



**Høgskulen
på Vestlandet**

BACHELOR'S THESIS

**Virtual Reality Learning Game for
Biomedical Laboratory Scientists – A
Prototype**

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We confirm that the work is self-prepared and that references/source references to all sources used in the work are provided, cf. Regulation relating to academic studies and examinations at the Western Norway University of Applied Sciences.

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Sammendrag: Our goal is to familiarize Biomedical laboratory scientists (BLS) with their lab-environment at HVL as well as the facilities at Haukeland. The product achieves this by creating a Virtual Reality learning game reflecting different parts of a BLS curriculum and day-to-day activities. In our product we have used Unity3D, a game engine that supports creating games in virtual reality and HTC Vive Eye Pro supplied by HVL. The result consists of two main components: one game flow at the Bioengineering lab at HVL, room F303, and another game flow at Haukeland. Through the use of the HTV Vive Eye Pro and it's two controllers we have created a product that allows the player to "walk" around both locations and interact with equipment, take quizzes related to their curriculum, partake in procedures relevant for BLS curriculum and their day-to-day activities. Our end product also underwent external user tests. The feedback from the user tests is presented in our Results and Evaluation of this report.

Målet med denne rapporten er å gi bioingeniør studentene kjennskap til deres labmiljø ved HVL, samt kjennskap til fasiliteten ved Haukeland. Produktet oppnår dette ved å lage et «virtual reality» spill som samsvarer med deler av en bioingeniør students pensum og daglig aktiviteter. I vårt produkt har vi brukt Unity3D, en spill motor som støtter spill utvikling i «virtual reality» og HTC Vive Eye Pro tilbudt av HVL. Resultat består av to hovedkomponenter: en spill flyt på bioingeniør labet ved HVL, rom F303, og en annen spill flyt ved Haukeland. Ved bruk av HTC Vive Pro og dens to kontrollere har vi lagd et produkt der bioingeniør studentene kan «gå» rundt lokalene og interagere med utstyr, delta på quizer relatert til pensum, delta i prosedyrer relatert til deres pensum og dagligdagse aktiviteter. Sluttproduktet gikk også gjennom eksterne bruker tester. Tilbakemeldingene fra disse testene er presentert i Results and Evaluation av denne rapporten.

Stikkord: VR Technology Head mounted display (HMD) Unity 3D	Biomedical Laboratory Scientists Serious games 360 image and video	C# EduGameLab Gamification
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Table of content

1 Introduction	4
1.1 Motivation and goal	4
1.2 About the project	5
1.3 Constraints	6
1.4 Resources	7
1.5 Structure of the report	8
2 Project description	9
2.1 Practical background	9
3 Project design.....	14
3.1 Possible approaches	14
3.2 Specification	16
3.3 Selection of tools and programming languages	16
3.4 Project development method	18
3.5 Evaluation plan.....	19
4 Detailed design.....	20
4.1 Architecture	20
4.2 Technical Design.....	21
4.3 Game flow	22
4.4 Making a virtual 360-space	24
4.5 Scene changes	25
4.6 Clicking on objects – displaying information.....	26
4.7 Blood sample video	27
4.8 Quiz	28
4.9 Haukeland Hospital mini-game (requisition and equipment)	29
5 Evaluation.....	31
5.1 Evaluation method	31

5.2 Evaluation result	33
6 Discussion.....	40
6.1 Consequences of the chosen approaches.....	40
6.2 How the choices influenced the results	41
6.3 How the result could be improved.....	41
7 Conclusion and further work.....	43
8 References.....	45
9 APPENDIX	46
9.1 Risk list.....	46
9.2 GANTT-diagram.....	47
9.3 User experience schema	48
9.4 Questionnaire about play-based learning (in Norwegian)	49
9.5 Interview questions.....	50
9.6 Technical overview of a Scene	52

1 Introduction

Biomedical Laboratory Scientist (BLS) students encounter various environments when they go to the places they need to practice or work. These practice- or workplaces, as well as the instruments and equipment, usually differ from the laboratories and laboratory instruments at schools. Therefore, it usually takes time to familiarize with different practical environments, even for the well-prepared and engaged students. BLS students have a steep learning curve as they need to familiarize themselves with the laboratory and the different, complex instruments and objects which are found there. They need to learn to handle everything in the laboratory, which is a time intensive task. Due to resource constraints, there are limited possibilities for BLS students to experience the different physical environments in-person beforehand.

1.1 Motivation and goal

The motivation behind this project is to construct a game that can “bring the different practical laboratory contexts” to the students. By utilizing current resources from Virtual Reality (VR), 360° videos, and Serious Games, the vision behind this project is to overcome impediments hindering students in understanding how the processes they learn at school laboratories can be utilized in practice, while at the same time offering them virtual training opportunities.

The goal of the project is to create a learning game in Virtual Reality to help the BLS students explore the haematology laboratory and compare it with potential workplaces with this type of facility. For this, virtual reality (VR) technologies will be used, i.e. computer-based technologies allowing users to be immersed in a 3D environment and interact with and manipulate objects according to predefined rules (Heldal, 2004). The application can be categorized as a serious game (SG) application defined and designed to contribute to learning (Susi, et al., 2007).

Furthermore, the genre of game can be categorized as "point-and-click", as this is the type of navigation available to the player using the head-mounted displays (HMDs). The realism of the environment is important to understand the practical context. Therefore 360°-video, and pictures taken in the laboratory at HVL and various locations at Haukeland University Hospital, was imported and visualized through the HMD. This environment was further developed by adding quizzes and functionalities to support learning in this context via the game development tool Unity3D.

In the final product, the BLS students will be able to explore the areas with VR-headsets, learn about the different instruments and accomplish various tasks designed for a learning experience. The included quizzes and information about the equipment were developed and inspired from the student's curriculum (Husøy, 2018).

The initial idea was that the equipment used and practical information for usage should be presented to the player when exploring the lab. This was realized in the Haukeland scenario, where the user can play through a mini game where he/she must pick the correct equipment for a blood sampling procedure at different rooms in relation to a requisition. Here the user can only proceed if he/she collects the correct equipment for each room.

1.2 About the project

The project owner is HVL (Høgskulen på Vestlandet, Western Norway University of Applied Sciences). The project is owned by EduGameLab, a doctorate project lead by Professor Ilona Heldal at HVL, and supervised by her and Tord Hettervik Frøland, who is responsible for technology development here. The aim of EduGameLab is to develop digital learning resources that can benefit BLS education by bringing the education closer to clinical health institutions (like hospitals) via interdisciplinary research for using applied information technology and BLS education. This is done mainly through using virtual simulation and gamification (Cristin, 2021).

1.3 Constraints

There were several limitations to this project, one of which was time. Furthermore, the project members had no previous knowledge of the game development tool Unity, as well as no experience with VR-development. Thus, the time to learn these topics was a constraint. In addition, the project members initially chose another bachelor project, and changed to the current one at a later than optimal stage. This compounded the fact that time was an issue. With more time, the project could have included more functionality and gamification elements, which could have elevated both the quality of the current product and learning experience.

Other limitations included user testing, knowledge of the biomedical equipment and the process of blood sampling. The user testing was done by combining user feedback, questionnaires and a semi structured interview with each tester. However, this was done in week 22, which means the feedback can only be used if the project is further developed (and not during development). Evaluating the correctness of the biomedical equipment also lies outside the project members knowledge, and consultation with instructors on the BLS course or literature on BLS procedures was needed. The project also required information around the blood sampling procedure, recording it and for a BLS instructor to perform it.

Another key constraint was the fact that the group only had one available HTC Vive Eye Pro. This made testing and developing the product harder, although this was worked around with a C#-script that made it possible to use the mouse to look around in the same manner as with a VR-headset. Also, the project was supposed to be implemented with Varjo HMDs (Head-mounted displays), but as they were quite late to arrive, the group decided to develop with the HTC Vive instead.

The last and most obvious constraint was due to the Covid-19 pandemic and restrictions. Originally, the plan was to take 360°-pictures and 360°-video at Haukeland University Hospital. However, due to Covid-19 restrictions, this became difficult, and the laboratory at HVL was chosen instead. For the project, this meant that the quality of the content was diminished as well as the level of gamification elements, which could have made a better learning experience and overall product. In the end, the team was allowed to take pictures at Haukeland too, which was added to the project. This improved the application, but it could have been even better if it had been possible to include Haukeland from the start.

1.4 Resources

The resources needed in the project included software, hardware, earlier work and information about BLS equipment and medical processes. The main software needed in this project was the game engine Unity, as well as programming/scripting in C#, either done through the integrated development environment (IDE) Microsoft Visual Studio or Visual Studio Code. SteamVR, which is a Steam application for VR headsets, was also needed to detect the VR-headset and controllers. Regarding earlier work, the application StikkeApp developed by Tord Hettervik Frøland was used as inspiration, and some elements like cut-out-photos of lab equipment were re-used in this project.

As for the hardware, the HTC Vive Eye Pro is being used for the VR development and user experience. Furthermore, a 360°-camera, the "Insta360 ONE X", was needed to take the pictures and videos that were being used in the application. Also, getting access to record in the laboratory at HVL from a BLS instructor was needed, along with guidance of the lab and equipment, as well as the instructor performing the blood sampling process that was filmed. In addition, much of the same was needed at Haukeland hospital, where some of the emergency department, patient rooms, blood sampling room etc. was taken picture of or filmed, along with guidance from a biomedical laboratory scientist.

1.5 Structure of the report

Chapter 1 introduces the project as well as its motivation and goal. It also provides a context, as well as listing different limitations. Lastly it provides information about the various resources used in the project.

Chapter 2 gives a project description with a practical background. Earlier work, initial requirements and the initial idea of a solution is provided, in addition to describing the project owner.

