CHALMERS
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Base Hunter

A chemistry based learning game

Bachelor of Science Thesis in Computer Science and Engineering

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Abstract

Students of today generally find chemistry boring and uninteresting. They claim that this is partly due to the fact that they do not understand how to relate to chemistry in a real world setting. This has led to fewer and fewer people studying chemistry. In hope of reversing this negative trend, Molecular Frontiers Foundation initiated this project. The purpose of the project is creating a game that puts chemistry into a context that students can relate to. The hope of this project is that contextual awareness might lead to an increased interest in chemistry.

The work started with a thorough study of pedagogy in order to know what approach the game should take on the educational part of the game. Base Hunter has to be considered enjoyable and achieving this is usually where most educational games fail.

The implementation of Base Hunter has involved 3D modelling in Blender and the development of the game has been done using the game engine Unity. The starting point of the implementation was the concept model which was developed based on the pedagogical aspects studied and the requirements from Molecular Frontiers.

The project has resulted in the game Base Hunter. The players ultimate goal in Base Hunter is returning home safely from an unknown planet that the player has crash landed on. For the player to be able to do so he needs protection against the hostile aliens living on the planet. This protection is attained by gathering different elements and raw materials and combining these, making a new type of protective suit of armour made of the newly formed material.

It is time-consuming to develop a game that is considered fun, especially when developing an educational game. Therefore it can be discussed whether or not Base Hunter is considered fun and inspiring. The game is in an early development phase but still has a stable foundation to build upon, even though it currently does not contain enough content to be considered educational and entertaining. The report contains a discussion covering these aspects and also covers several ideas for future development that are in line with the development methods used in pedagogical games.

Sammanfattning

Elever idag tycker överlag att kemi är tråkigt och ointressant. De säger att detta delvis beror på att de inte förstår hur de ska relatera till kemi i vardagen vilket har lett till att färre och färre väljer att studera kemi. I hopp om att vända på denna negativa trend har Molecular Frontiers Foundation initierat detta projekt. Syftet med projektet är att göra ett spel som sätter kemi i ett sammanhang som eleverna kan relatera till. Hoppet är att detta ska leda till ett ökat intresse för kemi.

Arbetet började med en grundlig genomgång avseende pedagogik för att få en förståelse för vilken struktur spelet bör ha för att skapa ett spel som är både roligt och lärorikt. Det är oftast den här kombinationen som de flesta utbildningsspel misslyckas med att uppnå.

Implementationen av Base Hunter har involverat 3D modellering i Blender och spelet har utvecklats i spelmotorn Unity. Utgångspunkten för implementationen var den konceptmodell som skapades baserat på den pedagogik som studerats samt kraven från Molecular Frontiers.

Projektet har resulterat i spelet Base Hunter. I Base Hunter skall spelaren ta sig hem från en okänd planet där han har kraschlandat. För att spelaren ska kunna göra detta måste han ha skydd mot de fientliga utomjordingarna som bor på planeten. Detta skydd uppnås genom att samla in olika grundämnen och råmaterial, genom att sedan kombinera dessa skapas en skyddande dräkt i det material som reaktionen utmynnar i.

Det är tidskrävande att utveckla ett spel som upplevs roligt, detta gäller särskilt vid utvecklandet av utbildningsspel. Därför kan det diskuteras huruvida Base Hunter anses vara roligt och inspirerande. Spelet är i ett tidigt utvecklingsstadium och anses vara en stabil grund inför fortsatt utveckling även fast det i nuläget inte innehåller tillräckligt mycket för att vara lärorikt och spännande. Rapporten diskuterar detta faktum samt innehåller ett flertal förslag för fortsatt utveckling som ligger i linje med de utvecklingsmetoder som bör användas för pedagogiska spel.

Acknowledgements

We would like to give special thanks to our supervisor Laura Kovacs for all her help throughout the entire project. We would also like to give a special thanks to Per Thorén, both for initiating this project and also for all the help provided with the chemical reactions. And finally we would like to thank Becky Bergman who helped us out with the report.

Emelie Svensson, Emil Edholm, Johan Becker, Johan Gustafsson, Pierre Gelter, Tove Larsson, Gothenburg June 4, 2014

Contents

1 | Introduction

The interest for chemistry amongst the Swedish students is declining, (Skolverket (2003)) resulting in fewer people studying to become a chemistry teacher. This is a very worrying trend and one fear is that there will be a considerable lack of knowledge in this area in the future (Lärarnas riksförbund (2013)). The Molecular Frontiers Foundation believes that part of the solution lies in putting chemistry into a context and has therefore proposed this project. The project has resulted in a prototype of a chemistry based learning game aimed at increasing the interest of chemistry amongst students.

1.1 Background

No later than in December 2013 the Swedish National Agency for Education wrote about the alarming results for Sweden in the Program for International Student Assessment, PISA (Skolverket (2012)). PISA is an international report issued by the Organization for Economic Cooperation and Development (OECD), which measures the skills of fifteen-year-old students in mathematics, reading comprehension and science. In the 2012 PISA results, that were published in December 2013, Sweden measured their lowest results so far and now places itself below the OECD-average. Furthermore, Sweden is the country with the biggest decline in the report. This downward trend is however not exclusive for Sweden and can be observed in many other well-developed countries as well.

Interest and knowledge is faltering especially within the science subjects and several studies have been conducted to gather more information on why this is happening (Oskarsson (2011), Skolverket (2003), Skolverket (2009)). One reason that can be observed is the difficulty for the students to see how these subjects are relevant and how they are related to everyday life. Failing to understand the importance of a subject and not knowing how to put it into context can make students feel frustrated, leading to a lack of interest in the concerned subject. The Swedish National Agency for Education wrote in their report ”Nationella utvärderingen av grundskolan 2003 (NU-03)” that when it comes to chemistry, more than half of the students answers yes to the statement “I just study this subject to pass the tests”. Additionally, NU-03 reports that subjects which the students can easily relate to and understand the purpose of, such as biology, do not show the same level of drop in interest and knowledge.

Another known problem emphasizing the lack of interest in chemistry is the extremely low interest in studying to become a chemistry teacher. In June 2013, the Swedish teachers association reported that there were only seventeen people who applied for this

education and they fear that in a couple of years there will not be any chemistry teachers left (Lärarnas riksförbund (2013)). This is a worrying trend and politicians are trying to find different ways of solving the problem (Flores (2014)). For example, politicians are investigating if fast-tracking associate professors into a teacher position in elementary school can help solve this issue.

The Molecular Frontiers Foundation is an international foundation initiated to raise the interest and understanding of molecular science in society. The Molecular Frontiers scientific advisory board consists of fifteen Nobel Laureates (Molecular Frontiers (2014)) and according to Dr. Per Thorén, initiator of this project and chief operating officer at Molecular Frontiers, they are very concerned about the large drop of knowledge in molecular sciences.

Based on the observation that interest in certain areas of science is declining, Molecular Frontiers proposed this project. The project aims at increasing the interest and knowledge of school-children in molecular sciences, by creating a computer game where students can expand and practice their knowledge in chemistry.

It might seem like a strange idea trying to increase students interest for science via computer games, but since young people today spend a lot of time playing computer games it is actually not strange (Hoffman (2009)). Today, 92% of the children between nine to sixteen years old say that they play computer games several times a week (Lozic (2013)). Also, between the ages of thirteen to fifteen almost 60% of the children say that they play computer games on a daily basis (Nordicom (2012)). By taking advantage of these hours to stimulate the curiosity for a particular subject the interest for the subject could increase. Games might be considered a controversial way of teaching but several studies have shown that they can provide a new dimension to learning that is appreciated by students and that games are in fact a good way of making things more context-based and interesting (Hoffman (2009)).

1.2 Purpose

The purpose of this project is to create a prototype of Base Hunter, a single player computer game that is to be both entertaining and educating for school-children between thirteen and fifteen years of age. The game is to be an isometric action shooter that takes place in outer space, where chemistry is needed in order to progress. The prototype should be presented to the Molecular Frontiers Foundation, providing them with an interesting case study for future development of education-based computer games.

