing interview was conducted in order to get more detailed information about the test participant's experience with the prototype. The participants who agreed to the debriefing interview were then asked if it was okay for the conductor to record the interview using a Dictaphone.

## 6 Experiment

The experiment consisted of two test parts: testing for continuation desire, and a small test to determine the mathematical skills of the participants. The purpose of this chapter is to explain the various testing systems. Both qualitative, quantitative and data collection during the play through were used to collect as much data as possible for getting indications of improvements for the prototype.

### 6.1 The Engagement Sample Questionnaire

In the article "Hooked!: Evaluating Engagement as Continuation Desire in Interactive Narratives" by H. Schoenau-Fog, the author aims to evaluate engagement as continuation desire in interactive narratives. Through the research the Engagement Sample Questionnaire (ESQ) is used to test engagement in the interactive application "The First Person Victim". The questionnaire and the intrusive approach are based on the Player Engagement Process (PEP) (Schoenau-Fog, 2011b). The idea behind the intrusion method is based on the assumption that even if an application is paused in the middle of a play through, the user will still have the feeling of wanting to continue the experience and should be able to indicate how much they want to keep on going, and reflect on why they want to continue in more detail (Schoenau-Fog, 2011a). The ESQ can be seen below:

ESQ Part One: Demographics (gender, age, frequency and amount of playing, favourite game / genre)							
ESQ Part Two: Before the experience							
Q1. Please indicate below the extent to which you agree or disagree with this sentence: "I want to begin the experience" (to quantify the users Continuation Desire (CD))							
Disagree strongly	Disagree moderately	Disagree a little	Neither agree nor disagree	Agree a little	Agree moderately	Agree strongly	Other
Q2. "What makes you want/not want to begin?" (to identify the user's CD and objective)							
ESQ Part Three: During the experience							
Q3. Please write the code which is written on the screen in the application: (identifying the latest event)							
Q4. Please indicate the extent to which you agree or disagree with this sentence: "I want to continue the experience now!" (Response options as in Q1)							
Q4. "What makes you want/not want to continue?" (to identify the source of the user's CD and objective)							
Q5. "What do you feel now?" (to indicate the user's affect)							
Q6. "What is happening in the experience?" (to explore the narrative generated by the user)							
Q7. "What do you want to do next?" (to identify the user's activity)							
Q8. "General comments concerning the experience so far" (technical, content)							
Q9. "Do you want to continue?" (yes/no) ("yes" resumes, "no" directs to the final part of the ESQ)							
ESQ Part Four: After the experience							
Q10. Please write the code which is written on the screen in the application: (identifying the latest event)							
Q11. Please indicate the extent to which you agree or disagree with this sentence: "I want to try again!" (Response options as in Q1)							
Q12. "What makes you want/not want to try again (in the application / experience)?"							
Q13. "What do you feel now?" (to indicate the user's affect)							
Q14. "What did you just experience?" (to explore the narrative generated by the user)							
Q15. "Why do you want/not want to try again?"							
Q16. "General comments concerning the experience" (technical, content)							
Q17. "How many minutes do you think you have spent in the experience?"							
Q18. Extra questions related to communication of the theme and learning outcomes, not used in this study							

FIGURE 21 - THE ENGAGEMENT SAMPLE QUESTIONNAIRE (SCHOENAU-FOG, 2011A)

The questions in the ESQ are organized according to four different categories, found in the PEP framework:

1. **Objectives:** These objectives can both be made by the experience or the user.
2. **Activities:** The activities which are performed in order to complete the objectives. This could be interfacing, socializing, solving, sensing, experiencing story or characters, exploring, experimenting, creating or destroying.
3. **Accomplishment:** This is when the participants complete an objective.
4. **Affect:** The affect is experienced by an engaged user who is performing an activity or completing an objective. Examples of this can be categorized into three types: positive, which is enjoyment or pleasure, negative, which is frustration or boredom, and absorption, which is flow or immersion.

The ESQ can be separated into four parts: The first part, which is designed to get demographic information about the test participants, asks questions about the participants' gender, age, time spent on playing, and favourite game/genre, as seen in the figure above.

The second part of the ESQ is designed to focus on motivation to begin the experience before the experience. To quantify the user's continuation desire, they are first asked how much they agree with the sentence "I want to begin the experience", which the participant has to answer based on a seven-point Likert scale as seen in Q1. To investigate the participants' desire to begin the application, or their objective, the question "What makes you want/not want to begin?" is asked as seen in Q2.

The third part of the ESQ is presented to the participant during the play through of the application and should be presented at multiple points during this run time. Here the participants will answer multiple questions as seen in ESQ part three. Again the participant is presented with the question of how much he or she wants to continue with the experience.

At this time the second question is still an open-ended question, but is modified to "What makes you want/not want to continue?", which is to investigate their objective.

The third question "what do you feel now?" is asked in order to investigate affect.

The fourth question "What is happening in the experience?" is asked to get information about the generation of (emergent) narrative, by the participant.

The fifth question "What do you want to do next?" investigates the participant's activity of solving the objective.

The sixth question "General comments concerning the experience so far" is included in the questionnaire to get technical feedback on the application, and can give feedback on improvements to the application.

The last question "Do you want to continue?" is a yes/no question, meaning if the participant answers yes, he or she will continue playing through the application, but if they answer no, the application will exit, and they should continue to the fourth and last part of the ESQ questionnaire.

The Fourth part of the ESQ is very similar to the third part. This part of the ESQ focuses on the experience after having played the application. The first question asks the participant if they would/would not try the application again, and why they want/do not want to try again. Furthermore, the participants were asked how long they think they spent on the experience, which could later be compared to their actual time. In "Hooked!: Evaluating Engagement as Continuation Desire in Interactive Narratives" the participants are asked other questions related to the subject of the interactive game First Person Victim. These questions are asked between parts of the ESQ and after. In this experiment, the participants were also asked different questions between the second and third part of the ESQ and after the fourth part. These questions will be described in the next section.

The first, second and fourth parts of the ESQ were set up into a Google Form, and the third part was implemented into the prototype. To connect the two result forms, the prototype gave the participant a code in the beginning of the play through which they would have to write into the Google Form.

## 6.2 Mathematical Questionnaire

To get an idea of the test participants' mathematical skills before, and more interestingly, after the play through of the prototype, a part of the questionnaire focused on solving mathematical algebraic equations. The level of the equations should be very low and should not be much more difficult than the level which was implemented into the prototype.

To get inspiration for the equations, the book "Gyldendals Gymnasiematematik: Arbejdsbog B1" was used. With inspiration from this book, eight different equations were constructed based on four different operations and levels. The eight equations consisted of four equations before the play through, and four equations after the play through. In the top of the two pages which tested for the level of mathematical skills, it said:

*"Try to solve the following equations (write answers in the form of:  $x = 2$ ) and if you are not able to solve it, just leave the answer field blank."*

This introduction was followed by the four equations, which are presented below.

### Equation 1

The first equation before the play through:

$$x + 1 = 9$$

After the play through:

$$x + 4 = 2$$

This type of equation is a very basic algebraic equation to see if the participant is able to subtract on both sides to isolate the x-value.

The solutions to the before and after questions would be:

$$x = 8 \text{ and } x = -2$$

### Equation 2

The second equation before the play through:

$$x - 6 = 8$$

After the play through:

$$x - 14 = 22$$

This type of equation is very similar to the first equation, but the participant has to add to both sides to isolate the x-value.

The solutions to the before and after questions would be:

$$x = 14 \text{ and } x = 36$$



### Equation 3

The third equation before the play through:

$$x + a = 4$$

After the play through:

$$x - b = 0$$

This type of equation has a variable instead of numbers. This equation was added to the questionnaire to see if the participants would be able to solve an equation with letters instead of numbers.

The solutions to the before and after question would be:

$$x = 4 - a \text{ and } x = b \text{ (but } x = 0 + b \text{ will also be accepted)}$$

### Equation 4

The fourth equation before the play through:

$$2x = 10$$

After the play through:

$$5x = 30$$

This type of equation was added to the questionnaire to test if the participant is able to operate with division in an equation. To solve the equations, the participant would in this case have to divide on both sides of the equation to isolate the x-value. Division was not implemented into the prototype, but it would still be interesting for determining the participants' skill level.

The solutions to the before and after questions would be:

$$x = 5 \text{ and } x = 6$$

## 7 Results

In this chapter the results from the experiment will be analyzed and presented to the reader. As the experiment consisted of two parts, namely a mathematical test and a test for continuation desire, this chapter will describe both of these parts separately.

### 7.1 Mathematical test results

In the experiment the participants were presented with algebraic equations before and after playing the prototype. There were four types of equations to test which mathematical skills the participants mastered

before playing the prototype, and the same type of equations were asked after playing the prototype to see if there were any indications of the participant having gained some mathematical knowledge.