In chapter 3 the design of the project is given. Firstly, a suggestion for a solution is listed, along with two different alternative solutions. Next, the chosen solution is presented, followed by the chosen tools used in its development. The project methodology is also presented, and lastly, there is an evaluation plan.

Chapter 4 describes the more detailed design of the project. It tells about how the project results are achieved and explains how the design and creation of the product has been made.

Chapter 5 is about the evaluation of the project. The different methods to evaluate the project are detailed. Also, the result of the evaluation methods are described.

Chapter 6 gives a discussion of the results. It discusses consequences of the chosen approaches, how the choices influenced the results and how the results can be improved.

In chapter 7 the conclusion of the project is given. A summary of the goals and if they were reached is also provided. In addition, remarks on further work are given.

Chapter 8 gives a reference to all the sources of information in the project.

Chapter 9 is the appendix, which includes how the project risks were handled (risk list), how the project was planned (GANTT-diagram), a user experience schema, a questionnaire about play-based learning, interview questions and the technical overview of a Unity scene.

2 Project description

2.1 Practical background

This project develops a serious game and uses different technical solutions. The aim is to support the learning of BLS students with knowledge transfer for when they will perform their practical training or finish their education and begin their work at different hospitals or health institutions.

Also, the purpose is to create a gamified solution where the primary purpose is not only entertainment but learning.

The project wishes to simulate different medical procedures and equipment that BLS students use as part of their practical education. This is to help them become familiar with the physical locations, equipment, and different tasks related to these. The project also wishes to give the students more opportunities to familiarize themselves with the practical side of their studies considering the insufficient time and availability these resources sometimes have.

The game developed in this study will be used at EduGameLab in the studies of BLS students, initially with the supervision of Tord Hettervik Frøland, but afterwards by the teachers in BLS education.

2.1.1 Project owner

As mentioned, the project is owned by the Western University of Applied Sciences (HVL) but is part of the EduGameLab project, which is supervised by Professor Ilona Heldal and Ph.D student Tord Hettervik Frøland. The technology will be used (further developed) by Tord Hettervik Frøland from the Department of Safety, Chemistry and Biomedical laboratory sciences. Tord developed several games for BLS engineers, e.g., StikkApp (Frøland, et al., 2020).

2.1.2 Prior work

In relation to virtual reality, the group has not been introduced to any prior work or solutions that are being used or built upon in this project. However, Tord has introduced his earlier work with "serious games". Specifically, we have gained a lot of insight through his StikkApp, which is a gamified approach to aid BLS students with conducting specific tasks related to their practice. These games include quizzes, collecting correct equipment, studying documents, and simulating procedures. Many of the components of the project, are ideas that are taken from this StikkApp, for instance the quiz-component, collection and inventory components, point system, and the ability to view videos.

2.1.3 Initial requirements

The project owner wanted to see a project solution that aimed to aid newly enrolled BLS students in becoming acquainted with the laboratory, its equipment and different medical procedures related to their studies. On behalf of the product owner, Tord Hettervik Frøland also made a list of sub-goals for the application:

Table 2.1 - Sub-goals for the project

Level	Goal
1	One functional scene where the user can look around in VR.
2	Navigation between scenes.
3	Interaction with hand-controller in scenes (highlighting of objects and simple menu-navigation).
4	Interaction with eye-tracking in scenes.
5	Simple game-elements in scenes (tracking of score, quiz-based minigames).
6	Player can interact with persons in the scenes.

All the goals did not have to be completed, nor was it exhaustive, it was made as an iterative guide for the project. This was made to ensure that the project had a clear direction and to facilitate the development.

An additional important aspect is that the product owner wanted the solution to be made in a configurable and modular way so that it will be easy to implement new scenarios and environments.

2.1.4 Initial solution

The initial solution was to build an interactive serious game which simulates the bioengineering laboratory using VR-headset equipment. The solution has used a 360° imaging hardware in conjunction with VR equipment to recreate locations in the laboratory, and its surroundings. These locations are specifically placed outside the entrance of room F303 (the haematology laboratory) and at positions inside room F303. The pictures taken inside the room will allow the player to be placed at various locations:

- Entrance of room F303
- The equipment cupboard
- The sink
- Blood sampling station

These locations are each placed in their own Unity "scene" (each Unity project can consist of many scenes) and are then linked together to create a seamless virtual tour of the entire environment.

Players can interact with various parts of the equipment cupboard and search and collect equipment while also having the ability to display names and equipment information. Different objects can be collected in the inventory system before moving on to the blood sampling station where they can continue only if they have collected the correct equipment. In the initial solution we had planned to incorporate an interactive simulation of a typical dialogue between a patient and a BLS student during a blood sample testing. The video was done by recording a real-life 360° video of a blood sampling. The idea was to make it so that students can watch, interact, and choose different dialogue scenarios with the patient to further familiarize themselves with the process.

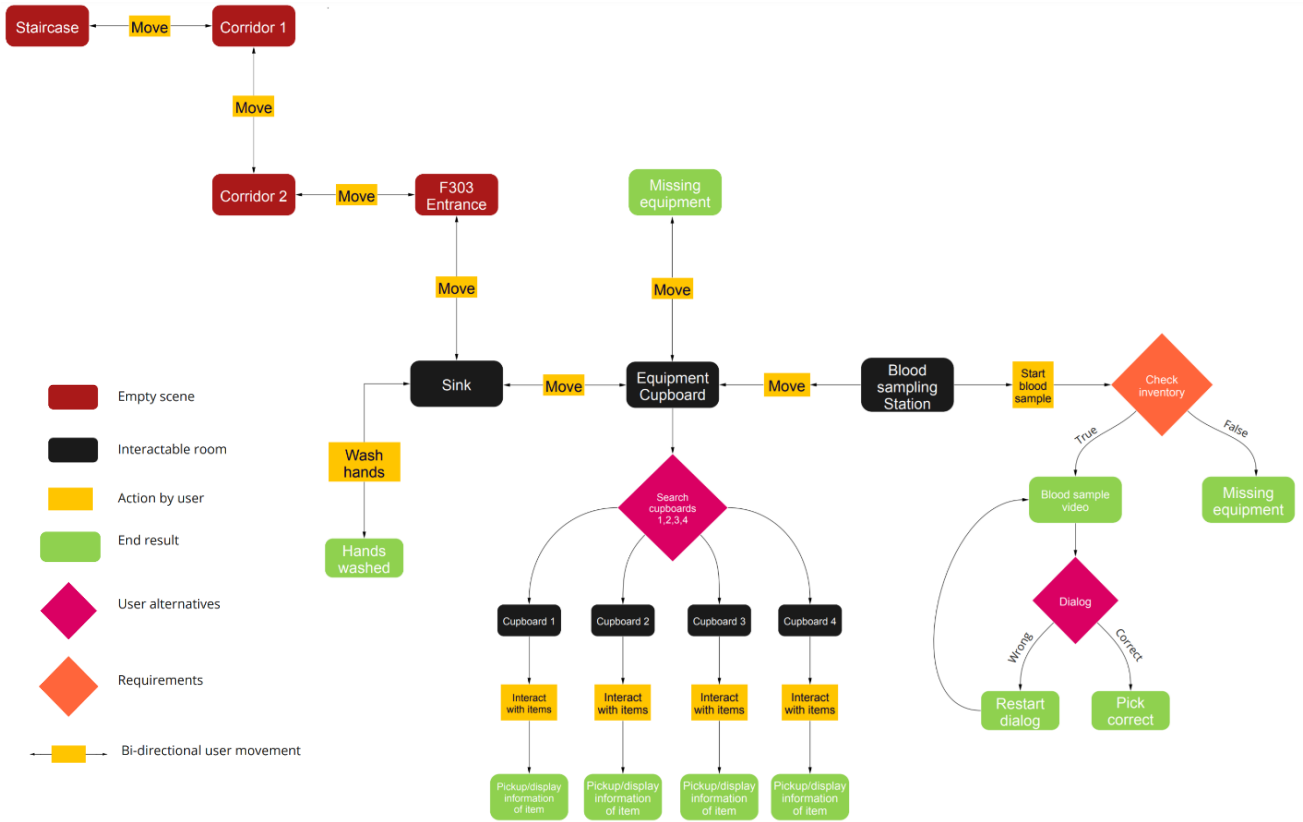


Figure 2.1 - Initial User Flow of game

In figure 2.1, "empty scenes" denote scenes that only have the visual representation of a 3D environment, but not any interactable objects besides clicking and moving to other scenes. Interactable scenes have more content and have interactable objects in them like cupboards and equipment. As seen in figure 2.1 the player starts in the empty scene "Staircase", the player then moves further on in the hallway through its corridors, which are also empty scenes. Eventually the player is inside the lab room F303 and can then move around to various locations and interact with cupboards and tables with equipment, quizzes and video.

Initially we thought that the player would be able to open and close cupboards 1,2,3 or 4 and click on equipment inside each of them to display information about it or collect it, from the "Equipment cupboard" scene. Our plan was also to interact with the sink, so the player would have to wash their hands before taking the blood sample. In our initial solution we also wanted to give the player the ability to interact in a blood sample video by choosing the correct dialogue answers. This blood sample would only be available when the player has collected the correct equipment to take a blood sample.

The VR equipment we were to use also has two sensor controllers that track movement in the virtual room. We wish to use these as practical aids in the game; being able to click and point at equipment to display information and collect them, being able to click on different parts of the room to move, navigate the quizzes and display inventory information.

3 Project design

3.1 Possible approaches

Even though the goal and the work method of the project was well defined, multiple approaches to achieve it were found. In the following subchapters, the different approaches are presented and evaluated in relation to the overall project goal. In the discussion, an evaluation of the pros and cons of each alternative is presented then followed by a conclusion where one is chosen.

3.1.1 Alternative approach 1 - Develop the game for HTC Vive and hand controllers

With the help of already existing technology, the idea was to develop a Virtual Reality learning game with the HTC Vive Head Mounted Display (HMD) and controllers. With the HMD, which scans its whereabouts, the user can look around in the environment and use the controllers to interact with different objects and functionality that has been added.