Since students claim that they find it difficult to put chemistry into context and how to apply it in everyday life the game should give the students some idea of how chemistry is used. This is done by showing them animations of the chemical reactions taking place when different types of materials are created. The prototype should be interesting and

entertaining, with realistic chemical reactions presented in a manner that is logical and instructive.

Additionally, the game is developed according to good software engineering practises in order to make it easy to extend and add new features and gameplay.

1.3 Problem Statement

The project aims to create a prototype of a game about molecular chemistry that aspires to teach and attract the player to further studies within chemistry. The focus area of this project is to create a game that is scientifically accurate from a chemistry perspective. One of the main challenges is making the game interesting and accessible to all students between thirteen and fifteen years of age, no matter what their other interests are.

In order to succeed with the purpose of the project, Base Hunter has to fulfil the following criteria:

- To simplify deployment at schools and other teaching institutions, the underlying game engine has to be chosen so that it is compatible with all major PC and mobile platforms, such as Windows, OS X, Android and iOS.
- Make the game enjoyable and instructive regardless of interest and previous gaming experience.
- In order to develop a game that is both fun and educational, pedagogical aspects about learning and teaching has to be studied and applied.
- The chemistry part of the game should be both realistic and relevant for the intended age group.

1.4 Project Limitations

The project contains a limited amount of research concerning both the pedagogy and chemistry part of the project. Both of these areas are big enough to be able to form an entire project on their own and it is not be possible, nor fair, to claim that they can be given sufficient space in this project.

Due to the limited amount of time in this project the prototype is only developed for Windows while using a game design that simplifies porting the game to other platforms.

Working with the graphical areas of a game is very time consuming and since the aim is to create a working prototype and not a finished product, the graphical standard in the prototype is not up to par with established industry standards.

Another part of game development that is quite extensive and that could be a project of its own is artificial intelligence (AI). Considering the complexity of an implementation and time needed to construct a good AI for the characters in the game, the project features a relatively simple AI implementation.

Since this project provides a prototype it only contains two levels and relatively simple game mechanics. Only having two levels in the game does not show the complete pedagogical structure, but still gives an idea for future implementation.

Adding sound effects to a game does a lot to improve the feeling of it. Making good sound effects takes a very long time and there are other more important parts to focus on when creating a prototype. Therefore the sound effects included in the prototype are very basic.

Whilst the game provides realistic chemical reactions the game takes artistic license on other areas of science such as physics, weapon mechanics and extraterrestrial life. This is in order to further develop the storyline and increase the entertainment value of the game.

1.5 Project Contribution to Society

If the prototype is well received and further developed, the completed game could provide an interesting aspect for both individuals and the Swedish society by proposing innovative means of educating school children. Results of the project combines educational and entertaining aspects of chemical sciences in a computer game platform, thus providing an easily accessible learning environment for school children. As suggested by the Molecular Frontiers Foundation, game-based teaching can significantly improve the quality of the Swedish school system. Since the Molecular Frontiers Foundation saw a need to initiate a project of this kind, the results of the study may provide an interesting approach to learning chemistry.

2 | Theoretical Background

The development of the prototype requires theoretical knowledge of chemistry and pedagogy as well as of software engineering. The chemical reactions that are present in the game are chosen in alignment with the curriculum for the Swedish secondary school. The chemical presentation requires theoretical study of pedagogy so that it is perceived in a way that encourages students to learn chemistry. Finally, with all background information gathered the implementation of the game has to be done according to established software engineering methods in order to facilitate the work process. This chapter covers the necessary background information in the above mentioned areas.

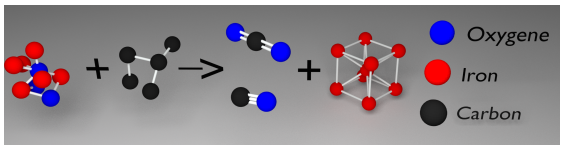
2.1 Chemical Processes

Base Hunter contains two different chemical branches, one covering metal reactions and another one covering carbon and hydrocarbon derivatives. The reason for separating these are that the reactions behave in different ways and the final products also differ. The metal branch consists of different types of metals and alloys. The outcome from the reactions in the carbon and hydrocarbon branch are different types of plastics and polymers. In Base Hunter there are three reactions presented; two in the metal branch and one in the hydrocarbon branch. This section explains the chemical reactions taking place in the prototype.

The reason for choosing these three reactions is that they are relevant to the game in a way that they can be used for protection against enemies. The reactions are chosen in alignment with the curriculum of Swedish students of age thirteen to fifteen. Some materials are only covered vaguely in the curriculum but since they are materials that are commonly used in everyday life, they are not considered too complicated to include. For example aramid fibres, more commonly known as kevlar, is a well known protective material.

One of the first reactions that is found in the prototype is the making of iron from iron ore. The reaction is shown in Figure 2.1. In order to create iron, the iron ore haematite is smelted in a blast furnace, together with coal and limestone (Turkdogan (2013)). The coal is used as a reducing agent and the limestone binds up any impurities from the iron ore. As can be seen in Figure 2.1 the limestone is not part of the chemical reaction, this is because this is a mechanical process. The byproducts from the process are, as shown, carbon monoxide and carbon dioxide.

The molecules in melted iron are bound together in a Face Centered Cubic form (FCC)



$$Fe_2O_3 + 2C \rightarrow 2Fe + CO + CO_2$$

Figure 2.1: The image shows the chemical process of making iron from iron ore. On the left side of the arrow there is a iron ore molecule and a coal molecule. When they react they form carbon dioxide, carbon monoxide and pure iron, as can be seen on the right hand side of the arrow (Turkdogan (2013))

(Atkins, P. (2013)), Figure 2.2. When cooling the iron the molecules take on the Body Centered Cubic form (BCC) instead, Figure 2.3. Although, in smelted iron there is still some carbon left in the material and this carbon forces the molecules to stay in FCC form making the cooled material hard (Turkdogan (2013)). When the cooled iron is in FCC form it is much harder but also very brittle. In order to get a material that is less brittle and more durable than iron, the carbon left in the material has to be reduced further, creating carbon steel.

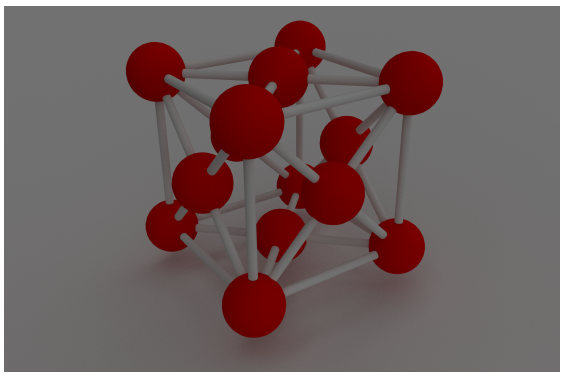


Figure 2.2: Molecules bound together in a Face Centered Cubic form

The creation of carbon steel is one of the other reactions shown in the game. Steel is created from iron by melting it and introducing an excess of oxygen into the process (Turkdogan (2013)). By forcing a great amount of oxygen into the melted iron additional carbon monoxide and carbon dioxide is released, causing the carbon level in the iron to drop further making carbon steel. As mentioned before this makes steel softer since more of the molecules places themselves in BCC form, although this also makes the material more ductile. By reducing the carbon content, fewer molecules are hindered from transitioning from BCC form to FCC form, thus creating a softer material (Atkins, P. (2013)). Therefore, the main difference between iron and steel is that iron is harder but also more brittle than steel.