To get an overview of how many of the participants were able to solve the equations, a summary of the equations presented before playing the game can be seen in the table below:

	Equation 1	Equation 2	Equation 3	Equation 4
	$x - 1 = 9$	$x - 6 = 8$	$x + a = 4$	$2x = 10$
Number of right answers:	19/20 (95%)	18/20 (90%)	10/20 (50%)	19/20 (95%)

Most of the participants were able to solve both the first, second and fourth equations, and only two participants out of 20 (10%) could not answer or made an error. One participant was not able to answer any of the equations, and based on the comments from this participant, he was unable to remember the mathematical skills required to solve the equations. One participant wrote a wrong answer in equation two, but by looking at the answer it could have been a case of the participant writing too fast, as the answer was “ $x = 14$ ” and the participant wrote “ $x = 10$ ”. The reason for suspecting this to be a typing error or calculation error is that the participant answered all the other equations correctly.

The participants had more difficulties answering the third equation before playing the prototype, and 10 of the 20 participants (50%) were either not able to solve the equation or gave a wrong answer. This could indicate that the participants found it harder to solve the equations as soon as a letter was added to the equation, even though the operations which had to be used to solve the equation were the same as with the first equation, which 95% were able to answer correctly. Here it is observed that there were three types of wrong answers: four participants (20%) were not able to answer and left the answer field blank, one participant (5%) tried to divide with the variable ‘a’ on both sides instead of subtracting, and five participants (25%) gave ‘a’ a specific value thus simplifying the equation.

After playing the prototype, the participants were again presented with four equations, which they were asked to solve. To get an overview of the equations and the number of participants who gave right answers, see the table below:

	Equation 1	Equation 2	Equation 3	Equation 4
	$x + 4 = 2$	$x - 14 = 22$	$x - b = 0$	$5x = 30$
Number of right answers:	19/20 (95%)	20/20 (100%)	15/20 (75%)	19/20 (95%)

Again it is observed that the first, second and fourth equations were the equations that most participants were able to answer correctly. This time two out of 20 participants (10%) made an error or could not answer on the equations. One participant (5%) made an error in the first equation by adding 4 on both sides instead of subtracting. In equation two, every participant was actually able to solve the equation. In the fourth equation another participant (5%) answered 5 instead of 6. One could suspect this to be a typo

or a calculation error since the participant was able to answer all the other equations correctly, but this answer is still seen as an incorrect answer. Similar to the equations before playing the prototype, the third equation was the one that most participants had difficulties solving. This time five out of 20 participants (25%) made errors or were unable to answer. It was observed that there were three types of ways the participants failed to answer: one participant (5%) wrote a question mark in the answer field, which was interpreted as a blank field, meaning that the participant did not know the answer. Two participants (10%) multiplied with the letter 'b' on both sides instead of adding. Two participants (10%) gave a specific value to the letter 'b', thus simplifying the equation.

When comparing the mathematical test results from before and after playing the prototype, it is observed that the percentage of participants who were able to answer the equation types one and four was 95% before and after playing the prototype. When looking at equation two from before and after, the percentage of participants who can solve the equation correctly goes from 90% to 100%, meaning that more participants were able to answer this type of equation after playing the prototype. In equation three, the percentage of participants who were able to solve the equation correctly went from 50% to 75%, meaning an increase of 25% in the number of people who were able to solve this type of equation after playing the prototype.

By going more into detail and observing each individual participants' progress, some interesting results were picked out to describe their experience. To identify the participants from each other, the randomly generated six-letter name, which they used to connect the Google Form and the game, was used as a name. A participant with some interesting results was selected for further study. His progress can be seen in the graph below:

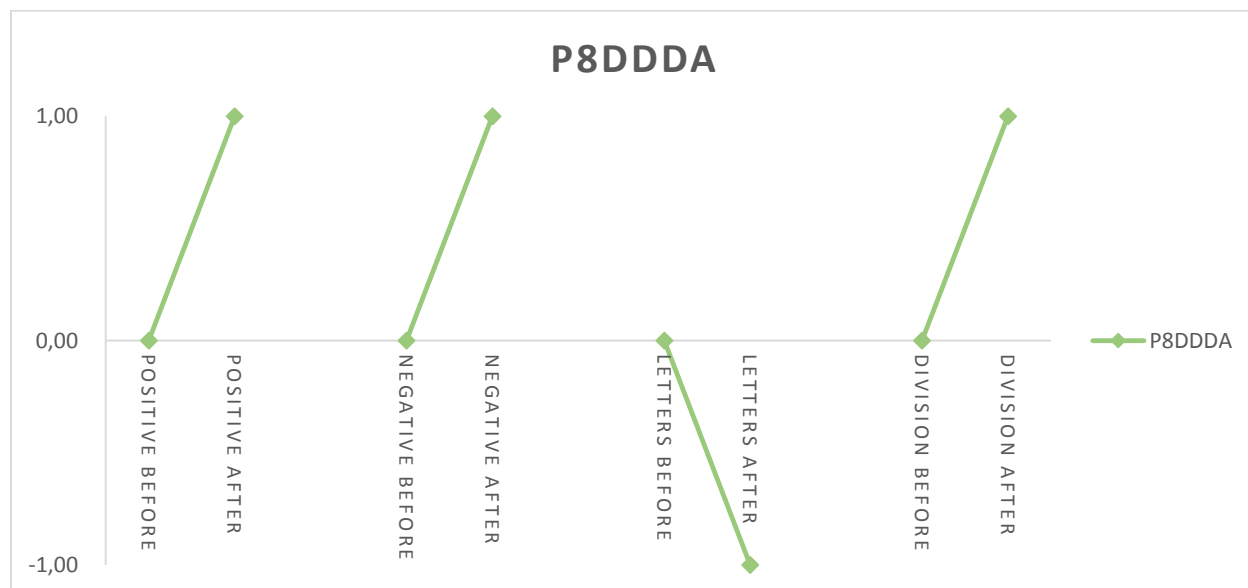


FIGURE 22 - GRAPH OF PARTICIPANT P8DDDA'S MATHEMATICAL RESULTS

In the graph the x-axis shows the different types of equations before and after the participant have played the prototype. On the y-axis it is seen whether their results were correct (=1), blank (=0) or incorrect (= -1). In this example we see that the test participant started out by answering all the equations before playing the prototype with a blank field. By reading the participant's comments, it was explained that the participant was not able to remember this kind of mathematics. As seen on the graph, the answers from the test participant changed after playing the prototype. Here he went from answering blank in all the equations to answering correctly in the first, second and fourth equation, and to answer incorrectly in the third equation. Other than the indication from the results showing that the participants' skills improved in three out of four equations types, it is also seen that he tried to answer the third equation instead of just leaving it blank. Based on observations from the test participant's own comments, he states that he felt like he had had his mathematical skills refreshed and that he had learned something from playing the prototype. When asked "What do you feel now?", which was a question implemented in connection with the continuation desire test, he answered:

*"I feel like I remember how algebra works now."* –Test Participant P8DDDA

So the test results show that this participant was able to answer 3 more equations correctly, and his comments also show that he felt like he learned something from playing the prototype.

By looking at the results, it is observed that 8 of the participants (40%) went from answering one or more equations incorrectly to answering correctly after playing the prototype. It was also observed that three of the participants (15%) went from answering correctly or with a blank field to answering one equation incorrectly. As mentioned earlier, this could be a calculation error, but it still shows that some participants went from answering a type of equation correctly to incorrectly. A table with the mathematical test results can be seen below:

	positive before	positive after		negative before	negative after		letters before	letters after		division before	division after
TPVD7P	1	1		1	1		1	1		1	1
BNQ9DZ	1	1		1	1		1	1		1	1
CFPTAQ	1	1		-1	1		1	1		1	1
W6AYHX	1	1		1	1		0	1		1	1
BLDM7Z	1	1		1	1		-1	1		1	-1
4UGNAZ	1	1		1	1		1	1		1	1
HL41H1	1	1		1	1		0	0		1	1
4A7UGS	1	1		1	1		1	1		1	1
TXW6HJ	1	1		1	1		-1	1		1	1
2R2HHH	1	1		1	1		1	1		1	1
UDKHD6	1	1		1	1		-1	-1		1	1
4173JB	1	1		1	1		1	1		1	1
2PJH24	1	-1		1	1		1	1		1	1
D8QU47	1	1		1	1		1	-1		1	1
THDM9H	1	1		1	1		-1	-1		1	1
H8ANLZ	1	1		1	1		-1	1		1	1
R5B9JV	1	1		1	1		-1	1		1	1
TZ6AC9	1	1		1	1		0	1		1	1
P8DDDA	0	1		0	1		0	-1		0	1
17G3GM	1	1		1	1		1	1		1	1

**FIGURE 23 - TABLE OF MATHEMATICAL TEST ANSWERS (1 = CORRECT, 0 = BLANK AND -1 = INCORRECT)**

The reason for some of the participants to go from answering correctly to incorrectly is unknown. Based on the amount of time the participants spent on the prototype, and the participants' comments, a guess could be that they were tired after the long test and thereby had a higher chance of making mistakes.

To see all the mathematical test results, see APPENDIX D – Mathematical test results.

