History Class in Virtual Reality for Elementary Education

Bachelor thesis

Supervisor: Dr. J. Zwiers
Critical observer: B.P.A. Spieker
Client organisation: Mariaschool Beuningen
Client: W. Vollenbroek

Student: Cis Sanderink
Student number: s1726730
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Short description

A quick overview of the project

In this bachelor thesis, an educational application for elementary history education has been developed. The client school for this project stimulates a more interactive and engaging method for history teaching, because, in their opinion, history must be lived and felt, not only seen or read. After hearing this, we decided to think of new way to teach the history curriculum to the children of the client school. Techniques like augmented reality and virtual reality were taken into consideration during a brainstorm. In the end, the choice was made to make an educational immersive virtual reality application to educate the students about the history material. The application was not only a visual and virtual experience, the user is also able to interactively learn about the history curriculum.

Because the virtual environment was not yet available at the start of this project, a whole new environment had to be designed. A single period in history was highlighted in the application. The information that is shared with the students is fully based upon the learning goals of the educational method used by the client school for history education, called Wijzer! The main goal of the project was to reveal how the skeleton for such an education application must be designed, so that in the future more educational applications can be developed to supplement the traditional teaching methods in Dutch history education at primary schools.

The fundaments of an educational application are found and broadly discussed in this thesis. Decisions have been thoroughly reasoned and explained why they suit the application as they do. Findings are that the students find it very interesting to being educated in a completely different way than that they are used to. The immersive aspect of virtual reality really makes an impression on the students and being immersed in a virtual world and having a companion friend there makes them feel excited. Additionally, they appreciate that they are now able to see the history in a new way, where the textbook sometimes is unable to impress the kids and give a good atmospheric impression of the historical environments. Future statistical research must reveal if this new way of teaching really improves the learning outcomes of the students.

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Abstract

Rapid introduction to the bachelor thesis

In this bachelor thesis, an educational application for elementary history education had been developed. The application is beyond 'cool and fun' and thus not only a visual and virtual experience. The students of the client organisation are able to interactively learn about the history curriculum. The main goal of the project was to reveal how the skeleton for such an education application must be designed, so that in the near future more content can be developed to supplement the traditional teaching methods in Dutch history education at primary schools. Additional statistical research must reveal if this new way of teaching is really improving the learning outcome of the students.

Introduction

Virtual reality teaching as a supplement to traditional education

History teaching is nowadays mostly done by traditional teaching methods, like watching videos and reading texts from a textbook. Although this way of teaching is useful and structured, history teaching for elementary education can be made more interesting and engaging. The history course is a very fascinating and important course in the development of a child's perspective on the world, however, it may not always be experienced as such by the students. Therefore, a bachelor research thesis is done to come up with possible ways to improve the students' empathy, engagement and interest in the history curriculum. In collaboration with a primary school in The Netherlands, an educational application has been developed, tested and improved where necessary.

The client organisation demanded a functional application that was beyond 'cool and fun' and allows the students to 'feel and life the history'. The educational application had to be a useful and meaningful teaching method to supplement the traditional teaching methods they were already using at the school. Hence, the application should fit the learning goals of the teaching method book neatly. The application should cause a rise in the students' engagement levels. To make the students enthusiastic about the history curriculum, it is decided to make an immersive virtual reality solution. This application has been tested by the students of the client school. The immersive aspect of virtual reality gives the learning process a new dimension that boosts the intrinsic motivation of the students.

Choices had to be made in multiple areas, like, what is the best go-to device, what are intuitive interaction methods and which history material is meaningful to implement. The design-guidelines, especially the teleportation system, the conversation handling and the integrated history curriculum are extensively examined and tested upon the students. After tweaking the application where needed, the experience is sufficiently self-explanatory so that the students are feeling comfortable in the virtual environment. The immersive virtual reality application that we developed has its foundations in the regular history teaching method, used by the client school. Consequently, the application is not just an enjoyable application, but it really adds value to the learning process. This project's content has focussed on the first farmers in the Netherlands and especially how they lived back in the day.