The carbon and hydrocarbon reaction that is presented in the prototype is the creation

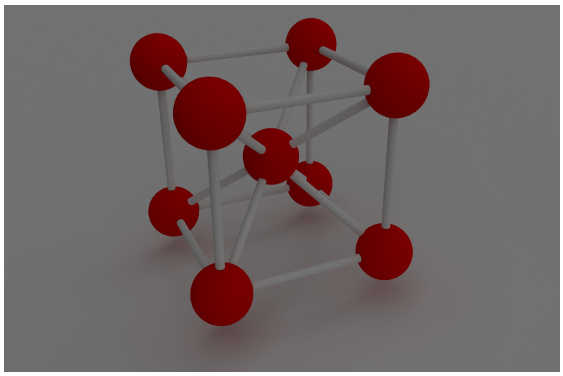


Figure 2.3: Molecules bound together in a Body Centered Cubic form

of aramid fibres, so called kevlar. Aramid fibres are aromatic polyamids, long chains of hydrocarbons, that binds together to form a fabric that is very strong and durable (Chang, K K. (2001)). In the prototype the player finds oil, from which amines and carboxylic acid halides can be made. When these two react with each other a polymer is created, this reaction is shown in Figure 2.4

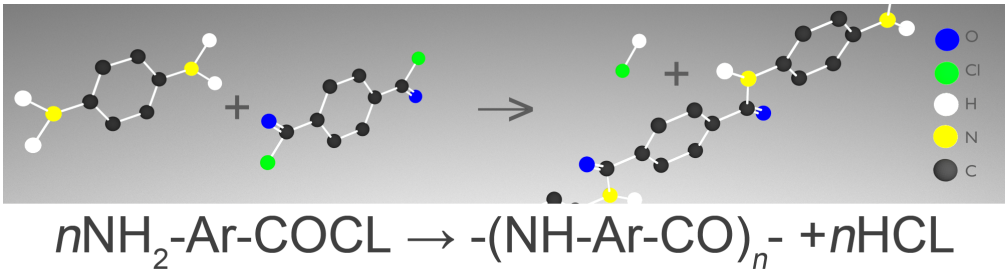


Figure 2.4: Visualisation of the chemical process of making aramid fibers from amines and carboxylid acid halides. The molecule to the far left is the amine paraphenylene diamine and the one beside it is the carboxlid acid halide terephthaloyl chloride. On the right hand side of the small molecule is hydrochloride acid and the longer one is the aramid fiber. The aramid fiber molecule looks as if it has been cut off but it continues out of the picture in the same repeated pattern

This polymer is then spun into a solid fibre using a spinneret and then the fibres are woven into a fabric creating aramid fibres. Aramid fibres provide the advantage of having a great strength to weight ratio and can receive a great amount of kinetic energy without breaking, this while the material is still in the form of a fabric (Chang, K K. (2001)).

2.2 Pedagogical Aspects for Game Development

Since the game aims to inspire students to learn chemistry, the pedagogy behind learning is a very important factor in the development process. The chemistry in the game needs to be displayed in a way that the player finds appealing. The pedagogical research is limited to cover only two areas due to the fact that pedagogy is a broad subject and it is not possible to cover it completely in this report. The first area studied was motivation; as mentioned in section 1.1 more than half of the students claim that they only study chemistry to pass the tests, other ways of motivating them have to be found. The second area covered is pedagogy used in games, and mainly what keeps players interested in a game.

This section covers the pedagogy studied and it begins by explaining the basics of motivation and what drives people to learn. Thereafter it moves on to describing the correlation between challenge and skill level so as to find the balance needed to keep up an interest. The section finishes off with a subsection about the pedagogy that is most commonly used when developing learning games.

2.2.1 What Drives People to Learn

When learning there are several things that can be motivating. Pink (2009) argues that there are two different types of people, one type that is driven by the external rewards that can be achieved when something is accomplished. This can be things like receiving a good grade, getting a good job or winning some kind of prize or award. The other type of people are instead driven by the inner satisfaction that is received when accomplishing a task. Furthermore, Pink argues that these are the two extreme personality types and in reality most people are driven by a combination of inner and outer motivation factors. In school it is easy to motivate the students that are driven by the external rewards such as good grades or having the teacher telling them that they have done something good. What is more difficult is to motivate the students that are driven by the inner satisfaction. In order to stimulate this type of award system the students must take interest in the subjects. (Mayer (2013))

2.2.2 Flow: A State of Mind

A word commonly used to describe the psychological state of a mind when a person is fully immersed and focused on a task, is flow (Csikszentmihalyi (1990)). Achieving this state leaves the person so dedicated to a task that they completely lose track of time and place. In order to attain flow there must be a balance between the difficulty of the tasks that have to be performed and the person's ability to achieve them. This means that the tasks can neither be too difficult, nor too easy. The person set out to complete a task should have to think and use his or her mind in order to achieve the task but

it should not be overwhelming. As can be seen in Figure 2.5, if the task is too simple it is considered uninteresting, if it is too difficult it causes anxiety (Csikszentmihalyi (1990)).

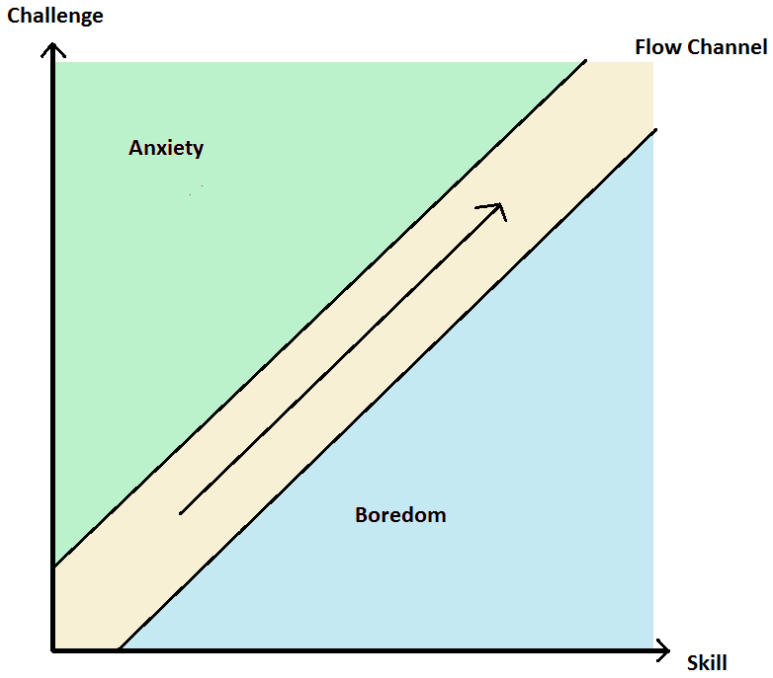


Figure 2.5: The concept of flow as visualized by Csikszentmihalyi (1990)

Flow is one of the main reasons people play games (Murphy (2011)). In order to create flow in computer games there are three elements that the game must provide to the player. The game itself has to be rewarding, it has to offer the right amount of challenges that matches the player's skill while also leaving the player in control of the game (Chen (2007)).

2.2.3 Pedagogy in Games

When it comes to different ways of developing games for learning, one common, but not efficient, method is called chocolate-covered broccoli (Farber (2014), Murphy Paul (2012)). These types of games are usually very similar to the assignments the students get in school but with the difference that it is in form of a game. This is why the method is called chocolate-covered broccoli, it is something important hidden under something that is fun. This method is not efficient since the students see through it and look at the game as a school assignment and not pay more attention to the game than to a textbook. Chocolate-covered broccoli usually happens when the educational parts of the game are added on to the gameplay instead of interacting with it. When using

the chocolate-covered broccoli method, the players are not encouraged to think on their own. Instead of letting the player figure out how to complete a certain level on their own, usage of chocolate-covered broccoli explains the steps necessary to complete said level. Thus reducing the possibility of achieving flow.

2.3 Software Development

In order to apply the gathered research concerning chemistry and pedagogy and turn it into a working game, a software development process had to be chosen. This development method had to fit the desired way of working and facilitate the communication issues that can appear when working in a group. This section describes the theory behind the chosen software development process.

The software engineering method that was found most suitable for this project is an agile software development process called Scrum. Scrum is a framework developed in the 1990s by Ken Schwaber and Jeff Sutherland (Sims C. (2012)). Up until then the most common method used in software engineering was the waterfall method. The waterfall method consists of one implementation cycle; first the specifications are set and then they are implemented, after that they are tested and when that has been done the cycle is complete. This way of working does not give any room for agility since all the specifications are set in the beginning of the project and can not be changed during the development process (Sommerville (2011)).