## 7.2 The Engagement Sample Questionnaire

In the experiment all the participants answered the question “How many minutes do you think you have spent in the experience?”. The result for this question showed that the participants thought they used an average of 21.8 minutes on playing the prototype, ranging from 5 to 60 minutes. Data collected from 18 of the participants' play through showed that they on average used 32.5 minutes on playing the prototype, ranging from 5.75 to 66.5 minutes. By comparing the difference between the time used and the time guessed by the participants, it was observed that on average the participants guessed 9.27 minutes below the actual time, ranging from guessing 6.35 minutes above to 27.83 minutes below the actual time. Further observations showed that 5 participants (25%) guessed higher than the actual amount of time they used, and 13 participants (65%) guessed lower than the actual amount of time they spent. This could indicate that some of the participants lost track of time while playing the prototype, and that they did not feel that they had spent as much time playing the prototype as they actually did.

8 out of the 20 participants (40%) played the prototype all the way through and solved all ten equations. Out of these eight participants, six participants (75%) wanted to try the experience/application again, mainly because they liked the open world/sandbox aspect of the game, the story and liked solving the equations/puzzles. Out of the two participants (25%) who did not want to try again, one (12.5%) thought that there were too many questionnaires and felt stressed to finish the play through, the other (12.5%) felt that after understanding how the puzzles/equations worked, the prototype was boring.

12 out of the 20 participants (60%) did not play the prototype all the way through. Here two (16.7%) quit the game by closing the application, and ten (83.3%) answered no when asked if they wanted to continue playing. The reasons for the participants to quit were not always clear, but based on their comments throughout playing the prototype, the main reasons for participants to quit were: lack of time, stuck in an equation, game bugs/technical issues, got bored by equation progress, too many questions and the mouse control. Out of the twelve participants, six participants (50%) wanted to try again. The main reason for these six participants for wanting to try again was that they would like to spend more time on exploring the world, and that they wanted to solve more equations. Three of the twelve participants (25%) did not want to try the experience/application again. Out of these three, one participant (33%) did not want to try again because of the lack of sounds and stimulus, as well as an entity to interact with and which could explain the mission. Another participant (33%) felt intrigued by the prototype, but did not want to try again because of the lack of feedback, goals, story and mechanics. The last participant (33%) did not want to try the prototype again because the participant was at work. The last three out of the twelve participants (25%) neither disagreed nor agreed to wanting to try the experience/application again. Two

of these participants (66%) answered that they did not know why, and one (33%) answered that it (the prototype) seemed fun, but had too many bugs.

To sum up, twelve participants (60%) wanted to try the experience/application again, five (25%) did not want to try again, and (15%) did not know if they wanted to try again.

### 7.2.1 Continuation Desire

To give an overview of the continuation desire for each participant, graphs which plot the participants' desire to continue through their playing experience, were made. All the plots can be seen in APPENDIX E – Continuation Desire scatter plots.

To see an example of different reactions to the prototype, the scatter plot below was made to compare the different experiences:

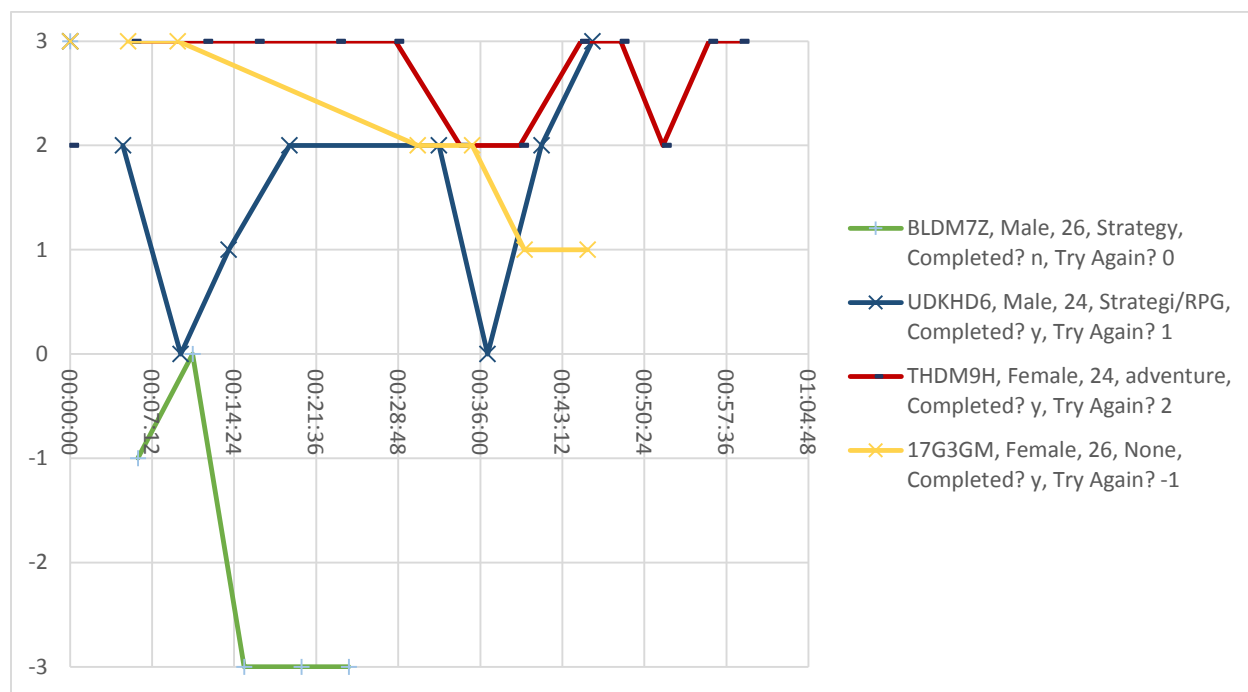


FIGURE 24 - CONTINUATION DESIRE EXAMPLE

In the figure the experience of four participants can be observed. The numbers on the vertical axis indicate how much the participant agreed with the statement “I want to continue the experience now!” where -3 indicated “Disagree strongly”, 0 indicated “Neither disagree nor agree” and 3 indicated “Agree strongly”. The four participants were chosen based on the fact that they had four different experiences with the prototype. The participants were asked to state how willing they were to continue the experience and were asked why. These questions were asked at three different points: Before playing the prototype, every third minute during the participant’s play through (all though this might be different from each

participant as the questionnaire would not show up while a participant was solving an equation), and finally after the participant was done with the prototype. The four participants' answers can be observed below:

<b>BLDM7Z:</b> Male, 26, Favourite Genre/Game: Strategy, Completed? No, Try Again? 0	
<b>I want to begin the experience:</b> Agree strongly. "Curiosity about that this test is about."	
<b>I want to continue the experience now! :</b>	
<b>05:57:</b> Disagree a little.	"I am a bit confused about what I have to do. "
<b>10:45:</b> Neither disagree nor agree.	"I just got to a new area where I have not been before. I want to see if it is any different compared to the previous area."
<b>15:17:</b> Disagree strongly.	"I am stuck inside a fence and I cannot escape from there."
<b>20:19:</b> Disagree strongly.	"I am stuck below a mountain. I can't figure out how to get out."
<b>24:28:</b> Disagree strongly.	"I can't continue any more. I am really stuck below the mountain now...."
<b>I want to try again! :</b> Neither disagree nor agree. "It seemed fun, but the game had a lot of bug issues. I am interested in playing again another time in the future."	
<b>UDKHD6:</b> Male, 24, Favourite Genre/Game: Strategy/RPG, Completed? Yes, Try Again? 1	
<b>I want to begin the experience:</b> Agree strongly. "Im always up for a experience"	
<b>I want to continue the experience now! :</b>	
<b>04:38:</b> Agree moderately.	"I want to try out and see what this game is about"
<b>09:42:</b> Neither disagree nor agree.	"Still quite dont know.what i am supposed to do"
<b>13:55:</b> Agree a little.	"Running around.trying to figure out what i am supposed to do."
<b>19:15:</b> Agree moderately.	"Something happend when i put the two cicles together."
<b>32:22:</b> Agree moderately.	"I think i found out.how im going to complete the puzzles"
<b>36:38:</b> Neither disagree nor agree.	"Im facing a puzzle.where its seems to be not working. Everytime I move a circle ore a square from the bottom, it stops moving anything else."
<b>41:22:</b> Agree moderately.	"Im solving puzzles. I found out the green stuff is important to read.cause it gives me good solutions and clues."
<b>45:50:</b> Agree strongly.	"I think its funny.now that i know.where i need to go and what to do with the puzzles."
<b>I want to try again! :</b> Agree a little. "I want to try this again, because i now know what to do. And i like little puzzles, that is funny and can challenge me."	
<b>THDM9H:</b> Female, 24, Favourite Genre/Game: Adventure, Completed? Yes, Try Again? 2	
<b>I want to begin the experience:</b> Agree moderately. "I want to see what is acquired and if it motivates me"	
<b>I want to continue the experience now! :</b>	