Students must follow a tutorial into using the virtual reality application, whereafter they are able to taste the atmosphere of the historical environment. More in-depth experiences make the students feel involved in the world. The user can freely walk around and have conversations with historical figures, who explains the way of life of the very first farmers. Talking with the historical characters that we included for this purpose is the type of interaction that motivates and excites the students to go on and explore the virtual worlds.

State of the Art

Comparison and discussion of contemporary teaching techniques and -technologies

In the early stages of this graduation project, the choice between augmented reality and virtual reality was to be made. These techniques have some things in common, but a short introduction into the both is needed to make a good distinction between the two.

Augmented reality (AR)

The best word to describe augmented reality is 'overlays'. Augmented reality is a technology which adds objects to our normal sight and world we live in. Computers can add elements and thus our view will remain partially the same. The technique of augmented reality thus is a supplement to our reality, not a substitutional reality. Augmented reality can be ultimately explained with concrete examples.

Figure 1: IKEA Place application

Figure 1 above shows the augmented reality application called IKEA-place, where users of the application can place furniture in their homes in a virtual way. By using the camera of their smartphone, they look at their bedroom or living room and can fit for example a table or a chair in their room. This immediately gives an impression on how the furniture suits the environment and thus can reduce the number of bad buys.

Virtual reality (VR)

Virtual reality can be described as an immersive experience. The users have the perception of being in another world, completely shut off from the world they really are present in. Using a head-mounted device, a virtual world is shown where users can look 360-degrees around. This technology has its roots in the early sixties of the nineteenth century, but currently, it is widely accessible for the large public, due to rapidly decreasing costs and growing application availability. A suiting example of this technology is Nespresso - de boer. Customers of Nespresso were shipped out a cardboard virtual reality headset, which must be folded into a head-mounted device. By following a link to the virtual experience, users can transport themselves to a coffee plantation in Colombia, where a coffee farmer explains to them how they work and process the coffee bones. This way, users can immerse themselves in the world and interactively and see where the coffee comes from which they consume every day.

Immersion is a crucial aspect in the case of virtual reality teaching. A 3-D virtual environment, presented on a screen, gives only partial the perception of being part of the world and thus the immersion is still low-levelled. However, higher immersion gives the user the perception of actually being present in that world. Bowman and McMahan (2007) have proven that a high level of immersion can reduce the information clutter. Information clutter is the problem when a scene is cluttered with other information, as notifications that pop up in your screen. Augmented reality can even strengthen the information clutter, due to its layered approach. High level of immersion can decrease this information clutter and the research argues that this potentially can lead to better comprehensibility and understanding of the environment.

Based on my own experiences and a conversation with the client organisation, history is basically focussed on reading information that is often supplemented by images or videos. However, this remains abstract in some cases. This could be changed by placing the users in the world they are being educated about, which could be realised by using virtual reality. In my opinion, this stays an underestimated technology that could be of great support to historical teaching. After some orientating meetings and conversations with the client organisation, we came to the conclusion that we both wanted to create an impact on the students, by showing them the history in a different way than that they are being education nowadays. The two techniques that were introduced earlier, are very different in creating impact. A choice between the two techniques will be made shortly after.

State of the Art

After orientational conversations with the client organisation and teachers in elementary education, an often addressed problem is that contemporary teaching methods are found to be uninteresting by elementary education pupils. Especially reading is an activity that bores many children born in the early phase of the twenty-first century. Even research shows that the youth wants to be educated in another way than in the past. Research by Jukes,

McCain and Crockett (2010) shows that 21st-century learners prefer to receive information quickly from various multimedia sources. Another claim by the researches is that children rather process pictures, sounds, colour and video than text. In this graduation project's virtual reality world, all those elements will come together and thus neatly suit the kids' preferred learning method. This results in better remembrance and retention of the information they have learned.

The aim of this graduation project is to reveal the characteristics of an immersive virtual world suitable for elementary education, especially for the history curriculum. Background research must be done in the field of serious virtual worlds in elementary education, to see how currently the virtual reality technique is applied to primary education. Multiple factors are important, such as the interaction between the teacher and the students. Also, it is of high importance to know to what degree the students should be let free in the virtual world. It can be imagined that if the students are fully responsible for their acts in the virtual world, some students are focussing on one particular point and thus are not fully exposed to all the available material. Since the students should learn how the world was looking in the past, the world should be a somewhat accurate representation of the world as it was back in the past. Is it necessary to have a picture-perfect world, or is a low level of visual resemblance enough to learn the students about the curriculum?