The virtual space depicting the real laboratory was to be taken with a 360°-camera. The photos and videos taken with the camera would then be inverted and placed inside a sphere-object in Unity. Furthermore, the rendering VR-camera in Unity was then placed in the direct centre of the sphere, which would give an illusion of a 3D-environment.

3.1.2 Alternative approach 2 - Developing the game for Varjo and eye tracking

This alternative is similar to the first one in terms of the game objects and functionality needed, but the interaction would be different. In addition to having hand controllers to trigger objects in the laboratory, the user would be able to benefit from eye-tracking, which would also highlight objects. The benefit of using Varjo was for this eye-tracking functionality, which could elevate the experience of the learning game.

3.1.3 Discussion of alternative approaches

A first consideration could be to simply look at the price difference between an HTC Vive HMD and a Varjo HMD, which is 1000 euros for HTC and 4000 euros for Varjo. Thus, the alternative cost for each Varjo HMD bought by HVL is equivalent to four HTC Vive HMDs. This means that developing for the HTC Vive would enable more students to experience the application at the same time, in addition to the fact that it could reach a larger audience in general with a less expensive VR-headset. The main project goal was to eliminate the limited access to experience the laboratory physically, so therefore it would probably be counterproductive to add another resource limitation.

The next consideration was the fact that when using the HTC Vive, the group could develop with SteamVR. The benefit here is that SteamVR functions as a general API-library for many other commonly used VR-headsets. As such, the product developed can therefore more easily be implemented with other VR-headsets as well. (Valve, 2021)

A last and final consideration was the fact that the group had to wait longer for the Varjo HMDs to arrive, with the HTC Vive being available approximately two weeks before. As the group already had lost time by switching bachelor projects, in addition to not having previous experience in game development with Unity, switching VR-technology on top of that was deemed unwise.

3.1.4 Chosen approach

Given the limited resources, waiting time for Varjo and the difference in cost, illustrated in the previous discussion, the team decided it would be more reasonable to pick the first approach, thus developing the application for the HTC Vive. SteamVR also works well with other VR-headsets, which makes it possible to support different ones in the future.

Regarding eye-tracking, the conclusion was that it would not significantly help reach the main goal of the project. Therefore, eye-tracking was pushed further down the list of goals, and in the end, it was not implemented as a functionality in the final product.

3.2 Specification

The goal was to create a fully functioning serious game which BLS students can benefit from. By using HMDs with hand controllers, the idea is to recreate the laboratory at HVL as well as different environments at Haukeland. Furthermore, the application uses point-and-click interaction with the hand controller for navigation and general interaction with objects. Specifically, the users can click on medical equipment and learn about them, they can watch a video of blood sampling with a video quiz, they can take a quiz and go through a minigame where they must pick the right equipment for different blood sampling routines (based on a requisition).

3.3 Selection of tools and programming languages

From an early point in the project planning, the choice of game development tool had to be made. Here there were two options: either Unity or Unreal Engine. Since the team did not have any previous experience with game development, Unity was chosen, as this appeared to be the easiest one. In addition, Unreal Engine requires better PC components (CPU and GPU) than Unity. Because the team had laptops with limited processing power, this was a factor in favour of Unity. However, the deciding factor was that our project owner had good knowledge of Unity, as well as previously having made an application in it himself (StikkApp). The programming language C# is used for the scripts when adding additional functions to the game, something the group members had learned in an earlier course.

3.3.1 Tools

HTC Vive Head Mounted Display

We will use the HTC Vive head mounted display to replicate the player's point-of-view and give the ability to use the included hand controllers to interact with the virtual environment.

Unity

Unity is a development platform for creating 3D and 2D games across multiple devices. The development flow consists of editing the 3D scene and the high-level game design in the Unity editor, while creating custom scripts to handle a lot of the behaviour of the game objects. It supports development on both MacOS and Windows, which was important for the project's development prospects. Unity also comes with a built-in collaboration service that was utilized. This meant that the team could share the whole solution within the application without the help of third-party services.

Microsoft Visual Studio/Visual Studio Code

The game's logic, that is; opening cupboards, doors, moving around, clicking and interacting with objects in each room etc., is handled by scripts written in C#. The group has used both Microsoft Visual Studio and Visual Studio Code, depending on what OS each member is working in.

Visual Studio Code is a lightweight but powerful source code editor which runs on your desktop and is available for Windows, macOS and Linux. It comes with built-in support for many programming languages and offers many extensions and runtimes such as Unity (Microsoft, 2021).

The Microsoft Visual Studio IDE can be used to edit, debug, and build code, and if needed, publish an app. An integrated development environment (IDE) is a feature-rich program that can be used for many aspects of software development. Microsoft Visual Studio includes compilers, code completion tools, graphical designers, and many more features to ease the software development process (Microsoft, 2021).

These two IDEs were used to create the scripts/programming necessary for the project.

Insta 360 One X

A special camera with two lenses that captures 360-degree photo and video. The camera is placed on a stand with at the height of the human body. The output file looks like a stretched image which is wrapped around a sphere in Unity to create a 3D-scene.

3.4 Project development method

3.4.1 Development method

The main development method revolved around agile software development. This means that we made long-term plans but were prepared for sudden changes that could result in alternative solutions that differentiate from the main one (Alliance, 2021). The work was divided into sprints, where each sprint lasted a week or more. When the sprints were over, we evaluated what had been done and if we needed to change our plan for the next sprint. The team's focus was also on producing a playable product with some bugs and glitches, rather than stopping the whole workflow because something was not working hundred percent as intended.

3.4.2 Project plan

The project plan can be found in chapter 9.2 in the appendix. This plan has been followed quite closely. However, user testing set for week 20 was postponed to week 22. Also, testing in week 23 would be after the new date for delivering this report, which meant that this was not done.

3.4.3 Risk Management

The risks involved in this project were handled primarily by developing iteratively. The initial goal of the project was quite quickly covered by the ease with which 360°-pictures and 360°-videos were taken and used in Unity scenes. Also, the initial list of sub-goals was meant as a guide, where the idea was to come as far as possible, but that the project did not *have* to accomplish all of them.

The risk of not having enough experience with Unity was covered by researching and learning about Unity and different solutions to required functionality. Having too many bugs was a risk that showed itself to be easily handled due to the visual development of the project, which made bugs and errors easy to find.

Not delivering a satisfactory product is a question of how beneficial the product is for learning. This was difficult to have a plan for and made more difficult by the fact that the laboratory at HVL was used differently than what was initially presented. Thus, more game-related aspects such as opening closets and drawers to get equipment were not relevant. However, an inventory system was logical at Haukeland, which made it possible to make a "game" focused on picking up the correct equipment for each room, based on a requisition. This might elevate the learning experience.

3.5 Evaluation plan

It was necessary to test the project both during the development and to receive feedback from user testing. Internal, functional, testing was needed to ensure correct behaviour from different implementations in the application. This was to be done iteratively and continually during the development of the project. Furthermore, the plan was to test with students, but this was not done due to time constraints. However, user testing was still accomplished with BLS instructors during week 22. The feedback from users would be very valuable for improving the current application. Chapter 5 gives a more detailed picture of the evaluation of the project.

4 Detailed design

4.1 Architecture

The solution revolves around three main components: visualisation (HTC Vive Eye Pro), logic (Unity with C#-scripts) and interaction (HTC Vive head tracking and hand controllers). The team's solution resembles a popular architecture called Model, View, Controller (MVC) which is used in many programming projects. The main purpose of this architecture is that you differentiate the components as own individual sections of the application (see figure 4.1). If this is done correctly, the application should be more solid and easier to use (CodeCademy, 2021).

In our case, the only component we are adjusting is the model component (Unity Engine), and as of now the components are combined for a solution that fit our purpose. Any major changes to the model component could make the game not work as intended or not at all. However, switching between HMDs that support hand controllers should give the same result.

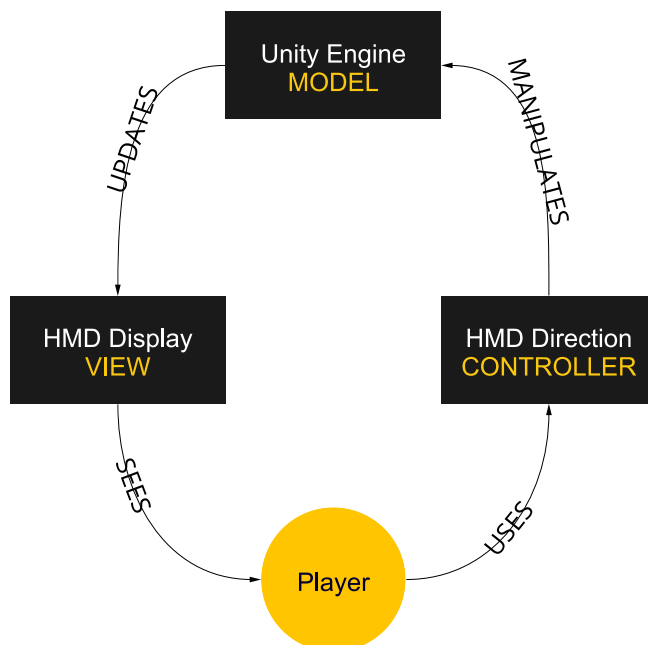


Figure 4.1 – Model View Controller

4.2 Technical Design

The project is composed of many different "scenes" in the Unity software. A scene can be used for many purposes like creating a menu system or individual levels in a game. A scene is used as a container for environments, obstacles, and decorations to mention some examples. Building a game in the Unity software consists of the use of numerous scenes to easily separate and work with unique levels or instances of a game (Valve, 2021).