Scrum on the other hand contains many short cycles of one to four weeks called sprints. Each sprint contains an entire software development cycle which means that the parts that are to be implemented in the sprint are also tested in the same sprint (Sims C. (2012)). This way of working is more agile than the waterfall method since the list of what should be implemented can be altered during the development process. Figure 2.6 shows an overview of how Scrum works, the different parts in the picture are explained below. An important part of working with Scrum is the project backlog where work items for future sprints are stored. The backlog consists of all the deliverables for the project divided into smaller tasks that can be completed within one sprint. The tasks in the backlog are spread out during the sprints according to priority where the tasks that are the most essential for the project have a higher priority. The tasks that are to be achieved during one sprint are added to the sprint backlog (Schwaber, K. (2013)).

When working with Scrum it is important to have several group meetings per sprint in order to keep track of what has to be done and what problems the team members might experience during the development process. These meetings are sprint planning meetings, daily Scrum meetings, sprint reviews and retroperspective meetings. Altogether these meetings cover everything that has to be done during the sprint; planning of the sprint, discussing the progress, updating the product backlog and reviewing the sprint (Schwaber, K. (2013)).

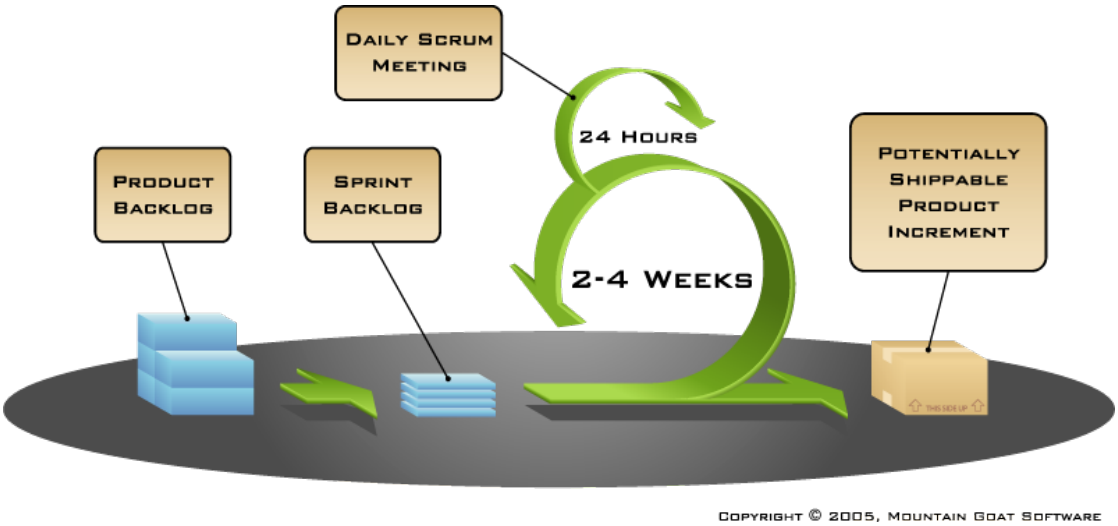


Figure 2.6: Image showing an overview of the scrum development cycle (Mountain Goat Software (2014))

3 | Method

This chapter presents the development process from the start of the project until the completed prototype. The chapter starts with an overview of the development process and continues to describe the steps more thoroughly in the following sections. Therefore after the overview, the chapter covers how the chemistry and pedagogical research was conducted. The chapter then moves on to explain the software development method used in the process. Finally the tools that were used during the implementation of Base Hunter are described.

3.1 Development Process

The first part of the development process was to gather information regarding chemistry and pedagogy. This had to be done in order to understand how the game should be designed so that it would fulfill its purpose of increasing the interest in chemistry. How this research was conducted is described further in section 3.2.

When the necessary information concerning chemistry and pedagogy was gathered the game was modelled. The first part in modelling the game was to define and specify exactly how the game was to work and what to include. Thereafter a concept model was made where the relations between the different parts of the game are visualized. This model can be found in section 4.2.

After the software modelling was completed, the implementation of the game started. The implementation of Base Hunter was divided into two different parts: game logic and game graphics. Game logic were more prioritised than the graphics because of the final product being a prototype where the backend is the most important part.

3.2 Chemistry and Pedagogy Research

The chemical reactions that are displayed in the game were identified together with Dr. Per Thorén from Molecular Frontiers due to the project groups limited knowledge in the area. The chemistry research also included studying the curriculum for Swedish students of the ages thirteen to fifteen in order to keep the game difficulty at a suitable level.

The pedagogical research was conducted by studying relevant literature found in the Chalmers library database. The choice of literature was done by filtering out pedagogical aspects related to gaming with motivation as a starting point. From there on, other aspects of game related pedagogy such as flow and chocolate-covered-broccoli, were found and studied closer.

3.3 Agile Software Development

As mentioned in section 2.3 the software development framework chosen for this project is Scrum, although the process used was not as formal as described. The time of the sprints were one or two weeks and after each sprint a reconciliation meeting was held where the previous sprint was discussed and the next sprint was planned. Planning for the next sprint included updating the product backlog as well as making decisions about possible problems.

3.4 Game Development

Before developing Base Hunter a game engine had to be chosen in order to assist with the development. To create all the models such as the terrain and characters a modelling program is needed as well. This section describes which applications were used for this project and why they were chosen.

3.4.1 Game Engine

Base Hunter was developed using the game engine Unity. The choice of which game engine to use is based upon the premise that deployment across multiple platforms had to be easy. Unity natively supports all major platforms and has a built-in cross compilation feature (Unity.org (2014)). Another factor that weighed heavy in Unity's favour was its large community and its asset store, where developers from all over the world can post assets for free or for sale. An asset is for example a finished model, sound, textures that can easily be imported into Unity. The asset store has not been used for the development of the prototype but, once again, it simplifies further development.

Unity provides many features that facilitates the game development workflow. Since almost all other game engines provide almost the same set of features, this did not make Unity stand out compared to other game engines. Instead it was thought of as a basic requirement for Unity to be considered at all. The set of features include physics, rendering, camera management and basic 3D tools.

3.4.2 3D Modelling

The 3D models needed in this project were created using the open source 3D modelling suite Blender. The reason Blender was chosen was due to the fact that it is free of charge and open source (Blender.org (2014)). Also, there are many tutorials available where Blender and Unity are used together which reduced the learning curve.

Blender contains many different tools that simplifies modelling objects for games. This includes tools for easily sculpting basic game objects, such as terrain and rocks, as well as tools for animating and texturing models.

3.4.3 Version Control

To make development and code management easier for multiple users, Git, which is a distributed revision control and source code management system, was used.

By default Unity uses binary serialisation for many internal data structures. Serialisation is the process of converting from one format to another, usually for storing data in some specified format. This means that Unity stores everything they need in a binary format that is not human-readable. Adding these binary files to the Git repository makes merging changes difficult, if not impossible. Fortunately it is possible to change the serialisation settings in Unity to a human-readable plain text format which resolves this issue.

4 | Game Design and Modelling

Based on the theoretical study made within the area of pedagogy and chemistry the game was designed and modelled. This chapter starts of by presenting the story of the game and then moves on to describing the software modelling and how the prototype is designed. Finally the chapter describes how the chemistry in Base Hunter is presented.

4.1 Storyline

The main character finds himself stranded in an abandoned base camp on an unknown planet. Since he is experiencing mechanical issues with his spaceship the player needs to explore the planet in hope of finding spare parts for the spaceship. In order to find these parts the player needs to explore the planet which is populated with hostile aliens that will attack the player if he ventures to close to them.

Therefore, the player needs to be able to protect himself from the aliens using his newly crafted armour. Since the aliens attack the player in different ways he discovers that his armour will not hold for long and therefore has to improve it. For example one alien may use acid weapons and an armour crafted to defend against fire attacks may not be optimal against the acid attacks. Scattered around the planet are different materials and resources which the player picks up and brings back to the base camp where he has found an old chemical crafting table. This allows him to let the collected materials react with each other forming new and stronger materials that can be used for protection against a variety of attack types. Using the crafting table correctly, creating new parts for the armour will let the player explore areas previously too dangerous to explore. Eventually, when the entire planet is explored the player has found all parts needed to repair the spaceship and the player will be able returns home to Earth.