During the background research, multiple examples were found of related projects where serious virtual worlds are integrated in elementary education. One of the most identifiable examples of this is 'Singapore History Alive with 3-D!'. This is a non-immersive educational package which uses various learning methods, such as animation videos, mini-games, lecture slides and quizzes, to educate the kids about Singaporean history. Fang and Tan (2013) analysed the educational package and came to the conclusion that the kids are feeling much more empowered and engaged while using the package, especially with the mini-games and quizzes. It must be stated that this experiment was solely based on observational research, no pre- and post-tests were executed to test the (improved) effective learning outcome.

Additionally, in *L'Oceanogràfic* of Valencia in Spain, one of the largest aquaria in Europe, a serious virtual world is implemented which goes by the name of 'the E-Junior project'. In this serious virtual world, kids were introduced to the ecosystem of the Mediterranean Sea in a virtual world, made with four projectors, projecting visuals on each wall of a 6 by 5-meter room. Augmented reality markers in the form of paddles were used by the kids to navigate in the virtual world. This virtual journey is intended for the children in K-12 education, comparable to the Dutch elementary school classes. From the experiment carried out by Wrzesien (2010) on this installation, it can be concluded that a rising engagement and empowerment was noticeable under the students. This supports the statements of Fang and Tan (2013), which also stated that rising engagement was one of the key findings of their research.

A third example is Google Expeditions, a platform by Google which aims to bring virtual reality to the classroom. On this platform, virtual tours are offered to experience locations that would otherwise be impossible to visit, due to time or financial constraints. However, this material is mainly based on recently made 360-degree photos or videos, so that makes it impossible to visit historical locations. This platform would be a nice supplement to geography or physics teaching, but is not suitable for history teaching. In order to make it a good addition to history teaching, ancient sights must be modelled or somehow created to make visiting historical situations possible. The good points of this Google Expeditions platform are the availability at low cost and ease of use. The only thing you need in order to use the application is a Google Cardboard (or other affordable head mounted display device) and a smartphone with the application installed.

This ease of use is an extremely important aspect of virtual reality teaching in class since this was mentioned to be one of the main obstacles according to multiple researches. Often, teachers are not willing to use virtual reality solutions in class, because of the difficulties it brings when using it for the first time. Youngblut (1998) already mentioned the bad user-friendliness as a big limitation of virtual reality teaching, but fifteen years later, Merchant et al. (2013) proved the same. However, the techniques are evolving and current virtual reality devices are much easier to use and thus should not fear primary school teachers from using it at school. It should definitely be taken into consideration when designing the application, that usage of the application should be easy and self-explanatory so that virtual reality can be integrated into education without any struggle.

Discussion

As seen before, previously worked out projects all have its advantages and disadvantages. It is a fact that immersive virtual reality solutions are getting more popular, although, often they are not suitable for history teaching. This is a result of lacking suitable content because most of the current virtual reality solutions are focussing on the present-day material. Unfortunately, virtual field trips to ancient places are not widely available, whereas app stores are full of virtual trips to modern-day sights. History teaching has been done in virtual worlds like in the *Singapore History Alive in 3-D* educational package, but this example did not make use of any immersive techniques since it was a desktop application. An immersive solution as the *E-Junior Project* has proven to involve the student more in the material what lead to a higher engagement under the students. This project's disadvantages are in particular the financial aspect. The system is very expensive as it makes use of four 6 x 5 meter displays and a lot of space is needed to place the installation. This is often not ideal for primary schools due to either lack of space or money. Even though the client school has sufficient space, the financial aspect will certainly make it impossible for a comparable installation.

The more affordable solution in the form of a head-mounted display device is more suitable for this project. Head-mounted displays, from now on called HMD, come in cheap

and expensive variants. Cheap variants as the Google Cardboard bring a decent immersive experience at a low price, while expensive solutions as the HTC Vive or Oculus Rift come closer to a real-life experience, as they are also capable of tracking hand movement and include controllers to interact with the environment. There are alternative headsets which all come at different prices with different specifications, but since the client school is not able to purchase expensive headsets, the headset to be used in this project must be relatively cheap. A more detailed exploration and discussion on headsets can be found in the following chapters.