In the project the group decided to use each 360°-image as an individual scene. In each scene the user can interact with different objects like doors to other scenes, open cabinets or drawers etc. This allows the user to interact by clicking on lab equipment to display its information and interacting with GUI for example.

The project imports the SteamVR Plugin. SteamVR makes it possible to have access to, use and manipulate the functionality of the VR-headset and its controllers. It also supports other common headsets like; Valve Index, HTC Vive and Oculus Rift. Due to SteamVR supporting many other types of VR-hardware, our project can also be run with other types of VR-headsets through SteamVR (Valve, 2021).

To organize each scene in the project there has been created a hierarchy of all the components a scene must have in order to function, and some optional components. These are divided into three main categories:

4.2.1 Custom created components

These are components that have some sort of functionality in the scenes. Like scene triggers to change scenes or objects that can be clicked to learn information about them.

4.2.2 Auto-generated components

There is only one auto-generated component in the hierarchy. The EventSystem component is a way of sending events to objects in the project based on input in a Unity Scene. Each scene has to have an EventSystem, and is autogenerated when a scene is created.

4.2.3 SteamVR components

These components are added to each scene and are either used to represent the scene in the VR-headset or used for the functionality of the controllers, to interact with the other components in the scene, like outline-objects or SceneTriggers for example. Each scene in our project has two main SteamVR components: CameraRig and SteamVR.

SteamVR is automatically added to each scene and handles many functions related to the setup and functionality of the VR-headset and controllers.

The CameraRig handles movement of the headset, movement of the controllers in the scene, and it also handles the view in the headset. The CameraRig has 3 components: "Controller Left", "Controller Right" and the "Camera", which is what renders the environment.

4.2.4 Scripts

If it is necessary, a component might also have one or multiple scripts attached to it. What the script does depends on the component it is attached to. For example, in the hierarchy of a scene (appendix 9.6), the SceneTrigger component has a "SceneLoader.cs" script attached to it. This script is run when the user 'clicks' on the SceneTrigger object in a scene, the code then loads the appropriate new scene into the user view, but also triggers the Fader object attached to the Camera to visually fade the user in and out of the new scene.

A technical overview of the hierarchy of components can be viewed in the appendix image 9.6

4.3 Game flow

When the player first enters the game, they are placed in a staircase at HVL. The group members wanted to start the game at a point where there was no particular point of interest, and therefore give the player time to adjust to a new experience with a HMD, test head movement and how the hand controllers look and feels inside a virtual space. In addition, this location was suggested by Tord Frøland.

When the player is ready to move on, they are presented with two options. They can either go to HVL's own haematology lab, or travel to Haukeland University Hospital

(HUS). The initial idea was that the students would enter the lab at HVL first and proceed through the lab and quizzes there, before entering Haukeland. Then, at Haukeland, they are placed into the BLS "trolley"-room, where the biomedical laboratory scientists collect equipment for blood sampling. From there they can travel further to a hallway in the emergency department, where they are presented with a mini-game to collect the correct equipment for blood sampling at different rooms. They have to pick correctly based on a medical requisition. After that, they can go back to the equipment room and receive the final score for the entire game. The whole game flow is illustrated in figure 4.2.

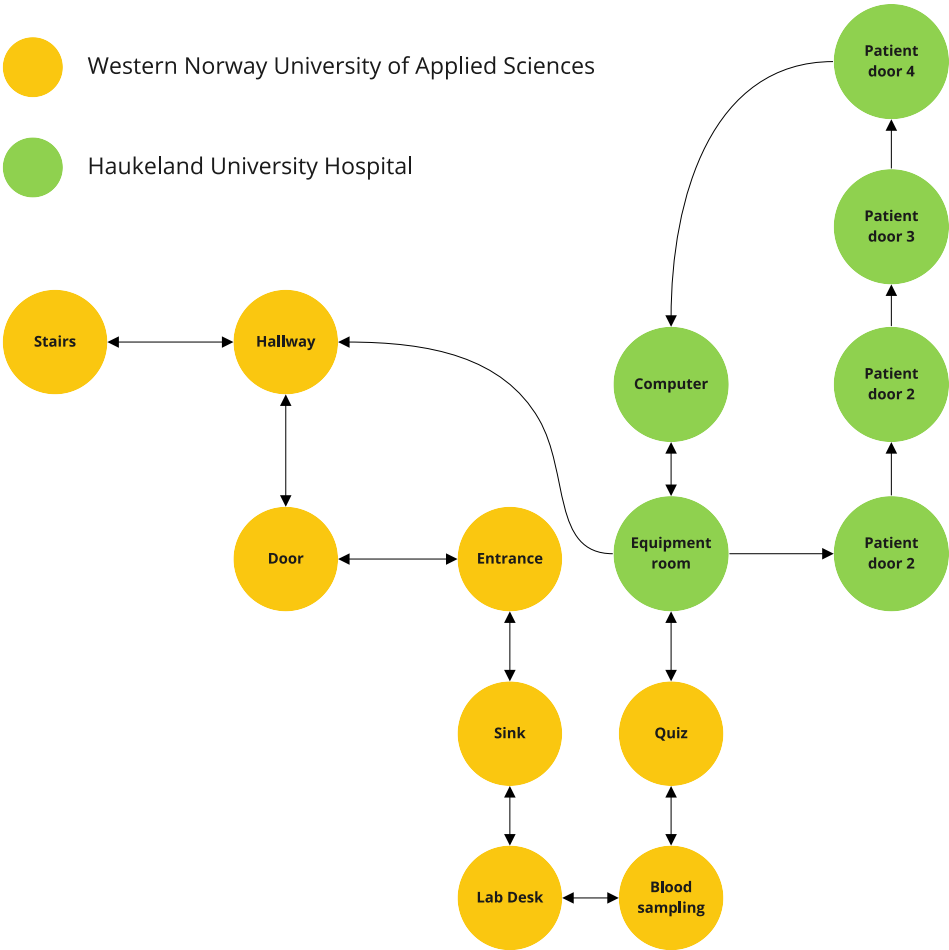


Figure 4.2 - Scene map

4.4 Making a virtual 360-space

To make this project possible the team needed a way to convert a real space into a virtual one. 3D-modeling everything would take too much time and would probably be a bad representation of the environment to be replicated. Luckily, the solution of formatting 360°-images into the project's 3D-scenes works well and is not overly complex.

First, a photo from the Insta 360 One X camera is taken. The raw format from this picture looks like a stretched wide lens image. This image is then wrapped around a sphere object in Unity and the camera (the player's point of view) is then placed in the middle of the sphere. It is same principle as the world map wrapped around a globe. The only difference is that instead of seeing the globe from the outside, you are seeing a horizontally flipped map from the inside.

The drawback of this solution is that if we are giving the player the ability to move around in the sphere, the perspective of the wrapped image would change, and the illusion of a 3D-world would break. As a way of navigating through the lab the team made multiple scenes with the same method as shown in figure 4.3.

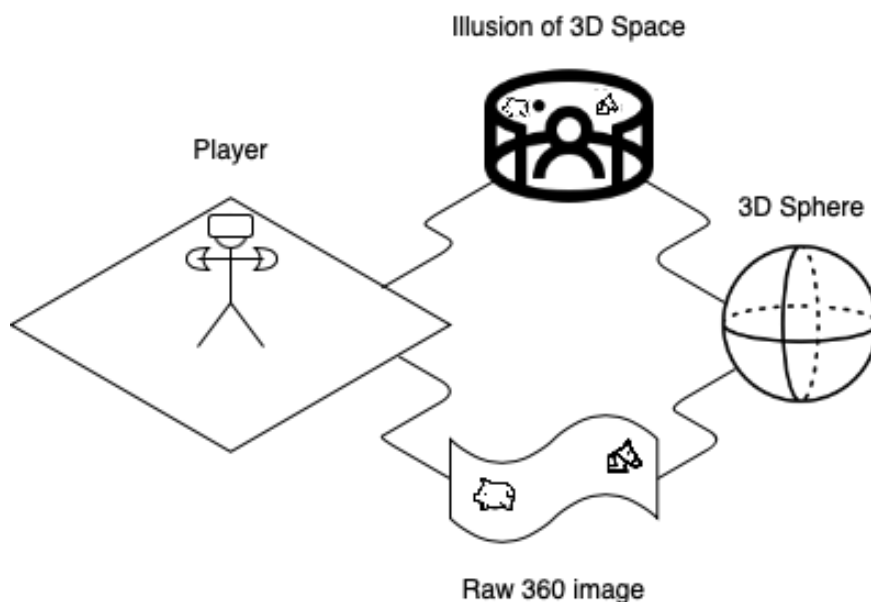


Figure 4.3 - 360 Image overview

4.5 Scene changes

The project needed a way to change between the different scenes in Unity. This was made possible with a rectangular 3D-object which used a script that showed only the object's outline when hovered over. An invisible Unity-material (information that sets the appearance of an object's surface) was implemented on the object, which is actually a rectangle. In addition, there was another script attached to the object, which, when clicked, would trigger a scene change. As one can see on figure 4.4, the