<b>05:29:</b>	Agree strongly.	"I want to figure out how to get to solving the puzzles"
<b>11:47:</b>	Agree strongly.	"I got in to a puzzle and accidentally got something right.need to see further to know why it was right so i know what to do next"
<b>16:17:</b>	Agree strongly.	"I found out that after solving the first puzzle i got 1/10 showing on the top left corner.that gives me the idea that there is 9 more to go and i want to find them"
<b>23:25:</b>	Agree strongly.	"I got a little stuck with a puzzle so i need to of course continue to see if i can solve it. i'm not a quitter"
<b>28:33:</b>	Agree strongly.	"I need to find the next blue glimpse since i have learnt that that is where the puzzles are"
<b>34:13:</b>	Agree moderately.	"I am stuck in a puzzle again. I put the filled shapes on the top of the blank ones and sometimes they disappear sometimes they don't"
<b>39:29:</b>	Agree moderately.	"I got stuck in a puzzle and thought i will try another one that was next to it but i found out that i get just as stuck in that one.don't know really why it is like that. i would like to know why i don't proceed so i must continue"
<b>44:50:</b>	Agree strongly.	"I figured out that i was trying to solve thepuzzle right but it was hard to get the shapes alligned so i didn't get further.at least i think so. gave me more trust in myself that i am doing some progress"
<b>48:19:</b>	Agree strongly.	"I am in another cave and what to solve a puzzle"
<b>52:01:</b>	Agree moderately.	"I got a huge chock for putting two shapes together because of the game sounds"
<b>56:05:</b>	Agree strongly.	"i have 9/10 puzzles solved so of course i want to know what happens when i have solved the last one"
<b>58:50:</b>	Agree strongly.	"i see the last puzzle"
<b>I want to try again! :</b> Agree moderately. "it was interesting and captivating. i was little confused at times, but i would really like to know how the story continues."		
<b>17G3GM:</b> Female, 26, Favourite Genre/Game: None, Completed? Yes, Try Again? -1		
<b>I want to begin the experience:</b> Agree strongly. "I'm thrilled to see what this is"		
<b>I want to continue the experience now! :</b>		
<b>05:05:</b>	Agree strongly.	im curious
<b>09:27:</b>	Agree strongly.	It is exciting
<b>30:31:</b>	Agree moderately.	I want to know more about the inverse of a
<b>35:17:</b>	Agree moderately.	are there more than the inverse of a and the squares and the balls
<b>39:53:</b>	Agree a little.	are there more than what I already figured out
<b>45:25:</b>	Agree a little.	find the last two puzzles



**I want to try again!** : Disagree a little. “I understood the concept from the beginning, and it became a little too easy in the end.”

If the reader would like to look more into the CSV files and the Google Form results, instructions may be found in APPENDIX G – Data on DVD.

### 7.3 Errors and Improvements

By reading through the comments of the participants, some ideas and technical corrections came to mind. From these comments a list of errors and improvements was made, categorizing the comments into Player Control comments, Equation System comments, World/Environment comments, and technical/bug comments:

Player Control	Equation System	World/Environment	Technical/Bugs
Mouse sensitivity should be adjustable.	The system should offer more variety in the type of equations.	The player should be able to keep the messages, so they can look at them at any time.	Players fell out over the edge of the world.
Mouse should cap to the game window.	There should be a more elaborate guide for using the equation system.	The game world variables and the equation system variables should be more connected.	Players fell through the mountain floor.
		The environment should offer more variation.	Players got stuck in the mountain.
		The game should adapt more to the player, participants had very different experiences of how easy the equations were to find.	Players got stuck inside the equation fence
		The world should offer a more guided start for the player, for them to feel less confused in the beginning.	
		It would be nice to have a map for navigation	

FIGURE 25 - LIST OF CATEGORIZED ERRORS AND IMPROVEMENTS.

## 8 Discussion

In this section different elements from the background, design and experiment chapters will be discussed in relation to the results presented in the previous chapter. This will lead up to the conclusion of this project.

### 8.1 Equation system

As part of the project and this paper, an equation system was designed and implemented based on algebra from a Danish textbook for high schools and the learning game DragonBox. To test the equation system, a white box unit test was conducted, and a small test group of three people tested the interaction and usability of the system. This was a very superficial test and was only designed to eliminate major bugs and usability faults that the system may have had. The idea behind the equation system was to make the design of it user-friendly enough for the participants to be able to use it, while not giving away all instructions as the idea was for the participants to walk around the world and find notes to understand the whole system. It was therefore also expected that some participants might experience difficulties in understanding the system, but at the same time it was hoped that the participants would still try to walk around the world and by doing so achieve an understanding of the equation system. However, despite the small pre-test of the equation system, some participants thought that the prototype had crashed or was frozen when the players began to drag a variable in from the bottom of the screen. The equation system worked in the way that if a person dragged a variable into the equation, they were not allowed to do anything before they had dragged a variable of the same type to the other side as well (to create balance between the two sides). To help the user, a message was displayed early on in the game that told the user about the principle of balance and that the user should add to both sides. The problem with this solution was that not all users found this message before they made it to the type of equation where the user would have to add new variables to the equation.

The prototype developed for this project may be characterized as a small conceptual prototype, and the testing that was carried out showed that it has the potential of creating continuation desire within players, but it would require more usability testing to find a more suited balance between guiding the user through the equation system and letting the user figure it out for themselves by exploring the world.

### 8.2 World generation

Due to the few resources and the limited time available for the implementation of this prototype, it has not been possible to create a big and detailed world for the player to explore. Instead, a world generator was implemented in order to give the player an illusion of having a free roaming environment to explore. Even though the prototype was a small proof-of-concept prototype, the world generator was implemented with the possibility of expansion in mind. The world would generate around the user by using a finite number of planes, which were selected based on certain criteria such as how many of the

planes should be shown and how probable it was for that particular plane to be selected. This was a simple way to generate an environment for the user to explore, but improvements could be made. Many participants in the experiment became confused, and some felt lost when walking around the environment. Even though it was intentional that the environment should feel mysterious and the players should get the feeling of being lost in a dark forest, it was not the intention to have them feel totally lost and disoriented. Because the world generation is randomly generated, more time should be invested in testing to discover those unique problems, which may occur. Some of these problems were experienced during the initial test where some of the planes would overlap the mountain cave and were removed. Based on the comments from the experiment, this problem still seemed to occur to one participant who was stuck in the caves due to some overlapping of planes.

### 8.3 Narrative

The goal has been to create a prototype which has a high level of continuation desire from the users. To achieve an engaging prototype, emergent narratives were researched and elements which could achieve emergent narrative were considered and added in the design of the prototype. To achieve emergent narrative, elements of abstractness were used when creating the narrative. The backside to this solution is that many of the participants started the experience by feeling very confused, and the majority of the participants were more focused on finding and solving the equations around the world than exploring the narrative. To create an overall goal for the audience and to help achieve emergent narrative, a goal of solving ten equations was added to the prototype to create an objective and create something which would encourage the audience to explore the world. It could be discussed that this backfired and made the audience focus more on solving the equations than experiencing the narrative. However, it has also been an aim of the prototype to facilitate mathematical learning, and in this respect the prototype has then been successful.

One of the ways that the narrative and game world tried to achieve emergent narrative and include the mathematical elements was to implement a simple AI with animal-like behaviour, which should also give the illusion of something happening in the world. Many participants were intrigued by the narrative, and some even started to make up new elements of the narrative which were not in the written narrative. These elements were not written anywhere in the game world, but were elements that the author had hoped the audience would create themselves.

### 8.4 Experiment

The experiment for the prototype was designed to be easily distributed to participants by making the data collection upload the results to a server. This worked almost without problems, but was still not an optimal solution as there were still many bugs in the prototype. Here it would have been nice for the test conductor to be at the same location as the participant to help when a bug occurred and to help them through the experiment.

In the experiment there were no specific criteria to be met by the participants, as the main goal was to look at continuation desire. With this said, it would have been interesting to test the prototype on Danish high school students to see how they would react to the prototype and to see if they would learn more from playing it. This was considered during the project, and a high school teacher was also contacted to see if it would be possible to test the prototype on their students. Sadly, this was not possible due to the students having projects and exams during the period when the prototype was finished and ready for testing.

The experiment was designed to measure continuation desire and used the method described in “Hooked!: Evaluating Engagement as Continuation Desire in Interactive Narratives”. This method involved presenting a questionnaire to the user in mid-game, thereby stopping the user in the middle of their play through to see if they felt like continuing. In the article, the interactive application First-Person Victim, which was first used to test the method, consisted of events where the user would be presented with the questionnaire after these event. In the prototype of this thesis, the events were not that clear, and therefore it was decided to present the user with the questionnaire every third minute. However, some participants in the experiment were complaining about too many questionnaires. Therefore, with the benefit of hindsight a better solution to this could be for the questionnaires to be shown after specific events, e.g. when the user has solved an equation or when they have left a specific location such as the house or the caves. More research should be conducted that look into flow in stories and games, and the questionnaires’ appearance in the prototype should have been designed according to this.

## 8.5 Results

Even though the results of the experiment indicate that many of the participants improved their mathematical algebraic skills after playing the prototype, a more detailed mathematical test should be conducted to establish whether the prototype helped the participants. To this should be added that several participants were already able to solve the equations before playing the prototype, and so with these participants it was not possible to document any progress in their mathematical skills.

It should be noted that there is still much data to analyze from the experiment. Among other things, it would be interesting to analyze the results from the engagement sample questionnaires with reference to activities, accomplishments and objectives.