4.2 Software Modelling

As can be seen in Figure 4.1 the game is modelled with the player in focus. The player is able to explore the different levels and find enemies. The enemy can attack the player using different attacks, either physical or elemental and the player should defend himself against these attacks, either by the different kinds of craftable armour or by dodging the attacks. The player also has the ability to defend himself by using various weapons

and thereby killing the enemies. All around the different levels, the player is able to find material and parts that can be used for further developing the armour for the next levels.

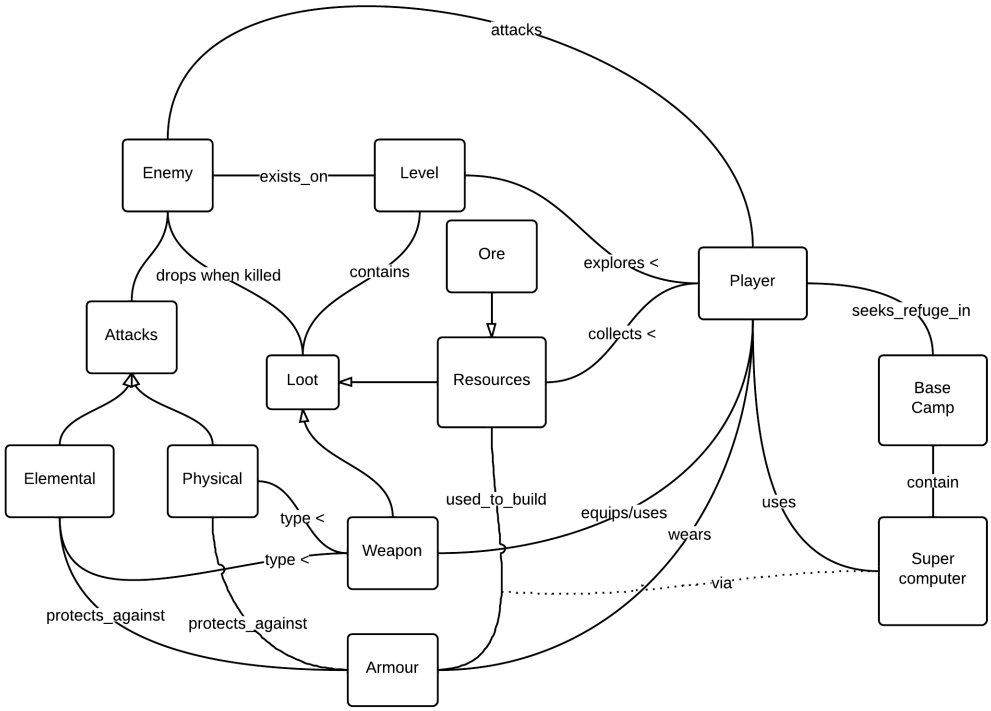


Figure 4.1: A conceptual model of the prototype outlining the different parts of the game

In between the game levels the player returns to the basecamp where inventory can be managed and various upgrades can be performed. As can be seen in the concept model there is a supercomputer placed in the base from which the player can receive information concerning how the crafting system works.

4.3 Chemistry Presentation

The chemical reactions taking place are shown to the player when the armour is being crafted. The main focus of the chemical presentation is on the reactants and the products. If the reaction requires any special compounds like catalysts or special environments, these are explained superficially since too much information may become overwhelming, and the important points may be lost. Most important is that the products are put in their specific context and shown as the solution to an earlier problem. In this way, the player can quickly see the use of the product, and has a greater chance to associate and remember the specific compound, and what was needed to produce it.

5 | Implementation and Result

This chapter presents the results from the implementation and also the logic behind them. This is a first prototype of Base Hunter and therefore several features are not at the level expected of a final product.

The chapter is divided into two sections; game logic and graphics. The section concerning game logic covers the implementation of how the game behaves, including importation of objects from Blender to Unity, character abilities and the in-game menus. The graphics section describes how the graphical parts of the game are implemented including 3D modelling and the different in game menus.

5.1 Game Logic

This section presents the logic behind the major features of Base Hunter. The section covers the both the implementation decisions taken and how the different features works logically. It starts by detailing the issues that occur when importing models from Blender to Unity and goes on to describing the implementation details about character movement, artificial intelligence, weapon mechanics, crafting system, armour and weapon mechanics.

5.1.1 Importing from Blender to Unity

Models and animations made in Blender can be used directly in Unity with the added precaution that the coordinate systems are different; the X-axis in Blender is equivalent to the Y-axis in Unity. This can be solved by either exporting the Blender file to a format that allows corrections of the coordinate system or immediately rotating the imported object after placement in Unity.

All characters and other objects used in Unity are referred to as game objects. In order to get the game objects to act the desired way, different components, such as gravity, can be applied to them. Due to the modularity of the Unity game engine each game object that is added starts out without any components added. Although, when importing models from Blender a few default components are usually added; these include a renderer and, depending on whether or not the model has been animated in Blender, an animation component as well. Depending on the intended purpose of the game object additional components and special features can be added to it.

For example, when adding character objects, components that add gravity as well as collision detection needs to be added. Gravity can be solved by adding a RigidBody component which takes control of the object's position in the game and simulates real-world physics. The collision detection is solved by adding a Collider component to the object. The Collider component gives the object a solid body which can be used for collision detection. These two components allows the character to walk around and interact with the environment in a natural way. If, gravity would not be added the character would just stay put in the position it was placed in. Similarly, if the collision detection was not to be added the character would be able to pass through objects and fall through the floor.

5.1.2 Character Movement

Being able to move around is an essential part of any game. There are a few different ways in which movement can be implemented in Unity. One way in which it can be done is by directly modifying the location of the character. Another way to do it is by using the built-in component called CharacterController. Both of these methods result in an unrealistic movement because they do not take gravity into account when moving; a consequence of this is that the movement contains no acceleration. A third way of doing it, which is also the method that has been used for Base Hunter, is by using the RigidBody component. When using this component the character is translated by applying a force to it in the desired direction. This results in a more natural movement since acceleration and deceleration is used instead of direct movement as in the two other alternatives.

5.1.3 Artificial Intelligence

A very simple artificial intelligence (AI) feature has been added to the enemy so that it can move around and decide where to move next. To simulate a somewhat normal movement pattern, the enemy is implemented to randomly change directions every few seconds if the player is not nearby. If the direction that is randomly selected faces a wall or other obstacle the direction is recalculated.

In order for the enemy to react to the player, two spherical triggers, one big and one small, have been added to the enemy. A trigger is a collider that instead of repelling objects enables them to trigger an event. The largest trigger placed on the enemy causes the enemy to attack and follow the player when the player is within the trigger boundary. The second, smaller trigger was added to stop the enemy from walking straight into the player and causes the enemy to stop when it is too close. Instead the enemy stays put and keeps attacking the player.

5.1.4 Items and Crafting System

Every item in the game is represented through scripts implementing an interface named IItem. Every item implementing this interface provides a name, a description, a 2D texture and a way for it to destroy itself. A more object oriented way of implementing this is through inheriting an abstract class. However, this is not possible since every script utilising Unity's functionality needs to inherit a class called MonoBehaviour and C# which the game is written in, only permits single inheritance.

An item's representation in the game world is done by attaching the script to a Unity game object that is then placed somewhere in the game. When the player enters the trigger boundary of the item it is transferred from the ground to the player's inventory.

The player inventory is modelled through an array of IItems. By using the functionality provided by this interface, the player is provided with all the information needed concerning the items placed in the inventory. To separate different types of items, each item implements a second interface that contains methods distinct to that type. Base Hunter currently contains the following types of items:

- Weapon
- Crafting material
- Crafting machine
- Spaceship part

The crafting materials and the crafting machines make up the game's chemical crafting system. Every chemical reaction in the game requires between one to three types of crafting materials and needs to be carried out in a particular crafting machine. Every possible reaction in the game is stored in a database. When the player tries a combination of items the database is queried and if the combination is valid, the player may choose to perform the chemical reaction. Upon activating the crafting system for the first time, the player is given a short introduction to as how the crafting works through the game's dialogue system.