The application that will be made will focus on one specific period in history since it would take too much time and effort to capture multiple periods in the application. The time period that will be elaborated is yet to be decided and the choice will be made after conducting a questionnaire at the target group. In this questionnaire, it will be revealed which time periods the students have the most problems with. In the application, the user is introduced to the historical environment and shortly after that, they can have a more in-depth experience in the virtual world. This in-depth experience involves the student in the virtual world and thus make the user feel present in the environment they are learning about.

It must be made clear that for this project the goal is to support contemporary history teaching and thus this application cannot be seen as a complete substitute to traditional teaching methods. History teaching should include reading texts and understanding relationships of events, but the application to be made is there to help to memorise this information and to let the students taste the atmosphere of ancient times. Helping the students visualise the material they are learning can potentially lead to better remembrance and retention of the curriculum.

Overall, it is clear that immersive virtual worlds are teaching the material in a different way than traditional teaching methods. Immersion and virtual reality have their proven advantages, such as higher engagement and a more visual learning experience. However, the disadvantages such as difficulties in usage and expensive devices should not be underestimated. Research on existing material has shown that however immersive virtual reality is integrable in education, it often is not suitable for Dutch history teaching. The aim of this graduation project is to fill that gap and make a suitable virtual reality product that helps students grasp the abstract situations in history.

Client requirements

Requirements of the educational client organisation

The client organisation stated some special requirements for the application that will be developed in this project. The application, whether it was augmented or virtual reality, should educate the kids about the historical material in a useful way. It should not only be 'cool' or 'fun', it should be a more meaningful application. Therefore, they said that all the historical material that will be implemented in the application should be based upon the history book they have at their school, to make sure there will not be any differences in the material between the book and the application. Additionally, it was discussed that the application should not cover the whole history book, but only a chapter or even less. This was important because covering the whole history book and its topics in the application would be impossible to develop in the time of this project and hence would result in a too superficial experience. Additionally, enough time must remain to be able to test the application with the students of the client school.

The client organisation school has just a low number of students and thus some classes are combined in so-called 'combination classes'. Those combination classes are class 3 and 4, 5 and 6, and finally 7 and 8. Respectively, the ages of those students are 6 up until 8, 8 up until 10, and 10 up until 12. The client organisation wanted to make this application suitable for a single combination class, because all the combination classes have a different curriculum and thus are being educated about different time periods in history. Therefore, only one combination class should be used for testing the application. The last requirement of the client organisation was that the application should be suitable for individual use. The client wants to let a single user use the application fully on his/her own so that every student can use the application when wanted.

Summarising, the client organisation stated four important attention points that thoroughly were taken into consideration:

- Augmented reality or virtual reality should be used
- The application must be suitable for only one combination class
- Implemented history material must be based upon the students' textbooks
- Only one history periods should be worked out to save time for testing
- The application is designed or individual use

Ideation

Creative ideas for the educational application

Introduction

The goal of this graduation project's ideation-phase is to think of how the educational application could be designed. The decision between augmented reality and virtual reality should be made and choices have to be made in the area of experience and interaction design. This is done by thinking of creative ideas to teach the students about history and by looking at existing work. A Creative Technologist is characterised by the ability to combine new or existing techniques to reach the goal of the project. Therefore, a brainstorm session was done to come up with ideas of how the experience and interaction in the virtual reality world could be designed. Augmented and virtual reality are both taken into consideration in the brainstorm. The main goal of this application is, obviously, to educate the students. However, this application will not completely replace the current history teaching methods, it will only be developed to support the traditional teaching methods. The client organisation stated that some periods in history are hard to imagine and visualise, due to lacking visual content and material. This application should fill that gap and improve the students' ability to imagine and visualise chapters from their history books.