## 9 Conclusion

This project has been concerned with finding a way to transmediate the mathematical topic of algebra into an interactive emergent narrative experience which would give users the desire to continue the gaming experience despite the elements of mathematics in the game. The problem statement on which this project has been based is therefore:

“How can an early prototype be developed whose purpose is to facilitate the learning of the mathematical subject of algebra, and which is based on the theories of transmediation and emergent narrative in order to create a continuation desire?”

Research was conducted on the question of how to transmediate a subject from a passive medium into an interactive medium. Furthermore, to support the transmediation of the subject of algebra, research was also done on elements which needed to be considered when creating a narrative as well as requirements for emergent narratives.

The prototype which was implemented fulfilled all the points on the list of things that were characterized as “need-to-have” and also to some extent the requirements labelled as “nice-to-have”. Consequently, the prototype included among other things, a basic algebra system, an open world for the player to explore, narrative connected events, a simple drama manager, and an environment that changed according to the player’s actions.

The test, which was conducted on 20 participants, indicated that some of these participants had achieved some level of improvement in their algebraic skills. However, a more detailed test would have to be conducted to confirm this hypothesis. Furthermore, a test should also be conducted on participants with a lower level of algebra skills in order to get more feedback and to achieve a more solid foundation on which to measure progress. The test also showed that many participants enjoyed playing the prototype and both had the desire to continue playing and to play the prototype again. The test showed, however, that the prototype still needs work to make users keep playing, and many technical and usability improvements are needed.

On the basis of the test, it is my belief that the prototype holds promise and that with more improvements to the mathematical and narrative aspects, it would be possible to achieve an interactive application which can teach users algebra and perhaps even more advanced mathematics through emergent narrative.

## 10 Future works

Even though the mathematical test showed improvements in many of the participants' algebra skills, a more detailed test would be interesting to conduct to verify the hypothesis that the prototype could improve the algebra skills of the participants. The experiment resulted in a large amount of data to analyze. It would be interesting to analyze the results from the engagement sample questionnaires with reference to activities, accomplishments and objectives. It would also be interesting to look further into the data collection from the participants' play through, in order to connect their actions and whereabouts with their continuation desire results.

The prototype was implemented with the possibility of expansion in mind, and therefore the next step could be to add more levels of equations, more events to happen in the game world, and a more dynamic environment for the user to explore. Here the world generator, which also worked as a simple drama manager, could be improved and should be combined with more events to make the user achieve a richer narrative experience. As a start, the prototype's event system could include the meteorite event, which is supposed to instantiate a falling meteorite above the player. The meteorite is supposed to fall to a random tile in the world and trigger even more events at that location.

The equation system should be improved so that the interface would offer more guidance to the player. An example of this would be the dragging of variables. A way to improve this would be to show visual indications to the player, e.g. after placing a variable on one side of the equation, the other side would blink as a way to show the player that a variable of a similar type should be placed on the other side as well. More advanced algebraic operations could be added to the system such as division and calculations with parentheses.

To make the players achieve a deeper emergent narrative experience, further research should be conducted on the subject, and in this connection it could be interesting to look at the way First Person Victim achieves emergent narrative based on their "Interactive Dramatic Experience Model". Furthermore, additional elements from the emergent narratives requirements list by Aylett and Louchart could be added to the prototype.

After improving the prototype, it would be very interesting to test it on some first year high school students and even elementary students to see if it could help them improve their algebra skills.

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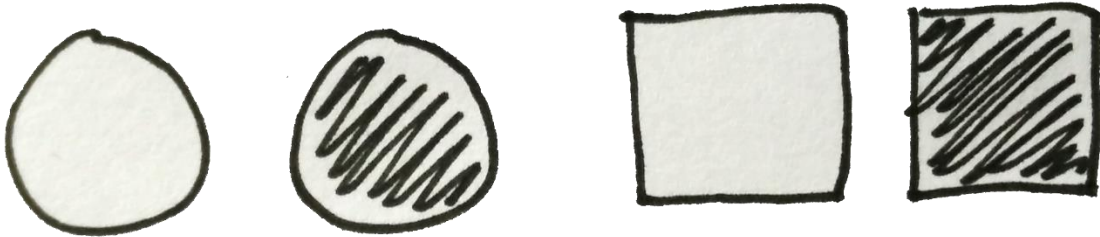
### Frontpage Image:

[http://washington.spps.org/uploads/algebra\\_cartoon\\_2.jpg](http://washington.spps.org/uploads/algebra_cartoon_2.jpg) (accessed 19-12-2015)

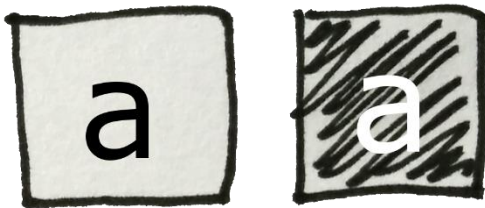
## 12 APPENDIX A – Pictures used for the prototype

Here the pictures which were used for the prototype.