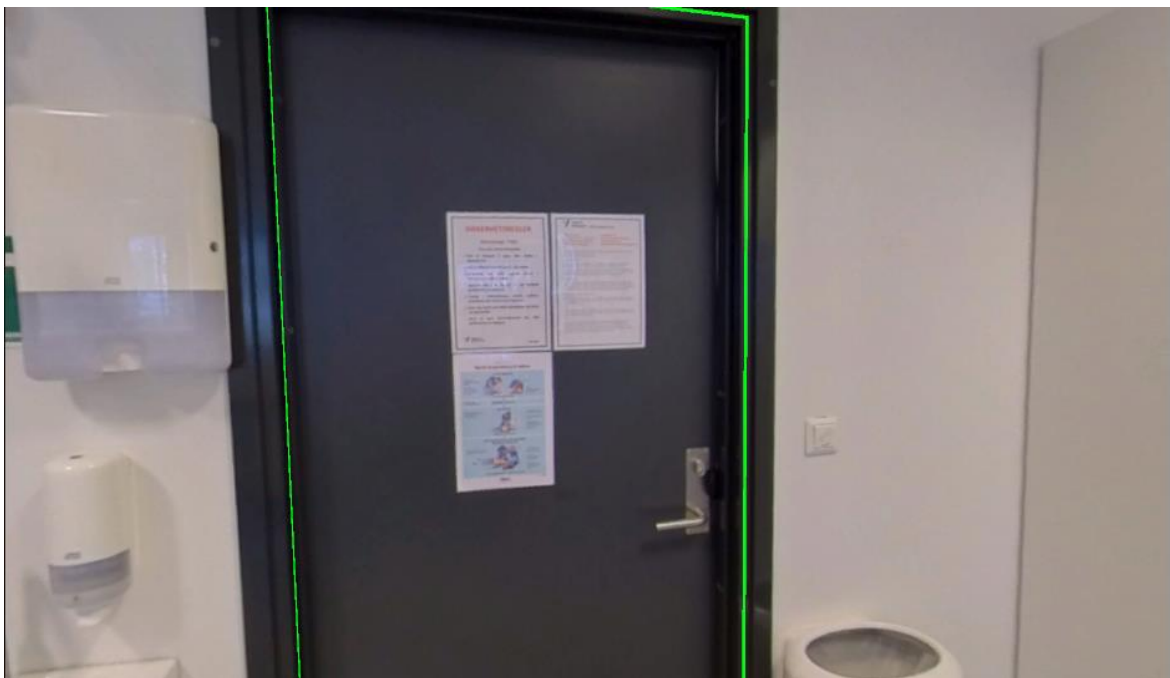


Figure 4.4 - The outline that appears when hovering over an area with a scene changer-object

outline of the scene changer-object appears when looked upon with the VR-headset or pointed at with the controller. Clicking inside the outline triggers a scene change to the next or previous scene. In addition, transition between scenes triggers a fader object on the main camera, which makes the scene transition fade to black before displaying the new scene. This is partly done to reduce the possibility of motion sickness and partly for a more natural transition between scenes.

4.6 Clicking on objects – displaying information

A large part of the VR-experience was to learn about the different equipment in the laboratories, both at HVL and at Haukeland. Thus, there was a need to create Unity-objects overlaying the "real" equipment, creating an illusion of an outline for the object. This was done similarly as the scene-changing objects, with only the object's outline being displayed when hovered over.



Figure 4.5 - The outline of an «invisible» Unity-object when hovered over or looked upon with VR-headset

When the rectangle object is clicked, information about the equipment it overlays is displayed in a canvas-object. This canvas also includes a close-up picture of the object, as well as a "read more"-button if the information has been split into two pages, and also a red "X"-button to close the canvas. The canvas can be seen in figure 4.6.



Figure 4.6 - The canvas that displays information about the equipment

4.7 Blood sample video

Using the same method that makes a virtual 360-space with images (see figure 4.3), the same result can be achieved with video files. As a way of utilizing this, the team filmed a blood sampling procedure where the camera was placed between the BLS instructor and the patient. The goal was to achieve an illusion where the player would get the point of view of the BLS instructor during the blood sampling.

The team also wanted the students to answer relevant questions while the blood sampling is taking place. This is to prevent the students from getting distracted and unfocused, and also testing their knowledge linked to the point of interest at a specific time in the video. For example, when the BLS instructor uses the stasis band, a relevant question about the stasis band appears. The video is then paused, and the user cannot continue before they have answered correctly. When a right answer is achieved, the video continues until a new question appears. This approach repeats itself until the blood sampling is done. An example of a quiz question can be seen in figure 4.7.

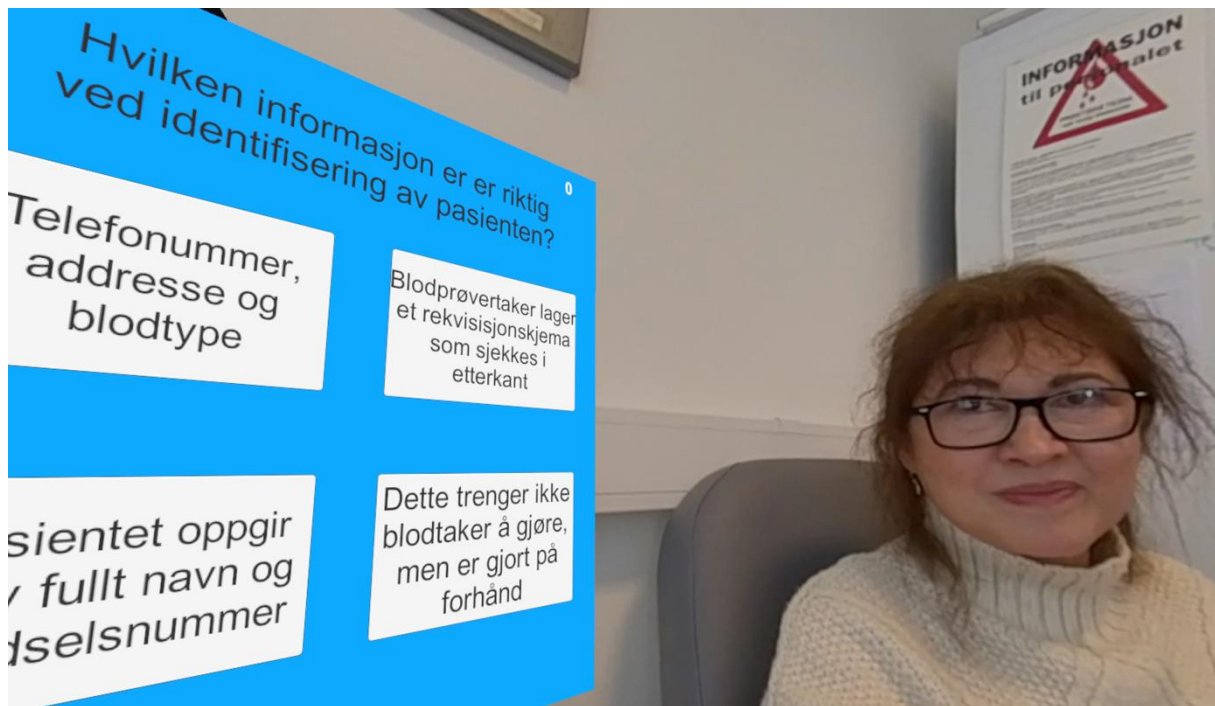


Figure 4.7 - The canvas that shows the question prompt during video quiz

4.8 Quiz

For the learning purpose of the game the group members thought that a multiple choice-quiz would be a good addition to the project. Questions and answers are generally a smart way to implement learning experience and works well across all subjects. The multiple choice-quiz also makes coding a solution easier and player interaction more intuitive. The students also get a score based on how many tries they need to get the right answer. The team hopes that a game score would make the students want to improve, and therefore try the game again and learn more. The questions and answers to the quiz is also parsed from a JSON-file. This means that it can be easily changed if something is wrong or needs to be updated. In figure 4.8, a question from the quiz is seen.

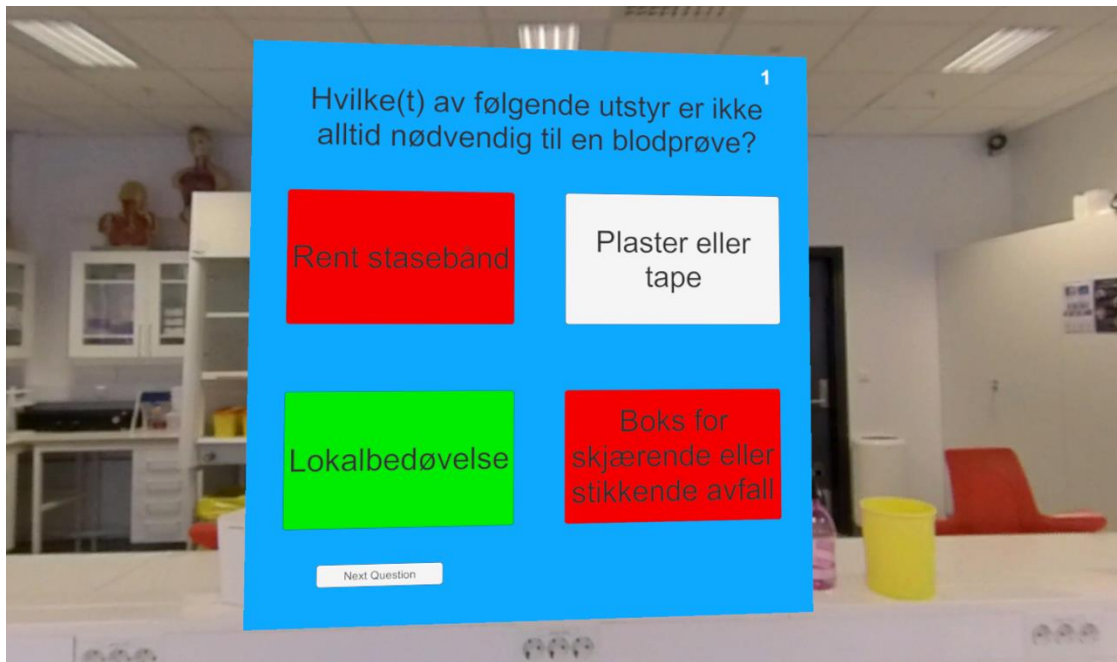


Figure 4.8 - Player view of quiz user interface

4.9 Haukeland Hospital mini-game (requisition and equipment)

At Haukeland the team got the opportunity to implement some unique features which corresponds more with a normal workday for a typical biomedical laboratory scientist. The mini game takes place in one of the many hallways at the hospital where the player can interact with different equipment in the cart in front of them. When the player clicks on an object, the object gets automatically added to the inventory at the bottom of the screen. If the object is already picked up, the object quantity will increment by one. The player can also choose to remove objects from the inventory to make space for other equipment.