5.1.5 Armour

The armour is divided into six different parts: helmet, left and right arm, torso, pants and shoes. Every part of the armour holds its own set of resistances to every damage type in the game. The effective resistance the player has against a particular damage type is the mean resistance of all individual armour parts the player has equipped. For example, if the player has three armour parts equipped with 50% resistance to fire, the effective resistance would be $\frac{50+50+50}{6} = 25\%$. Therefore, if the player receives 100 fire damage, 25 of the damage is neglected.

The armour system is heavily reliant on the crafting system. To upgrade or change a part of the armour the player needs to create a new part through the base's crafting system. Since different types of armour in the game offers a different set of resistances, it is possible to significantly change how much damage the player receives from various damage types. Essentially it makes it possible for the player to experiment with different armours based on the opposition in the different levels.

5.1.6 Weapon Mechanics

The weapon mechanics featured in Base Hunter are implemented in two different ways. The first method creates a physical object, representing the bullet, which is provided with a force in the direction it is fired in. The size of the force depends on the weapon used. This process is repeated for every bullet that is fired and therefore Unity treats every bullet as a unique physical object. When each bullet is handled individually they can ricochet or collide with other objects in the game in unique ways. Physics enabled bullets may have a negative impact on performance. This is usually not apparent on most systems, but may cause issues when running the game on mobile phones and other mobile devices. To reduce the performance impact every weapon projectile implements a small script which removes the projectile and releases the resources after a certain amount time.

The other method that has been used for implementing the weapons utilises Unity's ability to raycast. Raycasting means that a ray is fired in a given direction from a set point and detects any collision of the ray. A good analogy is a laser beam, where raycasting means that the point where the laser beam hits is pinpointed. The raycast fires from the barrel of the weapon in the direction the player is aiming, thus giving the position and object that were hit. This is an instantaneous attack and does not involve any physical object. Weapons using this method are therefore much more effective from a performance standpoint but this method limits the way the attack can be used within the game since the bullets are not able to ricochet for example.

5.2 Graphics

This section covers the graphical parts of the game and their implementation. Since both levels, the base camp and the models have been made in 3D, the chapter starts by explaining how these models have been created. It then moves on to describing how the models, both 2D and 3D have been textured. With that information given, the section presents how the heads-up display looks in the game and finishes by explaining the features of the main menu.

5.2.1 Game Models

When creating 3D models in Blender the starting point is usually a cube, as can be seen in Figure 5.1. The most common method of sculpting the model is by translating the vertices to the desired positions and extruding new faces from the cube. Figure 5.2 shows the first steps towards creating the head of the enemy alien used in the prototype.

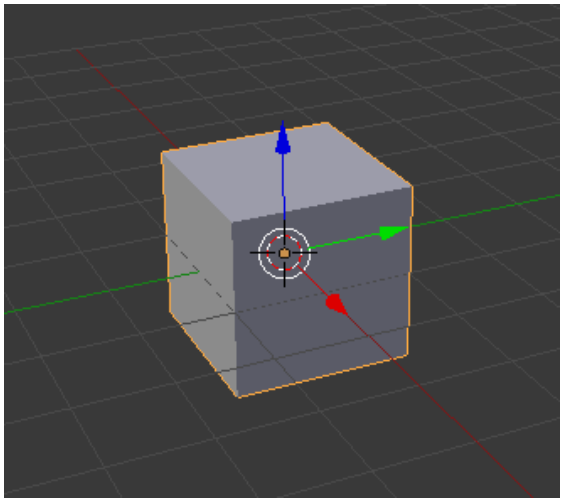


Figure 5.1: A cube representing the starting point in Blender

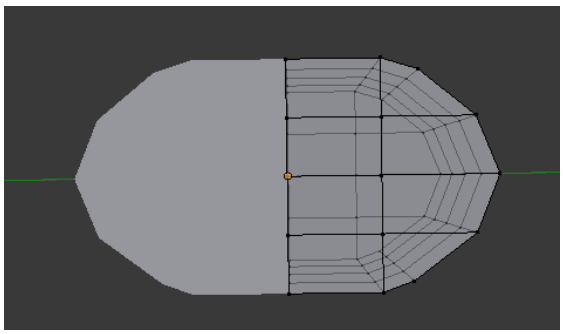


Figure 5.2: The cube as seen after a few modelling steps

When creating the characters for the game, the player character as well as the enemy alien, the models must be able to simulate realistic movement. To be able to make animations the model first has to be told where the movement joints are located. This is a process where "bones" are created and placed inside the model. For example, when creating an anthropomorphic model this means creating a simplified human skeleton and fitting it to the model. The next step in the process is applying weight paint to the model. This step involves associating a movement ratio between the bone and the model that indicates how much the model should move when moving the bone. Figure 5.3 shows the modelled alien in mid-pose. The lines that can be seen in the model are

the added bones.

When creating animations in Blender, a timeline is formed as an outline of how the animations plays out. The character is placed in a starting pose at the beginning of the timeline. For example if you are animating a run cycle, the first pose is part of the running motion. After the first pose you create a so called key frame on the timeline. The key frame represents the next step of the animation. In the run cycle example, this is how the running motion looks after roughly half a second. The animation process consists of adding more and more key frames until you reach the end of the animation. The more key frames added, the smoother the movement looks. Returning to the previous example, the last key frame is the same as the first one since when the animation playback reaches this frame you have completed one run cycle. When playing the animation Blender and Unity calculates how to move between the manually defined poses as smoothly as possible and the result is a complete animation sequence. For example, looping one run cycle makes it seem as the character is running continuously.

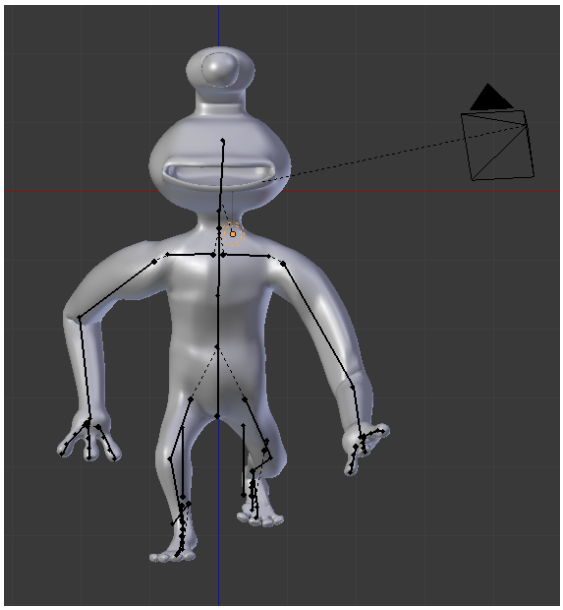


Figure 5.3: A finished alien without textures

When modelling the terrain for the levels the starting point was a flat plane instead of the usual cube. The plane was sculpted to simulate mountains and valleys. At this point borders were created around the terrain to prevent the player from being able to fall off the level. The borders were represented as stone walls to create an illusion of being in a crater.

As to create a realistic and alive environment and not just an empty plane, different kinds of stones were created. These were sculpted from cubes and with the help of various modifiers they took on a rock-like appearance.

5.2.2 Texture Mapping

When the models are finished, they need to be coloured, to create the illusion of the model having skin and clothes. This is done by adding textures to the model. Since the textures created are in the form of a 2D-image the model has to be flattened in order to apply a texture to it. In order to do so the model is divided into separate parts by using seams and then flattening these parts using the standard unwrapping tool. For example adding a seam across the middle of the model divides the model into two halves that can easily be handled. Figure 5.4 shows the texture that was placed on the alien model in Figure 5.3. As can be seen the alien has been divided into several parts, that have been flattened out, in order to make the texturing process easier.