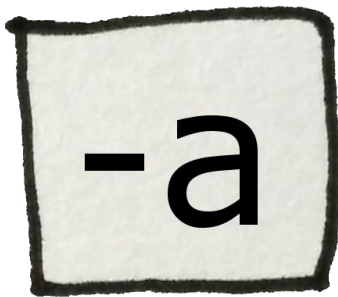
**The Variables:**



**The Variables with letters 1:**



**The Variables with letters 2:**



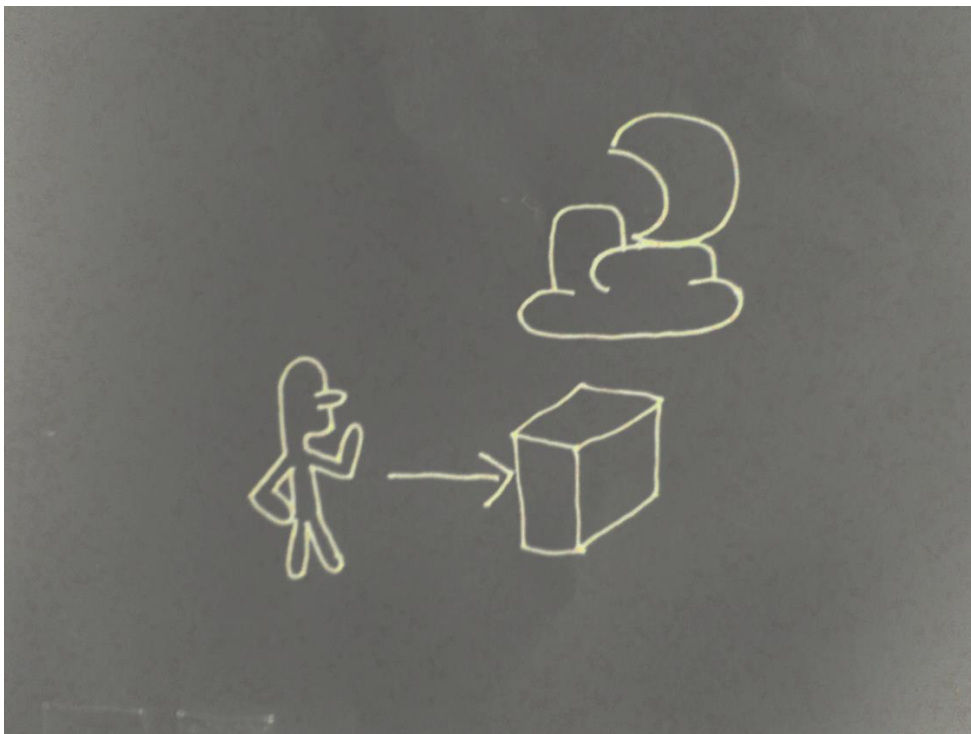
**The Exit Button:**



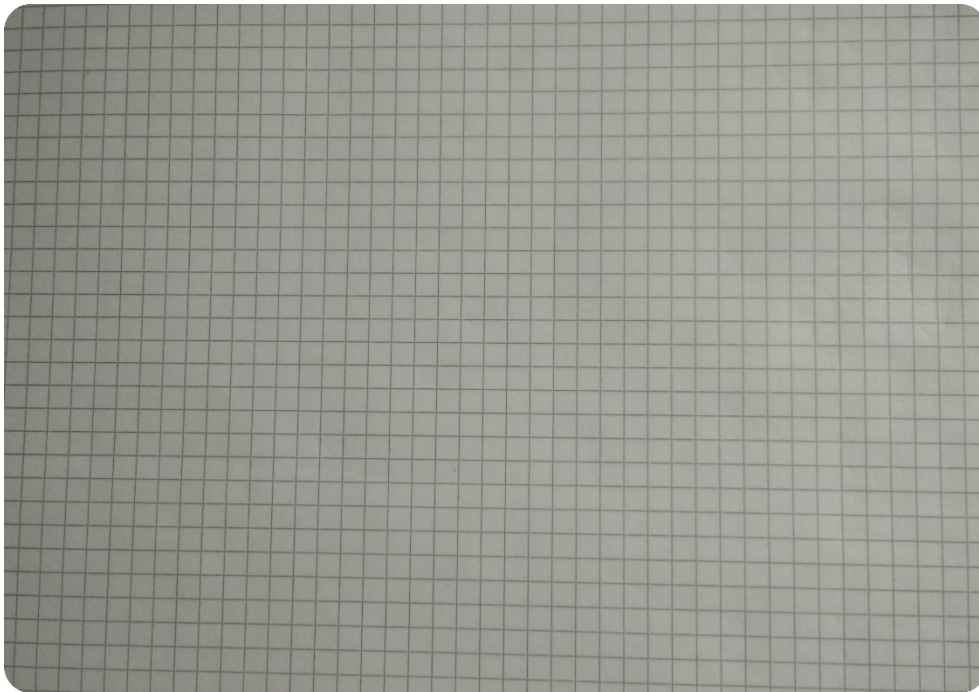
**The Equation level Indicator:**



**Picture used for the cave wall:**



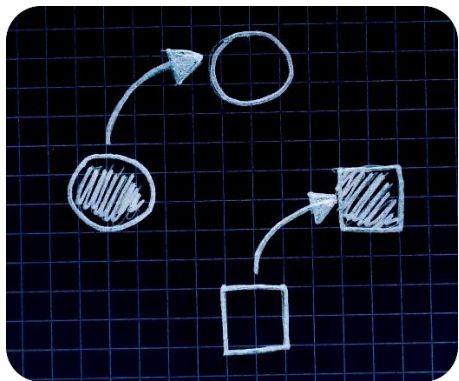
Background for the equation system:



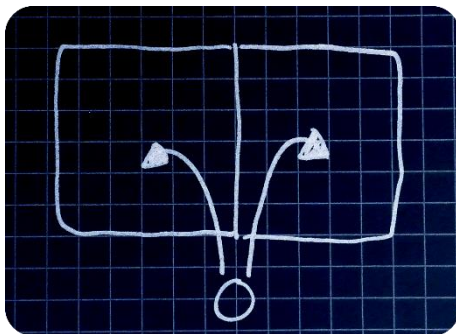
Sprite sheet for the objects used for the equation system:



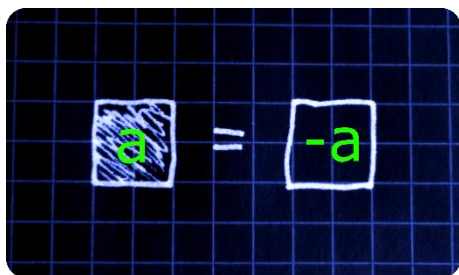
Message images:



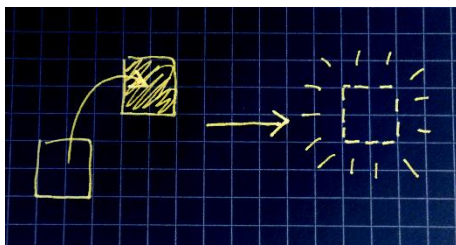
EquationHelper0



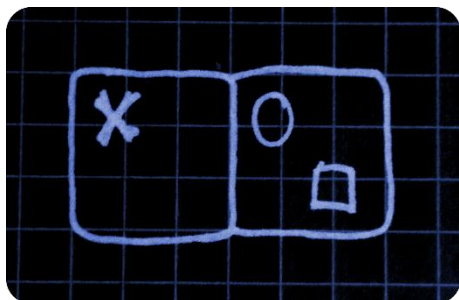
EquationHelper1



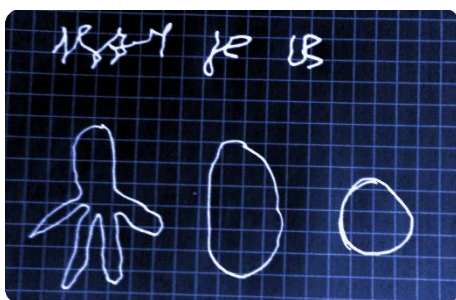
EquationHelper2



EquationHelper3



EquationHelper4



History0

## 13 APPENDIX B – Messages from CSV file

The text below is from the Messages.csv used in the prototype:

1. Message,It seems as if the world square and ball creatures are connected to the laws of the paper.
2. Message,Some of the creatures are still free to jump around, but I have found many that are trapped and can only be released by solving the puzzles on the paper in front of them.
3. Message,I have been able to solve some of the puzzles by isolating the X on the left side of the papers.(img)EquationHelper4(/img)
4. Message,My observations show that each shape have an inversed shape(img)EquationHelper0(/img)
5. Message,You can only keep balance by adding on both sides(img)EquationHelper1(/img)
6. Message,These creatures...(n)I don't think this is how they have always looked like.
7. Message,When combining the opposite shapes, they disappear(img)EquationHelper3(/img)
8. Message,I can no longer tell if it is day or night anymore. It must have been months since I last saw the sun.
9. Message,I have now seen a new square type multiple times, but only on the paper. This new type of square have the letter A writte on it, but acts like a normal square.
10. Message,Weird...(n)When I woke up today, my body felt so stiff...it took several minutes before I could fully move my arms and legs.
11. Message,Yesterday I figured out that the inversed of A is both the black A and - A:(img)EquationHelper2(/img)
12. Message,It is getting worse.(n)My limbs are getting more stiff for each day, and I could swear that my arms are starting to change shape.(n)Am I starting to see things?
13. Message,I can no longer use my right hand! Or should I say, what's left of it.(n)My right hand have turned shape. My fingers have grown together and I am unable to squeeze my hand.
14. Message,I am so close to finding the answer!(n)I just hope I finish my research before I lose the ability to write any more letters.
15. Message,(You can just barely understand the letter)(n)(n)This will be my last letter.(n)My hands have now completly turned, and I can barely write this letter.(n)I don't even know if anybody have found my letters.(n)If you are reading this, I hope you succeed where I have failed.(n)Good luck my friend!
16. Message,(You can't read this, it just look like a childs drawing)(img)History0(/img)

## 14 APPENDIX C – Equations from CSV file

The text below is showing the equations from the equations.csv file used in the prototype:

```
1,var;A;true;LeftSide,var;A>false;LeftSide,var;B>true;RightSide,var;B>true;RightSide
1,var;B>false;LeftSide,var;B>true;LeftSide,var;A>true;RightSide,var;A>true;RightSide
1,var;B>false;LeftSide,var;B>true;LeftSide,var;A>true;LeftSide,var;A>false;LeftSide,var;B
;true;RightSide,var;A>true;RightSide
2,var;A>true;LeftSide,var;B>true;RightSide,var;B>true;RightSide,butt;A>false>false
2,var;B>true;LeftSide,var;B>true;RightSide,var;B>true;RightSide,butt;B>false>false
2,var;B>true;LeftSide,var;A>true;LeftSide,var;B>true;RightSide,butt;B>false>false,butt;A;
false>false
2,var;B>true;LeftSide,var;B>false;LeftSide,var;A>true;LeftSide,var;B>true;RightSide,butt;
A>false>false
3,var;B>true;LeftSide,var;C>false;LeftSide,var;B>false;LeftSide,var;C>true;LeftSide,var;B
;true;RightSide,var;B>true;RightSide
3,var;C>true;LeftSide,var;B>false;LeftSide,var;B>true;LeftSide,var;B>true;RightSide,var;A
;true;RightSide,butt;C>false>false
3,var;C>true;LeftSide,var;B>true;LeftSide,var;B>true;RightSide,var;A>true;RightSide,butt;
C>false>false,butt;B>false>false
3,var;C>true;LeftSide,var;A>true;LeftSide,var;B>true;RightSide,var;A>true;RightSide,butt;
C>false>false,butt;A>false>false
4,var;B>true;LeftSide,var;D>false;LeftSide,var;B>false;LeftSide,var;D>true;LeftSide,var;B
;true;RightSide,var;B>true;RightSide
4,var;D>true;LeftSide,var;B>false;LeftSide,var;B>true;LeftSide,var;B>true;RightSide,var;A
;true;RightSide,butt;D>false>false
4,var;D>true;LeftSide,var;B>true;LeftSide,var;B>true;RightSide,var;A>true;RightSide,butt;
D>false>false,butt;B>false>false
4,var;D>true;LeftSide,var;A>true;LeftSide,var;B>true;RightSide,var;A>true;RightSide,butt;
D>false>false,butt;A>false>false
```

## 15 APPENDIX D – Mathematical test results

Results from before playing the prototype:

Participant ID	$x + 1 = 9$	$x - 6 = 8$	$x + a = 4$	$2x = 10$
TPVD7P	$x=8$	$x=14$	$x=4-a$	$x=5$
BNQ9DZ	$x = 8$	$x = 14$	$x = 4 - a$	$x = 5$
CFPTAQ	$x = 8$	$x = 10$	$x = 4 - a$	$x = 5$
W6AYHX	$x=8$	$x=14$		$x=5$
BLDM7Z	8	14	2	5
4UGNAZ	$x =8$	$x = 14$	$x =4 - a$	$x = 5$
HL41H1	$x = 8$	$X= 14$	$X = ?$	$X = 5$
4A7UGS	$x=8$	$x=14$	$x=4-a$	$x=5$
TXW6HJ	$x=8$	$x=14$	$x=4/a$	$x=5$
2R2HHH	$x=8$	$x=14$	$x=4-a$	$x=5$
UDKHD6	$x = 8$	$x = 14$	$x = 2 - a = 2$	$x = 5$
4173JB	$x=8$	$x=14$	$x=4-a$	$x=5$
2PJH24	$x = 8$	$x = 14$	$x = 4 - a$	$x = 5$
D8QU47	$x=8$	$x=14$	$x=4-a$	$x=5$
THDM9H	$x = 8$	$x = 14$	$x = 3$	$x = 5$
H8ANLZ	$x = 8$	$x = 14$	$x = 2, a = 2$	$x = 5$
R5B9JV	$x=8$	$x=14$	$x=4$ if $a=0$	$x=5$
TZ6AC9	$x=8$	$x=14$		$x=5$
P8DDDA				
17G3GM	$x=8$	$x=14$	$x=4-a$	$x=5$

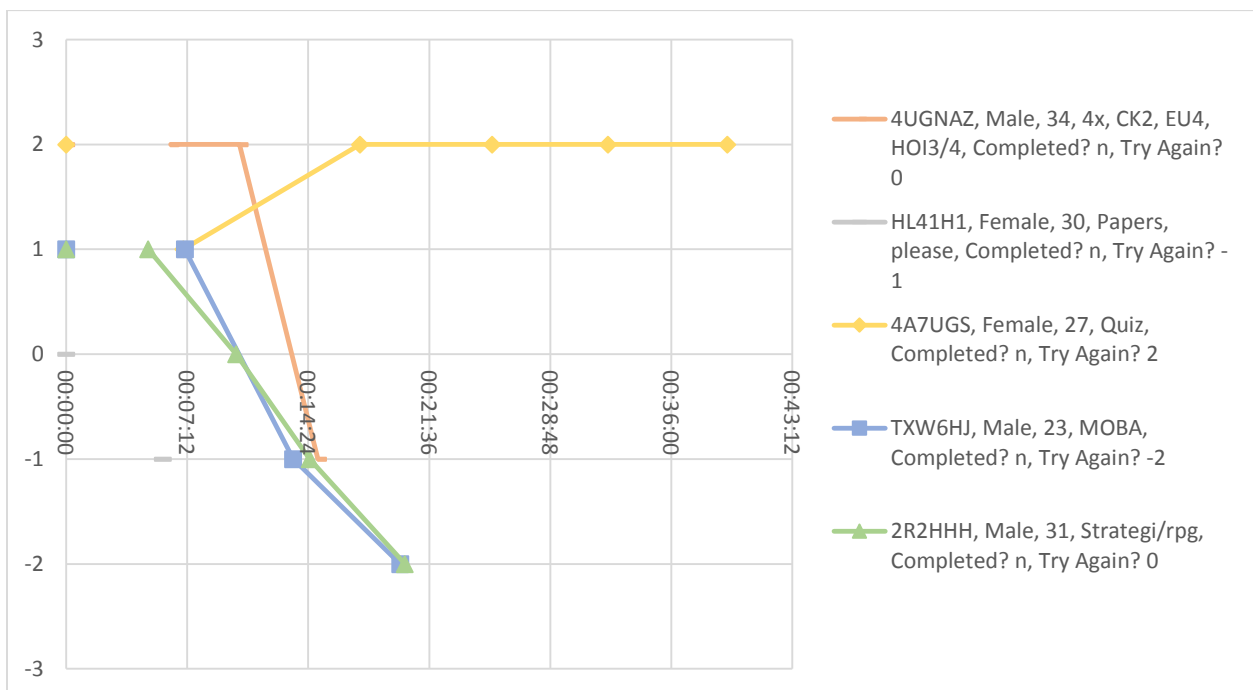
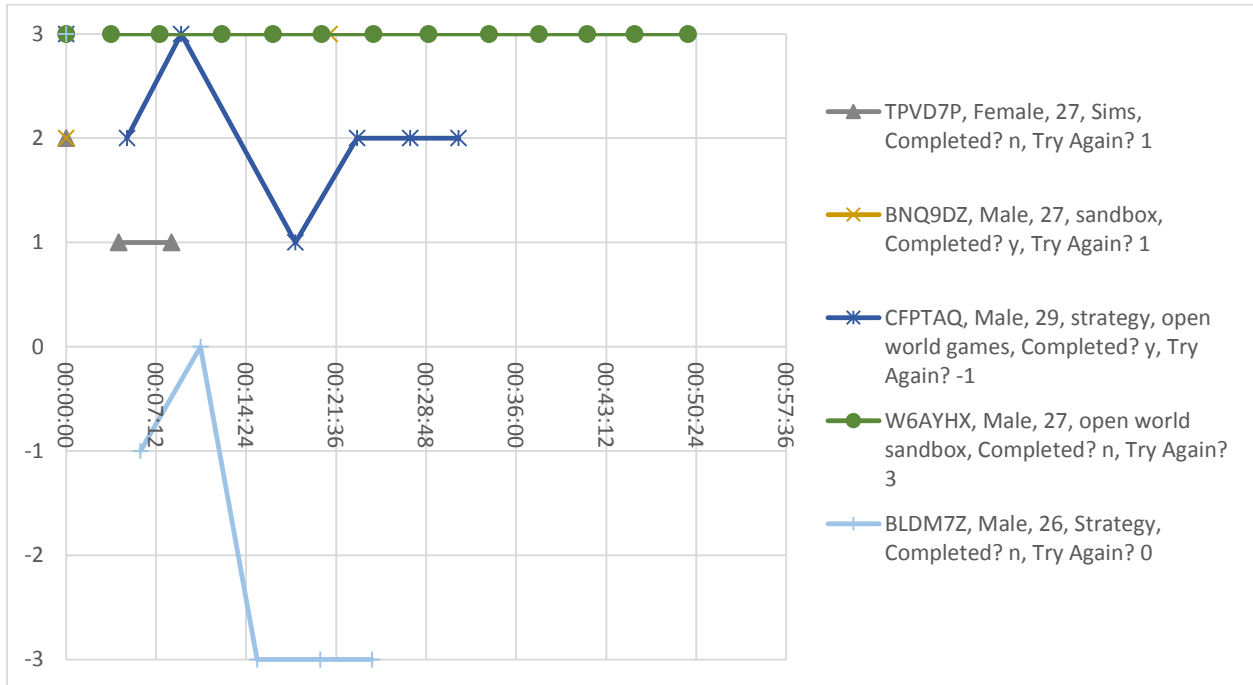