The game's purpose is to get the right equipment and quantity given the requisition's room number and blood sample analysis. The room number in the requisition corresponds to the actual room numbers in the 360-degree environments. The requisition was supposed to be displayed by pressing a controller button, but currently it only works by pressing the spacebar key on the keyboard. The player will then need to click on the patient door to check if the equipment in the inventory fulfils the requirements. If the inventory does not match the required equipment, the player is presented with a warning message telling them that they are missing some

equipment. As an extra challenge, they also need to disinfect their hands by clicking on the antibacterial bottle.

When the player has the right equipment and disinfected their hands, they will be presented with the opportunity to move further down the hallway where a new patient room awaits.

This implementation can also be improved in a way where the given blood sample analysis from the requisition is randomized and therefore gives a unique experience for each playthrough. This will again give the students an incentive to play the game again and continue to improve their skills.

After completing four patient rooms the player can go back to the equipment lab where they finish the game by clicking on a computer, as shown on the left in figure 4.9. The computer will then show their total points from Haukeland and HVL. The visual look of the mini game is shown on the right in figure 4.9.

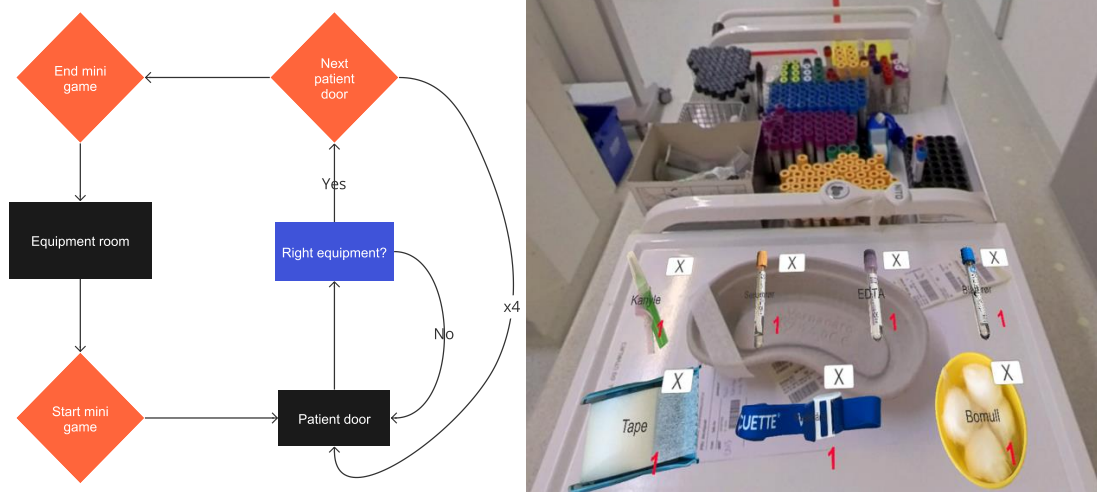


Figure 4.9 - Requisition mini-game flow at Haukeland University Hospital

5 Evaluation

5.1 Evaluation method

The project needed to be tested in different manners, both internally and externally with users. Internal, functional testing was to ensure that all parts of the application worked correctly. User testing was to receive feedback on the learning benefit as well as the overall experience of the application. Both of the testing methods were valuable for the project, where the user testing is most relevant for further work.

5.1.1 Internal evaluation

During the development of the project, iterative testing has been used after each new iteration. This is part of "agile software development", which is "the ability to create and respond to change" (Alliance, 2021). Agile development was a natural pick for this project, due to the fact that it was started on later than usual, which gave a greater need for flexibility. Also, functional testing has been the main way to test the application. The group members continually tested all of the elements of the project as they were introduced. Because the project is a VR-project and the group only had one HTC Vive-headset, a script for manoeuvring with mouse-clicks was used for testing the different Unity-scenes. This enabled all members to simulate the VR-experience without having the HTC Vive at hand.

The project was developed in Unity with "Unity Collaborate", which is a method for several people to develop a Unity Project in a cloud-hosted environment (Unity 3D, 2021). This made it easy to test all the functionality produced by different members, as well as testing with the HTC Vive. Tord Hettervik Frøland was also added as "collaborator" to the project, which made it possible for him to test it as well. The plan was also to involve BLS students to test the product. Instead, 3 instructors from the BLS department at HVL tested the application. The largest positive here is that the instructors are trained to teach students, and this can be helpful in evaluating the learning benefit of this application.

The project had a couple of clearly defined goals in the beginning. These were:

1. Recording 360°-video and taking high-resolution 360°-pictures of laboratory environments and objects.

2. Adding points-of-interest in each scene that can be highlighted by looking at the object/area by the use of eye-tracking and head-mounted displays (HMDs).

3. Creating an interactive game experience that helps students familiarize themselves with the environment by performing actions in games.

Furthermore, Tord Hettervik Frøland created an iterative plan/requirements list with different levels for some of the possible goals the project could aim at achieving. This was not a strict plan, but a way for the project to have something more than the general goals that had been presented initially, as seen above. The goals he included can be seen in table 5.1.

Table 5.1 - Sub-goals for the project

Level	Goal
1	One functional scene where the user can look around in VR.
2	Navigation between scenes.
3	Interaction with hand-controller in scenes (highlighting of objects and simple menu-navigation).
4	Interaction with eye-tracking in scenes.
5	Simple game-elements in scenes (tracking of score, quiz-based minigames)
6	Player can interact with persons in the scenes.

This list can be used, to some degree, to evaluate the final product. Functional tests have been carried out in regards to this list.

5.1.2 User testing method

In week 22, the project was tested by three instructors from the BLS study. It was tested by 2 women and one man in the age range of 48-61 years. They will hereby be referenced as tester 1, tester 2 and tester 3. Tester 1 has taught laboratory-exercises for one year, tester 2 for between 12 to 15 years and tester 3 for 13 years. In the testing of the application, they experienced the entire product in a natural manner, with the HTC Vive Eye Pro and controller.

The plan and method of the testing had several elements. First, they had to fill out a consent form to take part in the testing. After that, they had to fill out basic information about themselves (contact info, age), along with answering questions about play-based learning (see Appendix 10.4: Questionnaire about play-based learning (in Norwegian)). This was done to have context about each test person and their experience with game-based learning in general. Following this, the user test of the VR-game was to be conducted. Afterwards, there was to be held a semi structured interview with each person. This was done to receive feedback on the experience. Here the idea was to find out what can be improved, what worked well, what did not work well etc. Lastly, a user experience form was to be filled out (Schrepp, 2014).

5.2 Evaluation result

5.2.1 Internal evaluation result

The project had several general goals as well as sub-goals for the actual content of the application. Most of the goals and sub-goals have been reached and developed. Additional content/functionality has also been added. For instance, the project has a video of a blood sampling procedure, where the video is stopped at certain time intervals and the user is prompted with questions related to blood sampling. In addition, 360°-video and 360°-pictures have been taking at Haukeland University Hospital, which was not guaranteed earlier because of Covid-19 restrictions. Thus, the project includes both the haematology lab at HVL and scenes of different locations at Haukeland. Below, the sub-goals of table 5.1 are discussed.

Taking the 360°-video and photos went well, using the "Insta360 One X" camera with its tripod. The pictures were imported into Unity and placed onto sphere-objects which rendered the photos. When scenes are played, it gives the proper, realistic view of each location. Thus, the VR-experience automatically has high quality from such a "simple" starting point.

Navigation between scenes works smoothly, with a "fade-to-black" transition effect between each scene. This makes the transition between rooms feel less abrupt and it is less likely for the player to feel motion sickness, something the team themselves tested with the HTC Vive. This worked simply by attaching a black canvas right in front of the VR headset camera in Unity, which would activate and cover the players view with a brief black canvas when loading a new scene for the player. This logic would be scripted so that it was activated each time the user clicked a SceneTrigger object in the scene.

The interaction with a hand controller also works correctly. A user can click on different objects that are highlighted and interact with them (either with a scene change or information about said object).

Eye-tracking has not been implemented in the project. The group saw this as a bonus if there was enough time, which has proven insufficient. The HTC Vive Eye Pro does however trigger the highlighting function when the user looks directly at an object through the middle of the headset, the user does not have to use the pointer to point directly at the object to see that it is interactable. Considering this, there is some similar functionality to eye-tracking.

Different game-elements have been created, such as scene changer-objects, outline-objects, canvases with information, a quiz, as well as a mini-game for blood sampling at Haukeland hospital. As this is a highly visual project, it is also easy to see when something is not working. All the created game-elements work as intended, so then the only issue becomes the visual quality of them. Thus, this is an UI-design consideration, which is more of a bonus on top of required functionality.

The user/player cannot directly interact with person(s) in the scenes. The idea was to create a dialog between a user and a person in a scene to be filmed from a POV (point of view)-angle. Here the person in the scene would react according to the user's answers, which would need to be filmed through different scenarios and result in a lot of work depending on how the conversation progressed. Though this was not implemented, a video scene of a blood sample procedure exists, in which the user must answer questions about the procedure at certain moments. They then get points for how many correct answers they give.

5.2.1 User testing evaluation result

Each test person had their own time slot to show up and received information about the project and had to sign a form of consent for testing the VR-game, answering a questionnaire, being interviewed etc. After having given their consent, they were introduced to the HTC Vive and shown how to use the headset and controllers. After that, each tester was introduced to basic functionality inside the game like movement, scene changes and interaction with objects.

Following this, they were to explore the haematology laboratory first, where they interacted with closets and different equipment, as well as navigating. Here they had different levels of understanding the VR-technology and how to navigate in general. Scene changes that were placed on the floor of the next location showed itself to be less intuitive than imagined, as several of the testers needed guidance on where to go. Also, when clicking on different equipment and having information displayed, all of the users thought that it was probably *too* much text, and that it should perhaps be more condensed and structured.