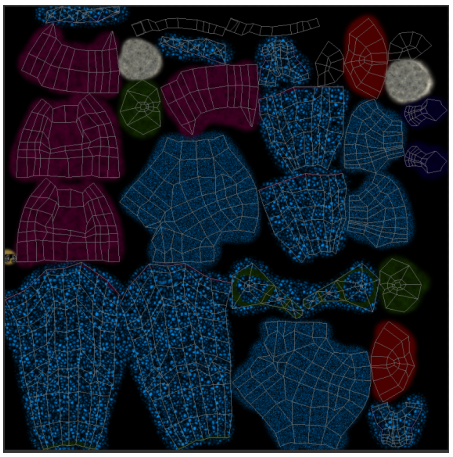


Figure 5.4: The texture for the alien model

When the model has been unwrapped it acts as if the texture image has been wrapped around it, therefore there is a possibility to draw the textures either directly on the model in a 3D view or on the flattened image. There is also the possibility of placing an image on the texture which can be useful when creating more advanced textures such as reptile skin. Figure 5.5 shows the alien in in Figure 5.3 after texture application.

5.2.3 Heads-up Display

The game features a so called heads-up display (HUD). A HUD gives the player a visual illustration of in-game information such as current player health and player inventory.

The game HUD includes the following components:

- Player health bar
- Player stamina bar

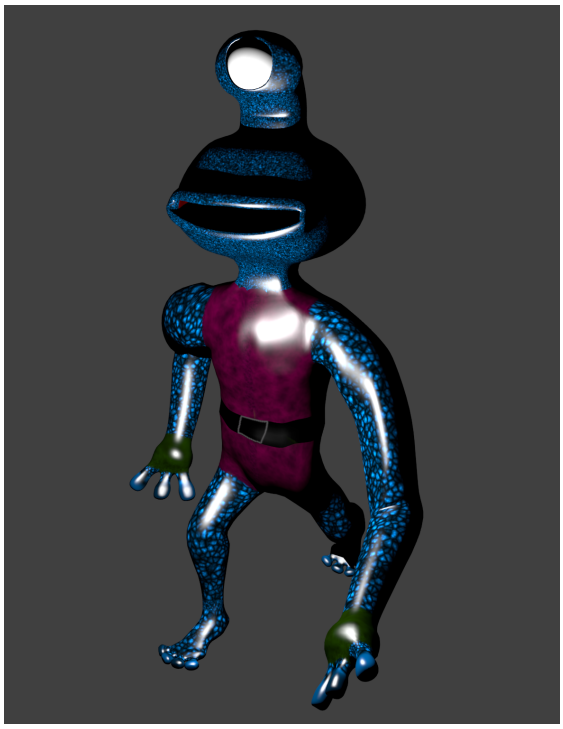


Figure 5.5: The finished alien after modelling, rendering, animating and texturing

- Player inventory/backpack
- Enemy health bars
- Item hotbar

The item hotbar is the small grey area in the bottom-center of the screen as can be seen in Figure 5.6. The items placed in this hotbar, such as weapons, represents the players currently equipped items. These items can then be used via predefined hotkeys. As can be seen in the figure, the health and stamina bar are placed in the upper left corner, the green bar at the top serves as health and the yellow one below it representing stamina. To the right the inventory can be seen, in this case there are quite a few items in the inventory.

The HUD as seen in Figure 5.6 was implemented using Unity's built-in graphical user interface (GUI) system. Its graphical representation was done by drawing textures at positions dynamically determined at runtime. The size of the textures are also determined at runtime to make it scaleable to various screen resolutions.

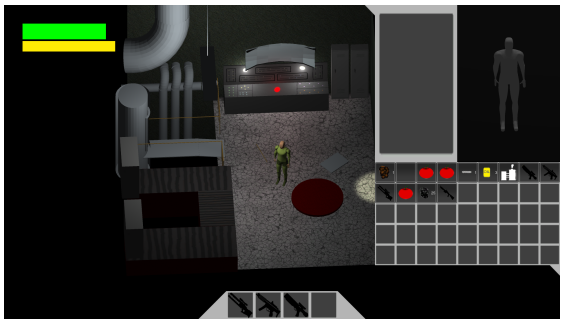


Figure 5.6: The game as seen with the inventory open.

5.2.4 Chemistry Crafting System

The base contains a crafting station which can be activated by the player. Upon activation, the player is presented with a GUI of the chemical crafting system as seen in Figure 5.7.

The crafting GUI is divided into several parts. To the top left are three vertical buttons where the player can choose what crafting material to use in the reaction. The crafting machines the player can choose between are presented in the top-centre. If the player chooses a valid combination of crafting materials and crafting machine, the top right box shows the product of the chemical reaction. Finding a valid combination also enables the ”Craft” button in the bottom right. Pressing this button shows an animation of the chemical reaction taking place in the bottom centre of the crafting system, as can be seen in the Figure 5.7.

5.2.5 Main Menu

Since one of the project goals is to provide a game that can be used on several different platforms, a dynamically adjustable menu system has been designed.

Figure 5.8 shows the main menu system of our game. The menu includes the necessary features of a main menu. ”New game” loads the first level of the game. ”Options” shows an option menu where the player can set the volume, resolution, and chose whether or not full screen mode should be used. Pressing the ”Credits” button shows a scrolling list of the creators of Base Hunter and supervisors. ”Load game” is not implemented yet but is still there because it is considered an essential part of the final game.

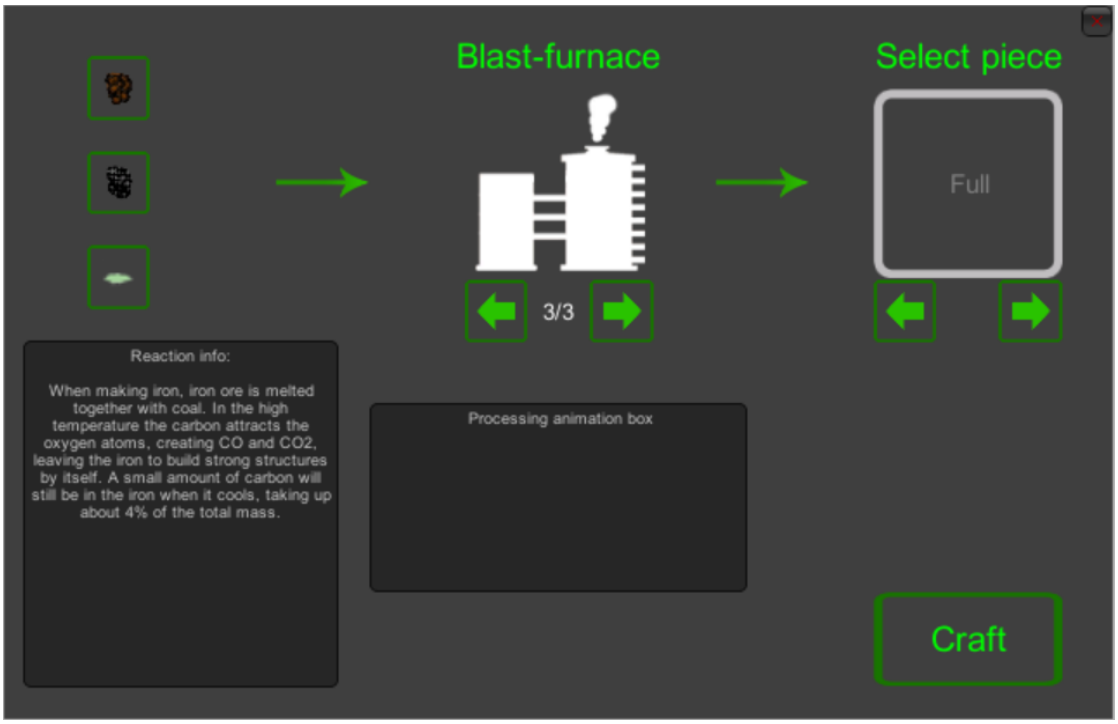


Figure 5.7: The game as seen with the crafting window open.