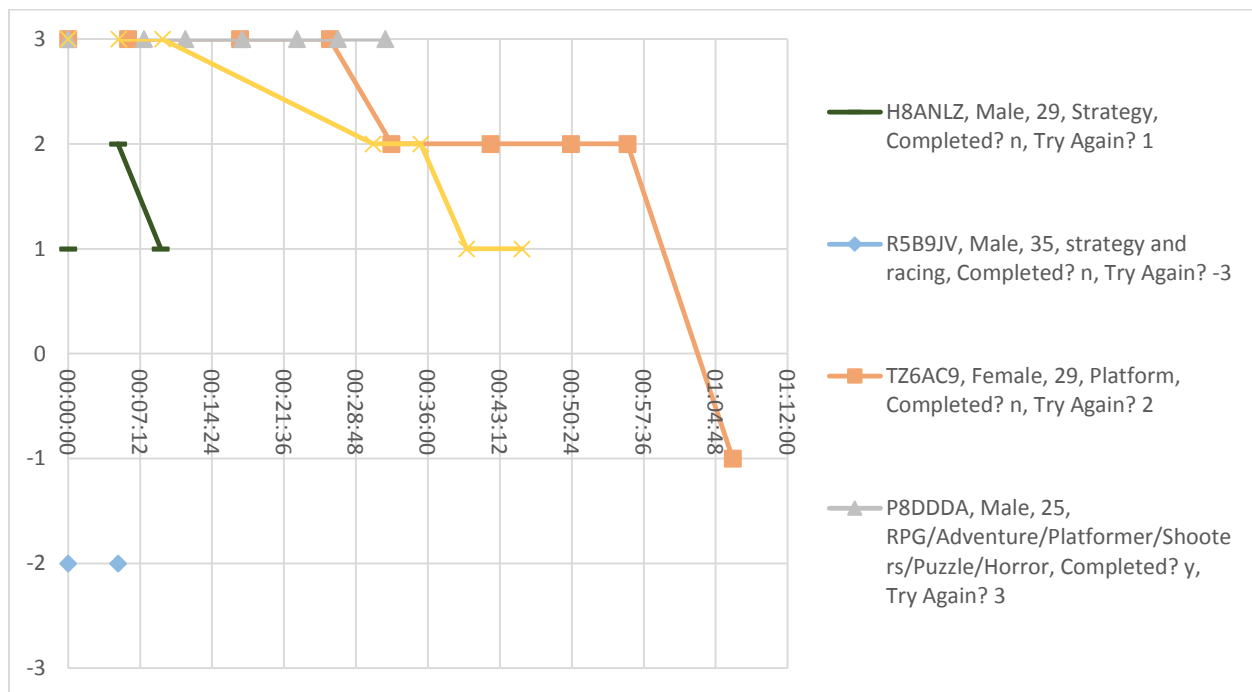
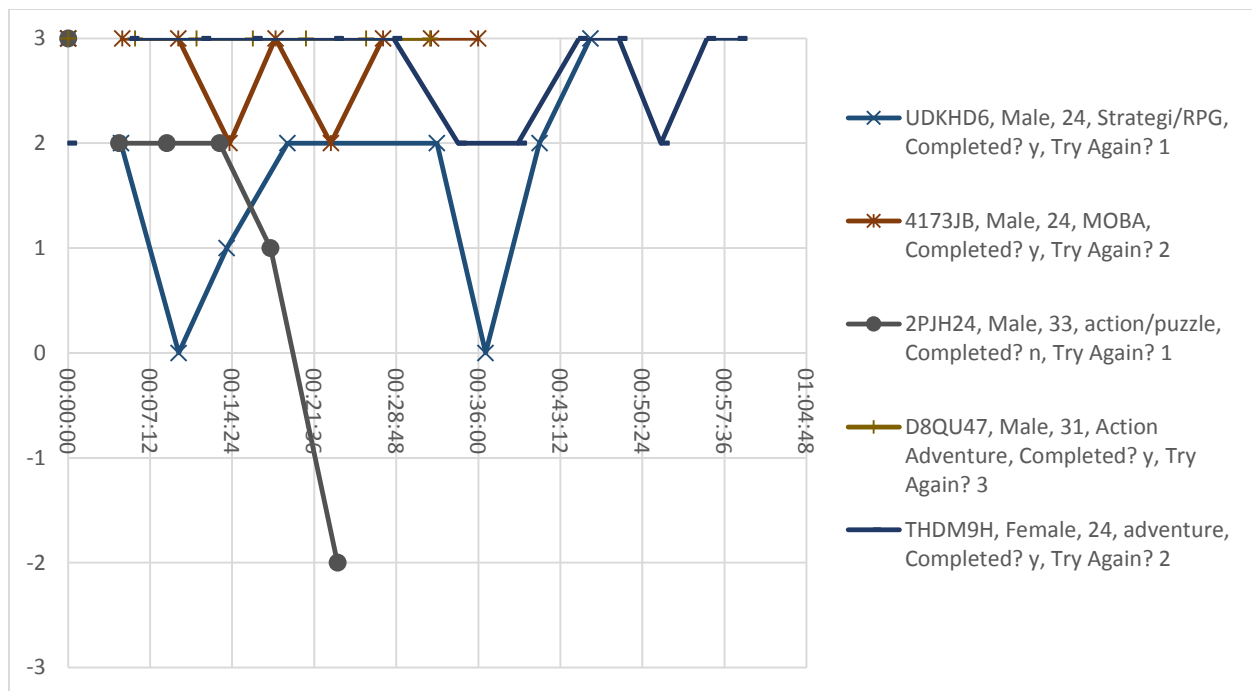
Results from after playing the prototype:

Participant ID	$x + 4 = 2$	$x - 14 = 22$	$x - b = 0$	$5x = 30$
TPVD7P	$x=-2$	$x=36$	$x=b$	$x=6$
BNQ9DZ	$x = -2$	$x = 36$	$x= b$	$x = 6$
CFPTAQ	$x = -2$	$x = 36$	$x = 0 + b$	$x = 6$
W6AYHX	$x=-2$	$x=36$	$x=b$	$x=6$
BLDM7Z	$x = -2$	$X = 36$	$x = b \text{ and } b = x$	$x = 5$
4UGNAZ	$x = -2$	$x = 36$	$x = b$	$x = 6$
HL41H1	$X = -2$	$X = 36$	$X = ?$	$X = 6$
4A7UGS	$x=-2$	$x=36$	$x=b$	$x=6$
TXW6HJ	$x=-2$	$x=36$	$x=b$	$x=6$
2R2HHH	$x=-2$	$x=36$	$x=b$	$x=6$
UDKHD6	$x = -2$	$x = 36$	$x = 0 - b = 0$	$x = 6$
4173JB	$x=-2$	$x=36$	$x=b$	$x=6$
2PJH24	$x = 6$	$x = 36$	$x = b$	$x = 6$
D8QU47	$x=-2$	$x=36$	$x=0b$	$x=6$
THDM9H	$x = -2$	$x = 36$	$x = 2$	$x = 6$
H8ANLZ	$x = -2$	$x = 36$	$x = b$	$x = 6$
R5B9JV	$x = -2$	$x=36$	$x = b$	$x=6$
TZ6AC9	$x= -2$	36	$x=0+b$	$x=6$
P8DDDA	$x = -2$	$x = 36$	$x = 0b$	$x=6$
17G3GM	$x=-2$	$x=36$	$x=b$	$x=6$

## 16 APPENDIX E – Continuation Desire scatter plots

The graphs below show the participants' continuation desire while playing the prototype, the numbers have following meaning: -3 = Disagree strongly, -2 = Disagree moderately, -1 = Disagree a little, 0 = Neither disagree nor agree, 1 = Agree a little, 2 = Agree moderately, 3 = Agree strongly.





## 17 APPENDIX F – Google Form Questionnaire

### Test

In this test, You will play a prototype which was created to include elements of mathematics. In the prototype you as a player will have to walk around and explore the environment.

There will be some questions before, during and after playing the prototype.

PLEASE NOTICE:

The test can only be completed on a Windows PC and takes approximately 15-30 minutes.

**\*Required**

1. **Gender \***

Mark only one oval.

- ☐ Male  
☐ Female

2. **Age \***

.....

3. **How many hours a week do you play video game? \***

.....

4. **What is your favourite game/genre? \***

.....

5. **Please indicate below the extent to which you agree or disagree with this sentence: "I want to begin the experience" \***

Mark only one oval per row.

	Disagree strongly	Disagree moderately	Disagree a little	Neither disagree nor agree	Agree a little	Agree moderately	Agree strongly
Answer	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

6. **What makes you want/not want to begin? \***

.....

.....

.....

.....

Try to solve the following equations (write answers in the form of:  $x = 2$ ) and if you are not able to solve it, just leave the answer field blank.

7.  $x + 1 = 9$

---

8.  $x - 6 = 8$

---

9.  $x + a = 4$

---

10.  $2x = 10$

---

## Now play the game

You control the character with the W,A,S and D key, and look around with the mouse. You can interact with certain objects (usually the ones that glow in blue or green colour) by pressing F, and it will say so on the screen.  
(Headset and a mouse is recommended)

Go to the next page when the game tells you to.

Download for Windows:

<https://dl.dropboxusercontent.com/u/6554334/MasterProject/MasterProjectThais.zip>

1. Download the file
2. Find the file and unzip it (by right-clicking and choose the unzip)
3. Run the MasterProject file (for best performance, change Graphics quality to Fast and keep screen resolution to 1024x768)
4. After getting the code in the prototype, press ALT+TAB
5. Write the Code below
6. Go back into the prototype and play

11. **Please write the code which is written on the screen in the prototype: \***
- 

## After playing the prototype

12. **Please indicate the extent to which you agree or disagree with this sentence: "I want to try again!" \***

*Mark only one oval per row.*

	Disagree strongly	Disagree moderately	Disagree a little	Neither disagree nor agree	Agree a little	Agree moderately	Agree strongly
Answer	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

13. What makes you want/not want to try again (in the application / experience)? \*

.....

.....

.....

.....

.....

14. What do you feel now? \*

.....

.....

.....

.....

.....

15. What did you just experience? \*

.....

.....

.....

.....

.....

16. Why do you want/not want to try again? \*

.....

.....

.....

.....

.....

17. General comments concerning the experience: \*

.....

.....

.....

.....

.....

18. How many minutes do you think you have spent in the experience? \*

.....

Try to solve the following equations (write answers in the form of:  $x = 2$ ) and if you are not able to solve it, just leave the answer field blank.

19.  $x + 4 = 2$

.....

20.  $x - 14 = 22$

.....

21.  $x - b = 0$

.....

22.  $5x = 30$

.....

**Thank you so much for taking the test!!**

---

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 Google Forms

## 18 APPENDIX G – Data on DVD

If the reader would like to investigate further into the data from the test of try the prototype, these data are placed on the attached DVD.

### Prototype

The prototype of the project is placed in a ZIP file on the DVD in the directory of:

\Prototype\MasterProjectThais.zip

To play the prototype, unzip the file and run the EXE file called “MasterProject.exe”.

### Collected data

The CSV data files which were collected during the test participants play through are located on the DVD in the directory of:

\Data\Data Collection

### Test Results data

The CSV data files with the questionnaire results, which the participants answered during the play through, are located on the DVD in the directory of:

\Data\Test Results

### Test Results Google Form

The Google Form results were exported from the site and are placed on the DVD in the directory of:

\Data\Master Project Continuation Desire (Responses).xlsx