The video of blood sampling along with its quiz was then taken, in which it was remarked that the some of the questions and answers were not correct in regard to biomedical procedures and equipment. Following the blood sampling video, the testers went through the quiz, where they pointed out the same issues as with the video quiz. After the quiz, they could "travel" to Haukeland University Hospital, where they first explored the area where biomedical laboratory scientists gather the required equipment for blood sampling on trolleys.

Next, the testers travelled further in the game, to the emergency department at Haukeland, where they would go through the minigame with a requisition. Here most of them said that the inventory system was quite difficult, because it was placed on the trolley, and they had to look down all the time. Also, the game logic was wrong in relation to the requisition, where the game needed one blood sampling tube for each test, but in reality, the same one can be used for several. Also, one tester thought that 4 rooms might have been too much, as the process of picking equipment from the trolley was quite repetitive. In figure 5.1, one can see a BLS instructor testing the application.



Figure 5.1 - Testing the application

After the testers completed the minigame at the emergency department, they travelled back to the "trolley-room" and could see their total score based on correct answers in the quizzes and the mini-game. This marked the end of the test and the user experience of the game.

The users made several comments during the playthrough of the game. All of the users agreed that there was too much text information about each object. Furthermore, two of the users experienced motion sickness to some degree, while one did not experience it at all. Also, all of them thought that the "Next question"-button was too small in the quizzes, in addition to the fact that answers and questions were not always correct or relevant for biomedical contexts.

After having played through the game, they filled out their contact information and the questions about play-based learning found in appendix 9.4. Here the answers of the test subjects were quite similar.

Table 5.2 – Question and answers about play-based learning

	Tester 1	Tester 2	Tester 3
Do you consider yourself to be experienced with computer games (for both entertainment and learning)?	No	No	No
Have you previously used digital learning games in your classes?	No	Somewhat agree	No
I think play-based learning is positive	Somewhat agree	Agree	Strongly agree
I want play-based learning in my education programme	Somewhat agree	Agree	Strongly agree

As one can see in table 5.2, the testers generally had little experience with computer games, as well as two of them not having applied digital learning games in their classes, while one of them had. They all generally agreed that that play-based learning is positive and that they want play-based learning in their classes.

After this, there was conducted a semi structured interview with each test person. This interview was based on questions from Appendix 9.5: Semi structured interview. Several points were brought up by all the testers:

- There was too much text about the equipment – should be less and more structured.
- They all felt the environment was realistic.
- All of them said they could use the game in their classes.
- Navigation was a bit tricky – they needed some guidance.
- They thought the application can help the transition from being a student/studying to a practice/work-environment.

In addition to these similarities, they had several different points for improvements. The first two testers felt motion sickness, and especially in relation to the experienced "height" in different scenes, which they felt sometimes "broke" the illusion somewhat. Tester 1 and tester 2 thought that the "Next question"-button in the quizzes was too small. Tester 3 thought that it was difficult sometimes to click on equipment objects. Tester 2 thought that the game could have a better guidance for the user (arrows for where to go, for instance). Tester 3 wanted to be able to enter the patient rooms at Haukeland, for the purpose of "taking" a blood sample (in a more interactive, 3D-manner). A video of a blood sample routine was filmed at Haukeland, but there was too little time to include it in the project.

Tester 1 thought that the questions and answers in the quizzes could/should be improved and that working with someone from the BLS programme would be beneficial (something that was not done on this project). The "hallway-game" at Haukeland was difficult to understand initially, according to tester 3. Tester 3 also thought that the game could be beneficial for the students, where they possibly could play it in a group setting and also discuss it. Analytical tests of the blood sample tubes (with machines) could also be useful to include, according to tester 1. An interactive dialog with a patient is something tester 3 thought would be a good addition.

Lastly, the testers filled out the user experience found in Appendix 9.3: User experience schema. This was done to give a grading score for different criteria related to the experience. The idea is to be more objective than in an interview.

Tester1	Tester2	Tester3		1	2	3	4	5	6	7		
			annoying	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	enjoyable	1
5	7	6	not understandable	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	understandable	2
5	6	6	creative	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	dull	3
5	2	2	easy to learn	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	difficult to learn	4
2	2	2	valuable	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	inferior	5
2	2	3	boring	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	exciting	6
5	6	6	not interesting	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	interesting	7
5	7	6	unpredictable	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	predictable	8
5	4	4	fast	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	slow	9
5	3	4	inventive	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	conventional	10
5	2	3	obstructive	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	supportive	11
5	6	6	good	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	bad	12
2	1	2	complicated	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	easy	13
5	5	4	unlikable	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	pleasing	14
5	6	5	usual	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	leading edge	15
N/A	6	6	unpleasant	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	pleasant	16
5	6	5	secure	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	not secure	17
5	2	3	motivating	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	demotivating	18
2	1	3	meets expectations	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	does not meet expectations	19
2	1	3	inefficient	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	efficient	20
5	6	6	clear	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	confusing	21
2	2	3	impractical	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	practical	22
5	6	6	organized	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	cluttered	23
3	2	2	attractive	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	unattractive	24
3	1	3	friendly	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	unfriendly	25
3	1	2	conservative	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	innovative	26
6	7	6										

Figure 5.2: User experience questionnaire

As one can see on figure 5.2, the users graded the experience generally the same. In totality, the answers were positive towards the application.

6 Discussion

6.1 Consequences of the chosen approaches

The Virtual Reality learning game that has been created is somewhat in alignment with the expectations laid out in the beginning. The initial idea was that the laboratory at HVL had closets and cabinets where students would gather the required equipment themselves, which would make the game quite interactive. Filming the lab had to wait 3 weeks after the project was taken, where the group prepared functionality for opening and closing closets and created an inventory system. However, it was later revealed that BLS instructors gather the equipment for the students before each lab visit, which made opening closets and cabinets redundant. Therefore, some of the preparation with learning Unity, coding and designing functionality was somewhat wasted.

Looking at the result of the project though, the main goal(s) were covered quite well. There has been made two virtual environments; one at the hematology lab at HVL and one at Haukeland University Hospital. Here the students can explore and learn about equipment, take quizzes and go through a mini-game with an inventory system at Haukeland. This means that the project still had use of most of the functionality developed early on.

Developing for the HTC Vive showed itself to be quite simple, even with only one HMD for the entire group. This was due to the fact that clicking on objects with a controller and looking around with the HTC headset was emulated with a mouse, through a C# script the group implemented early on. Therefore, developing with the constraint of only one HTC Vive became less of a challenge. Also, by using SteamVR, it enables the project to be used by several other HMDs like the Oculus Rift, Valve Index, Windows Mixed Reality Headsets and others.

6.2 How the choices influenced the results

Looking back, the project development could have been more agile. This was especially in relation to functionality that was developed for the laboratory at HVL (opening and closing closets) that revealed itself to not be relevant for BLS students. Therefore, time could have been spent on creating other game-elements. Fortunately, the inventory system initially developed for the part at HVL was later used at Haukeland.

Regarding the development in Unity, this showed itself to be a good idea. The reason was that the group members found Unity to be an intuitive tool. Furthermore, using the HTC Vive was also a good choice, as there was a script that easily emulated the use of it and its controllers. This meant that even with only one HTC Vive, the group members could test and develop with very similar results as using the HMD.

The limitation of not having more direct, interdisciplinary contact with someone from the BLS degree, affected the final product in a negative manner. If there had been more collaboration on this front, information about equipment, relevance of different game-elements, quizzes etc could have been more easily determined. Also, someone with direct expertise on this field could more easily guide the project in a better direction.

6.3 How the result could be improved

The project could have been improved if the group picked it as their bachelor project earlier, and also if it had been possible to take pictures of the laboratories/environments at the beginning. However, this was not possible due to Covid-19. Instead of knowing the exact manner in which the laboratories operated, the project members worked with an incomplete overview of the actual situation. With an earlier start, the project could also have been tested with users at several stages, instead of only at the very end, like now. Then alterations based on feedback from users could have been implemented.

Another improvement for the project could be to add eye-tracking. Adding more gamification-elements like picking up VR-objects that look like their real counterpart and collecting them would also be an interesting addition.

In regards to user testing, the feedback received has illustrated many possible improvements, as well as highlighting what is working well. The test revealed that the application could be more intuitive, and that more guidance inside the game should be added (arrows, instructions etc), as the users needed help from the group members during the test. There was too much text about the equipment, as well as it being too condensed. This can be improved by structuring the text in bullet points with the most essential information instead. Also, to benefit from the VR-technology better, there could be added more mini-games where for example the user is to send the blood sample tubes for analysis (an important process for BLS).

Working with someone from the BLS degree would be beneficial to improve the information in the quizzes and in general about the equipment. Interdisciplinary work could more easily determine the relevance of each game element for new BLS students. The user test also revealed that a dialog with a patient as well as having an interactive blood sample procedure where the user gets to do it with VR-objects, would elevate the learning experience. Creating 3D-objects that can be grabbed and interacted with was deemed too time-intensive and difficult this time around, but is definitely something that could improve the application.

7 Conclusion and further work

The overarching goal of the project was to help Biomedical Laboratory Scientist (BLS) students familiarize themselves with the equipment, laboratory, and blood sampling procedure *before* entering the lab physically. It was also important for the application to allow the students to familiarize themselves in realistic depictions of the actual environments. This was to be achieved by taking 360°-pictures and 360°-video of the laboratory at HVL and, possibly, at Haukeland University Hospital. Furthermore, the idea was to add points of interest in each scene which could be highlighted with the use of eye-tracking and head-mounted displays (HMDs). In addition, performing actions in game for an interactive game experience was desired.