Brainstorm

In a brainstorm that was done at the beginning of the project, multiple ideas come up which could eventually be implemented in the educational application for primary school students. One of the ideas was to make an augmented reality application that would allow the students to scan existing buildings in the neighbourhood that have a 'historic layer' over it. This layer would then inform the students of how this building developed over time. For example, if the students scan their school, an overlay is shown of how the school looked in earlier times and why. Students can scroll through multiple periods and see the development of that building over time. Or the students could look at a farm and the overlay shows them how the farm would have looked like in the stone age, so the contemporary agricultural machines will vanish and will be replaced by handcrafted tools. This application could be installed on a smartphone, but also on an augmented reality headset. The good thing about this idea is that is a very practical approach to learning the history material. The children should actively visit locations that have been included in the application and that lets them leave the classroom.

A second idea was to work out a project that I contributed to in an earlier phase of my study. This project made use of augmented reality as well. The application allowed the users to use a device, like an iPhone, iPad or Android phone or tablet, to scan their regular history book, where the application would show additional overlays to the curriculum. The application was capable of showing additional information card, images, videos and solutions

to exercises. This application could be improved and extended to make it more interesting. For example, additional markers could be created where the kids could do certain exercises or games with to make them more enthusiastic about the history material. Even though this was a nice addition to the traditional way of teaching, I wanted something else for my graduation project that makes more of an impact.

Although augmented reality is a very cool and useful technique, augmented reality is not capable of making an impact in the way virtual reality can. Learning in a virtual reality environment can immerse and submerge students in for example the Roman Empire. Students can read about the way the people cooked, worked and thought, but the client organisation agreed on the fact that history must be felt and lived, not read or seen. This mention of the client organisation fits neatly to virtual reality because being immersed in a virtual world can impact people in a certain way that would suit the needs of 'feeling and living the history'.

In order to make the students feel more comfortable with the curriculum, they should feel more engaged with the material they are learning about. This could be done by using immersive virtual reality and placing the users in the centre of a historical world. As mentioned before, various researches have proven that virtual reality techniques are resulting in higher engagement under the students who are using it. By being actively present in the world they are learning about, engagement levels will rise and students feel more empowered in the learning process. The way the virtual reality application will be designed has to be discussed. Ideas during the brainstorm were that the students will be introduced to the historical virtual world and afterwards they will be exposed to a more in-depth experience. For example, the student can have a conversation with a person from the time period. In this conversation, the virtual person can provide additional information to educate the students about their way of life. This approach is more concrete and to the point than only being exposed to a historical environment.

It can be very meaningful to let the students experience how it must have been to live in ancient times. Therefore, another idea is to let the student do specific tasks in the virtual environment. The main reason to do this is that the student will be actively involved in the virtual environment they are being taught about. The user should be able to freely walk around in the virtual world and be obliged to prepare a meal, harvest the land or do cultural activities. This more practical approach of giving information is a good alternation to feeding the students with written or verbal information. This contributes to the statement made by the client organisation, who believes that history must be felt and lived, not read or seen. It must be taken into account that when the user has to do more complex activities in a

Application design

It must be made clear that for this project the goal is just to support contemporary history teaching and thus this application cannot be seen as a complete substitute for traditional teaching methods. History teaching should include reading texts and

understanding relationships of events, but the application to be made is there to help to memorise this information. Helping the students visualise the material they are learning can potentially lead to better remembrance and retention of the curriculum. Maybe in the future, this teaching method can replace history textbooks, but for this project, this is in no way the goal and the aim is solely to support traditional teaching methods.

Since the application was being tested on students who, overall, do not have any experiences with virtual reality, virtual reality has to be introduced to them. Therefore, the application should contain some sort of 'tutorial scene' where the students are introduced to the basic principles of virtual reality. In this tutorial scene, the user must be introduced to the basic principles of virtual reality. How to look around and select objects and such are vital elements of a virtual reality application, and the children should be shown how to do these actions. After the tutorial is completed, the children should be able to travel back in time and learn about the history in an immersive way. How this will exactly look, will be decided in a while.

The application that will be made will focus on one specific period in history since it would be infeasible to capture multiple periods of history in the application. Content creation is a time-consuming activity and the time is simply not there. The time period that will be elaborated is the time period of the very first agricultural societies in the Netherlands. A small historical setting will be recreated wherein the user can experience how societies looked back in history. The goal of the application is to help the students visualise the material better. The goal of the application is not to make the world as real as possible, giving the students a good atmospheric impression of ancient times is enough for this project.