Figure 5.8: The main menu

6 | Discussion

The main goal of the project was to make Base Hunter enjoyable for all students in the ages of thirteen to fifteen whilst still giving them an idea of how chemistry can be used in real life. This chapter discusses how well the project has succeeded and which future implementation ideas that might turn the prototype into an even more successful game.

Base Hunter has not been tested on the intended age group. This is partly due to lack of time and partly due to Base Hunter still being an early prototype, which still lacks many essential features. Although, we would still recommend doing player testing to firstly observe how children are playing the game and secondly, more importantly, what features they feel are missing from the game at this stage. Feedback from the intended player base is always valuable even if much of the feedback on the prototype probably would focus on how the graphical fidelity is not up to par or how many current features of the game feels unfinished.

6.1 Structure of the Game

When developing a game there are many basic features that has to be implemented before the game can be considered playable. This includes features such as moving around, weapon mechanics and inventory. Since the project group did not have any previous experience with the game developer tools used, implementing and designing these features took considerable time and effort.

What makes a game fun can be discussed endlessly since the idea of what is considered fun varies from person to person. A game that tries to cater to everyone will most likely contradict itself. A good analogy is to try making a toy that suits every child, it is simply not possible; the toy would have to be a car, a doll and a ball at the same time. Therefore, stating that the game should be interesting and accessible to everyone might have been a too big task. Despite this, the game is developed with the idea of catering to as many children as possible in the ages of thirteen to fifteen. Therefore we believe that there is a good foundation to build on, and continued implementation of the game along the same line as now results in a game where the chemistry is presented in a fun and educating way.

The theoretical study made concerning the pedagogy concluded that one of the most important implementation strategies that had to be avoided in order for making the game fun was chocolate-covered broccoli. Base Hunter is implemented in a way that

makes chemistry a fundamental part of the game since the player has to try out different chemical reactions in order to be able to progress in the game. In theory, this is not considered to be chocolate-covered broccoli.

6.2 Chemistry Considerations

Since it is an educational game an important task of the project was to make the chemical reactions realistic and displayed in a logical and instructive way. The chemistry crafting system, Figure 5.7, shows the reaction taking place between the selected materials whilst also explaining the reaction at the same time. The research conducted in the beginning of the project showed that the reactions used in the game are realistic.

Using the crafting system the students get to experiment with different materials and see which of them can be combined into something useful. When combining materials they get to see how the molecules react. While doing this they also get an explanation of how and why this reaction takes place. Hopefully this leads to the students gaining a better understanding about the underlying chemistry behind the creation of the new material. Previously the students might have read about the reactions in a textbook but to actually see the reactions illustrated in an interactive way should give students an increased understanding of how chemistry can be used and why it is important.

As mentioned previously in the report, students generally claim that they only study chemistry to pass exams. One reason for that is that they fail to see how chemistry can be used in every day life. We believe that Base Hunter increases the knowledge and understanding for chemistry and how it can be used. An increased understanding often leads to an increased interest which in turn leads to a desire to keep studying the subject. There are however other factors that play a big role when choosing an education, such as expected salary and future job opportunities. Therefore it is important to see Base Hunter as part of, but not the complete solution.

6.3 Game Development Choices

One of the goals set forth in the purpose for this project was a game that is playable on most major platforms. Base Hunter is currently only developed for Windows but the choice of game engine makes it possible with little to no work to port the game to different platforms. Therefore it is possible to easily build the game for other platforms such as Android without having to start from scratch.

The project would have benefited from an early user study sent out to the intended age group. The user study could have been in the form of a questionnaire containing questions concerning what the participants expects from a game and what they think constitutes a fun and rewarding game. However this was not thought of in the beginning

of the project but as the work progressed the conclusion was drawn that this would have been of benefit to the project. Nevertheless, Base Hunter has been developed following the requirements set forth by the Molecular Frontiers Foundation, and hence integrates the pedagogical and sociological aspects that they consider to be important.

6.4 Continued Work

As previously discussed it is impossible to create a game that everyone finds interesting and entertaining. However, in order to come closer to the goal of creating a game as enjoyable as possible, more content would have to be added to the game in order for it to be rewarding and challenging to the player. Adding more content to the game widens the range of people that might find it interesting since the new content could appeal to them. Content that has to be added includes more levels, loot, character customisation and weapons.

The project builds upon research concerning both chemistry and pedagogy. Based on that research several areas for further work has been identified. The development ideas have been divided into two categories; work that focuses on further implementation of more game levels and additional features that can provide a new dimension to the game.

6.4.1 Further Implementation of More Levels

To keep the game challenging for the player, the game difficulty needs to gradually increase. This can be implemented through more levels where it is possible to find new materials and items as well as to encounter new enemies. The new materials found in each level will help craft different types of armour that can be used for protection against more dangerous enemies. This aspect of increasing level difficulty is currently hard to show in Base Hunter since the current version is missing most of the levels that makes this possible. However, Base Hunter is developed in way that allows further development according to these aspects.

The graphics in a game are important since it creates immersion. The graphics of Base Hunter are quite simple and would benefit from further development in order to create a more fun and inviting environment for the player. This not only includes making more detailed models and textures but also adding more variety.

6.4.2 Additional Features

To attract a wider array of players, a character creation screen is a good feature to implement. This would let the player customise the character model used, including being able to choose the sex and appearance of the model. For some people the game

experience might be enhanced if they are allowed to personalise the character. Some people might prefer a female character for example and some players might want to choose the colour of the hair.

In order to attract players that like games where there is a chance to use their creativity, a feature to implement is the ability to change the colour of the suit or the hair in the game. This could be combined with showing more aspects of chemical usage. Dyes contain a variety of chemicals which could be mentioned when the player wishes to use the dye. The creative player might also want to decorate the armour or maybe create jewellery, this could also be done if the right materials are found.

Some students might have a problem with reading, for example students with dyslexia. For these students the texts explaining the reactions might be difficult to read and the final version of the game would therefore benefit of having an option to have these texts being read out loud.

Another feature that that would be nice to have is an additional but optional information box. A button could be added that provides additional information about the concerned chemical processes for the interested player. Listing the reactions with all related information in the main menu might provide a way for the students to use Base Hunter as a complement when studying for a test.

In order to further develop enemy attacks and the player's understanding of what happens when a material is hit by a certain attack, a short animation could be added showing this. The first time a player is hit by, for example an acid attack, a short animation could be shown demonstrating the reaction taking place between these two materials. In this way the player can see which materials are good for protection against which attacks in a more intuitive way. For example, a certain acid might have a greater impact on some materials and this could be visualised so that the player understands the need for changing to another armour.

7 | Conclusion

Students of today find it hard to put chemistry into context and therefore they find it uninteresting and complicated. Hence, a new way of getting them interested in chemistry is needed. In this project we addressed this issue and proposed a game-based educational environment for increasing the student's interest in chemistry.

People are however driven by different things, either outer or inner award systems. People who are driven mainly by the inner award system are more difficult to motivate since they need to find the subject interesting in order to find it rewarding. When developing an educational game this has to be kept in mind, as well as keeping the difficulty at the right level. The game should be challenging for the player but at the same time not too difficult.

The project has resulted in the game Base Hunter that aims to increase students' interest for chemistry. The game is based on an unknown planet that the player has to explore in order to find its way home. To survive on this planet the player has to build an armour to protect himself against the hostile aliens. To manufacture this armour raw materials need to be gathered. By letting these materials react with each other, new types of materials that provides better or different kinds of protection can be created.

Base Hunter shows the chemical reaction taking place when materials are created. The player can observe and learn what different elements can be used for whilst seeing an explanatory animation of the reaction. The hope is that this way of implementing the game increases the players understanding for how chemistry is used in real life.

The outcome of this project is the first prototype of Base Hunter, which means that the pedagogical aspects are not fully implemented. To make Base Hunter even more interesting and widely accessible, the game needs further development by adding more levels and content. However, the current version of Base Hunter is constructed according to established pedagogical aspects, and we therefore believe that Base Hunter provides a solid foundation for further development and increasing the interest of students in chemistry.

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