The project has reached a satisfactory point regarding the goals set by the product owner. There is now a Virtual Reality learning game where BLS students can explore both the laboratory at HVL, as well as Haukeland University Hospital. In table 5.1, there is a list of possible sub-goals for the project, of which most were achieved. In the final product, the students can learn about and interact with the equipment and the blood sampling procedure in a VR-environment. The user can move between different scenes, creating an interactive virtual tour of the laboratories. Highlighting with a hand controller works properly, and the game has a quiz with a score.

At Haukeland University Hospital, the game flow is a bit different than at HVL. The first room they can explore has information about equipment, in the same manner as at HVL. However, where they differ, is in the "hallway-game" at the emergency department. Here there is a mini-game where the user has to pick the correct equipment for a blood sampling procedure based on a requisition. This has to be done correctly for 4 different rooms, before they can leave the area.

Some of the possible subgoals were not reached. Interaction with eye-tracking was not implemented. This was due to time constraints as well as it being prioritised lower than other goals and functionality. The project members had initially chosen another bachelor project and switched to the current one at a later than optimal date. Another subgoal that was not reached, was for the user to interact with virtual person(s) in the scenes. This was partly because the group members did not set up a scenario for it when filming the laboratories, as well as this one also being an underprioritized goal.

This project can be useful for other groups and conditions and not only for BLS students. For instance, nursing students or doctor students could probably benefit from it. The blood sampling procedure would be especially relevant, in addition to all the information that can be learned about the equipment. Other developers/students of IT can also benefit from the application, to look at how VR can be used for creating a learning experience of a real environment. Thus, they can draw inspiration from this project for their own projects.

The application that has been developed can be expanded upon and used for further work. Additional scenes of medical environments can easily be added to the current project. There exists a "stock" scene with all the required Unity-objects for VR, which makes it a fast and streamlined task to add more scenes. This was also a wish from the product owner. All that is needed, in terms of assets, to set up a functioning scene is a 360° image of a room. In addition to this, videos of more medical procedures could elevate the learning benefit of the application. Furthermore, adding the interaction between a user and person(s) in the scenes could add to the interactive element of the experience.

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9 APPENDIX

9.1 Risk list

Risk	Probability	Impact	Risk factor	Mitigation
Lack of experience/skill with software	5	5	25	Search for resources online, identify what to learn
Not delivering a satisfactory product	3	6	18	Creating prototypes through iterations with continual additions of functionality and quality
Too many bugs	4	6	24	Testing the product and iteratively adding working functionality
Low quality VR-experience	4	7	28	Improving UI, visual objects in inventory and general quality

9.2 GANTT-diagram

Tasks	Start	End	Week 12	Week 13	Week 14	Week 15	Week 16	Week 17	Week 18	Week 19	Week 20	Week 21	Week 22	Week 23	Week 24
Project conception and start:															
Selecting a project	Week 12	Week 12	■												
Meeting project owner	Week 12	Week 12	■												
Project planning and development															
Learning basic Unity	Week 12	Week 14	■	■	■										
Creating base elements	Week 12	Week 15	■	■	■	■									
Taking 360°-video/pictures		Week 15													
Setting up VR-headset	Week 14	Week 15		■	■										
Project testing/further development															
User testing (bio-engineers)											★			★	
Internal testing	Week 16	Week 23					■	■	■	■	■	■	■	■	■
First prototype		Week 17						■							
Second version (development)	Week 18	Week 22							■	■	■	■	■		
Final version of application		Week 23												■	★
Bachelor report and related:															
Writing report	Week 15	Week 23				■	■	■	■	■	■	■	■	■	■
Pre-project report	Week 15	Week 15				■									
Pre-project report presentation		Week 16					■								
Status report		Week 18							■						
OA11 - Draft 1 for report		Week 21										■			
OA11 - Draft 2 for report		Week 22										■	■		
OA12 - Blog content		Week 21										■			
OA13 - Expo poster		Week 22										■	■		
OA14 - Final report		Week 23												■	★
Presentation report		Week 24													■

9.3 User experience schema

Please assess the product now by ticking one circle per line.

	1	2	3	4	5	6	7		
annoying	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	enjoyable	1
not understandable	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	understandable	2
creative	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	dull	3
easy to learn	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	difficult to learn	4
valuable	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	inferior	5
boring	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	exciting	6
not interesting	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	interesting	7
unpredictable	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	predictable	8
fast	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	slow	9
inventive	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	conventional	10
obstructive	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	supportive	11
good	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	bad	12
complicated	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	easy	13
unlikable	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	pleasing	14
usual	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	leading edge	15
unpleasant	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	pleasant	16
secure	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	not secure	17
motivating	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	demotivating	18
meets expectations	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	does not meet expectations	19
inefficient	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	efficient	20
clear	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	confusing	21
impractical	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	practical	22
organized	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	cluttered	23
attractive	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	unattractive	24
friendly	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	unfriendly	25
conservative	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	innovative	26

9.4 Questionnaire about play-based learning (in Norwegian)

Spørreundersøkelse 360°-spill

Bakgrunn

Personlig informasjon

1. Hva er navnet ditt og kontaktinformasjon?
2. Hvor gammel er du?
3. Hva er kjønnnet ditt?
4. Hvor lenge har du undervist i labøvelser (antall år)?

Om spillbasert læring

5.1.

	Nei	Litt enig	Veldig enig
Anser du deg selv som erfaren med dataspill (både for underholdning og læring)?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Kommentar:

5.2

	Nei	Litt enig	Veldig enig
Har du tidligere brukt digitale læringsspill i din undervisning?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Kommentar:

5.3

	Veldig uenig	Uenig	Litt uenig	Nøytral	Litt enig	Enig	Veldig enig
Jeg tror spillbasert læring er positivt.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Jeg ønsker spillbasert læring i utdanningen min.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Kommentar:

9.5 Interview questions

Intervju

Spillet du nå har testet er en prototype av et læringsspill hvor 360°-video og -bilder brukes for å skape et VR-spill i realistiske omgivelser. Vi ønsker at du vurderer spillets potensial som et læringsverktøy i din undervisning.

Spillet du nå skal spille er en prototype. Grunnleggende funksjonalitet er på plass, men det er fortsatt mye ekstrafunksjonalitet som kan legges til. Fokuser på hvilket potensiale nåværende løsning har, men forsøk gjerne å se forbi nåværende begrensninger. Kom gjerne med forslag til hvordan du ser det kan forbedres også.

Hovedaspektene ved spillet er:

- Oppleve virkelighetsnært miljø i VR.

Spørsmål: Var miljøene korrekte i forhold til de som brukes i virkeligheten?

- Savner du noen miljø? I så fall hvilke?
- Tror du det ville vært nyttig med uvanlige prøvetakingsmiljø, slik som ulykkesområder, i hjemmene til personer, eller lignende? I så fall hvilke?
- Var miljøet informativt nok? Er det ekstrainformasjon du gjerne skulle hatt i spillet?
- Tror du at dette spillet kan bli brukt i din undervisning (og hvordan)?
- Tror du at dette spillet kan være nyttig for å kontekstualisere kunnskapen (omkring blodprøvetakningsprosedyren)?
- Navigasjon rundt i miljøet:
 - Var navigeringen mellom scenene enkel og forståelig?
 - Kunne du navigere dit du ønsket i miljøene? Var det noen områder som manglet?
 - Kunne du navigere «på samme måte» som vill vært naturlig i miljøene for å bli kjent med de spesifikke kontekstene (som potensielt kan være nyttig før utplassering etc.)?
 - Hvordan opplevde du teknikken for å navigere
 - o HMDen (VR-headsettet)?
 - o Håndkontrollerne?
 - Kunne du se forskjeller på hvordan oppgaver utføres annerledes i de forskjellige kontekstene?
 - Kunne du oppleve deler av en bioingeniørs hverdag i et realistisk miljø? Hvorfor eller hvorfor ikke?
- Hvordan var interaksjon med objekter, for eksempel utstyr og maskiner? Målet er at studenten skal bli presentert med passende informasjon om objektene, quizzet om diverse temaer etc.
 - Kan vi legge noen flere quizzet i miljøene?
 - Er det noen "uvanlige" eller ukorrekte objekter som vi kan legge i miljøet for å skape en læringssituasjon?
 - Tror du applikasjonen kan støtte læring av diverse aspekter rundt prosedyrer og analyser som å velge korrekt utstyr og reagenser, bruke maskiner korrekt osv.?
 - o Savnet du noen objekt? Hvilke? Hvorfor?
 - Opplevde du at du kunne bli kjent med utstyr og maskiner?
 - o Finnes det mer utstyr og maskiner som burde være inkludert?

- o Burde abstrakt informasjon legges på utstyret etc. for å øke innlæringen?
- Å se utførelse av prosedyre eller analyse i 360°-video.
 - o Er det nyttig?
 - o Ville det vært bra å vise det i forskjellige miljøer?
 - o Hvilket alternativ foretrekker dere: Enten som utenforstående person (vist i prototypen), eller i førstepersonssynsvinkel? Hvorfor?
- Her er det mulighet for å legge inn interaksjon underveis i videoene, for eksempel om spørsmål om hva neste steg i prosedyren er, hvilket utstyr skal nå brukes, etc.
 - o Hva trengs?
 - o Hvorfor?
- Ha også i bakhodet at det er mulig å legge til andre kontekster/miljøer, øvelser, prosedyrer etc. Vi ønsker derfor også at du tenker gjennom hva du tenker spillet kan bli brukt til utenom det som blir presentert i denne prototypen.
 - o For hvilke andre applikasjoner?
 - o For å lære seg ferdigheter?
 - o For å lære seg «mykere» kunnskaper (prosedyrer, hvordan man handler i et miljø, hva man ser etc.)?
- For undervisning:
 - o Tror du at dette spillet kan hjelpe til med overgangen til praksis/jobb?
 - o Var grensesnittet forståelig?

9.6 Technical overview of a Scene