Experience design

To come up with good ideas for the virtual reality experience application, a brainstorm session is done in the first weeks of the project. There is thought of interesting ways to present the material to the students. In virtual reality, students can freely walk around in a virtual world, but this is not enough to educate the students about history. The virtual world should include different elements to learn the students new information. For example, having a conversation with a person from the history can be a good way to transfer information. Also, letting the users do specified tasks can also immerse them more and can lead to a higher feeling of involvement. Also, by doing specific tasks, information can be packed in a more practical way instead of reading about it in a text or hearing this information in a conversation or such.

The main new ideas of the brainstorm were not to have a real conversation with a historical figure but instead, have scripted/guided conversation. This will save a lot of time because a real conversation would need voice recognition in combination with machine learning, which is very hard to implement for several reasons. Although voice recognition is developing all the time, it remains hard to recognise kids' voices, in particular, Dutch kids' voices. Also, when implementing a scripted conversation, more information is guaranteed to

be transferred. If the students could freely ask what they want to hear, possibly several matters will not come to discussion due to the fact that the students do not know they exist.

A second idea from the brainstorm is a more intuitive way of interaction; namely nodding to reply in the conversation instead of selecting an answer. We nod every day, consciously and unconsciously, many times and nodding would be a very intuitive method of responding. If it decided to implement this in the virtual reality application, the roles in the conversation must be switched. The virtual persons the students are talking to are now asking the questions instead of vice versa, and the student must reply by nodding 'yes' or 'no'. Think of questions such as: "Do you want to know more about topic X?", or "May I introduce you to my father, who is influent in our city?". This, however, has to be examined how this could be implemented and if it is as intuitive as it seems.

A third idea which rolled out of the brainstorm was to let the user do certain tasks in the virtual world. In case of the previously mentioned time period of hunters and farmers, users could, for example, be asked in the conversation to go feed the cattle of the farmers or harvest the land to be introduced to the ways these things were done in the past. Actively executing these above-mentioned tasks can be more clear to the students, because reading about this can stay somewhat abstract due to misunderstandings.

Interaction design

To handle user interaction, voice recognition is a possible option, but voice recognition is very hard to implement in a virtual application like this, due to the technical difficulties and time limitations. Voice recognition is often not optimised for young public and in particular not for Dutch speaking students. If decided to implement voice interaction, this could lead to misunderstandings and inaccurate responses to the kids' questions. The client organisation earlier addressed that they would like to try and keep the children at their desks most of the time while using the virtual reality application. This means that the experience of this virtual world will possibly be held in a relatively noisy environment where unexpected noises can occur. This could cause great disturbance and unwanted voices are being picked up by the microphone. Also since headsets do not always have built-in microphones, additional hardware can possibly be needed in order to record any sound. If the children are sitting in the classroom with their peers, it is pleasant that the student who uses the virtual reality application is not making additional sound either. Therefore, voice recognition is not a suitable way of interacting with the virtual reality environment. Also, to prevent the peers from hearing the sounds that belong to the virtual reality environment, headphones for the user are needed to prevent that from happening. Finally, the users of the virtual reality application should not be speaking out loud. Because of these reasons, the application will not support voice recognition.

Since voice recognition is no option for this virtual reality application, other ways of interaction have to be implemented. The above-mentioned example of nodding in a conversation will be a good option since this is very intuitive and close to reality. Additionally,

the students should not have to talk or verbally reply, so this suits the needs of the client organisation, who wanted the application to be as quiet as possible. Virtual reality constantly makes use of gyroscope sensor values to determine where the users are looking at, so this sensor values could be used to detect a vertical nod (yes) or a horizontal shake (no). If this method of interaction will be implemented, it must be taken into account that the roles in the conversation will switch. In this case, the students are not answering the questions, but instead, the virtual person is posing the questions which the students can then answer by nodding. Think of questions as: "Do you want to know more about the way we get our food?", or "Are you interested in the way we feed our cattle?".

Another way to take care of the conversation can be the most recognisable way for virtual reality, namely selecting the options with the gaze. The gaze is a common way of interacting in a virtual reality environment. Once you are in the virtual worlds, you will see a small dot in the centre of your view. This is a selection marker. If you look at a selectable object in the environment, this dot will change and get an additional animation that tells the user to look at the object for X seconds. This interaction method is also introduced in the *'Cardboard Design Lab'* by Google. In this (virtual reality) application, the basic principles of virtual reality design are explained with concrete examples or how it should (not) be done. This application also introduced 'gazing', the interaction method that is explained above. This is very intuitive and recognisable for all users. This *'Cardboard Design Lab'* also gives additional tips and tricks to create a pleasant and fluid virtual reality experience.

Application requirements

Functional requirements of the application

Target group

In an orientating conversation with the client organisation is discussed which class(es) would benefit the most from this project. As mentioned before, the client school has multiple combination classes. Early on in the discussion, the first combination class was dropped out, because of age constraints. These students are too young to give useful feedback and follow-up given instructions in the usability tests, so these tests would be extremely hard to execute. Although the same problem could occur when using class 5 and 6, this group were dropped out due to the small class size, which leads to little respondents for the research. Additionally, the final two classes of elementary education, class 7 and 8, are simply the oldest students who are best able to provide useful feedback that contributes to a better research. Secondly, the client organisation said this classes would suit the new technology the best because they have more experience with technology than younger groups.

Time period in history

The learning method used at the client school is *Wijzer!*. It is a Dutch teaching method from the Noordhoff publisher. This history taught in this method is split up into ten time periods. The first period is the time of the first people on earth and then it continues with the Roman Empire, Middle Ages, Industrial Revolution, World Wars and ends at the present-day. However, all the history teaching methods in the Netherlands have the same structure where the history is split up into ten time periods, all with the same name in the different teaching methods. The grouping of the time periods can be found in Table 1. This teaching method is mainly focussed on the history of the Netherlands, which makes it a very specific method. For example, the first people on earth did not actually live in the Netherlands, but this method focusses on the first people in the Netherlands.

To decide which time period should be worked out in this project's immersive virtual reality experience, a short survey is conducted under the target group. In this survey is asked which time periods the participants found the most interesting, followed by the question with which time period they had the most problems visualising it in their heads. If it turns out that many kids have trouble visualising one particular time period, this time period will be chosen to work out in this graduation project, as the goal of this project is to improve the kids' ability to visualise a historical event. The results of the survey can be found in Appendix A.

Table 1: Grouping of time periods in history teaching method of client school.

Time of…	Time span
… hunters and farmers	Pre history
… Greeks and Romans	Antiquity
… monks and knights	Early Middle Ages
… cities and states	High and late Middle Ages
… explorers and reformers	Renaissance, Discoveries and Reform
… regents and monarchs	Dutch Golden Age
… wigs and revolutions	Age of enlightenment
… citizens and steam engines	Industrialisation
… world wars	First half twentieth century
… television and computer	Second half twentieth century

The results of this questionnaire are a bit varying and do not show a clear topic they have the most difficulties with visualising. Nevertheless, some time periods can be crossed out due to the fact nobody had many problems visualising them. Those periods are *'Greeks and Romans'* and *'television and computer'*. The latter is not difficult to explain because they actually live at this time. The former can be a result of this being a very visual time. Nearly everybody knows what the Colosseum is and was, knows how former gladiators looked like and remembers the costumes of Roman emperors. The other eight time periods were still relatively hard to visualise for the majority of the students in the target group.

When being asked which time period the students found the most interesting, clearly three time periods are not found to be interesting. Time periods of *'regents and monarchs', 'wigs and revolutions'* and *'citizens and steam engines'* are not the students' favourite time periods. In order to make the students enthusiastic about their new learning experience, it is desirable to introduce them to a time period which they find interesting and thus are more motivated to learn about. Therefore, in addition to the previously left out time periods, the above-mentioned triplet of time periods will also not feature in this projects virtual reality application.

As mentioned earlier on, the problem is that visual material is not always widely accessible in each time period of the history curriculum. After the invention of the camera, visual material became more and more available and that makes it why, nowadays, we have lots of pictures and videos from the world wars. The goal of this project is to visualise a time period that has not much visual material available, and thus the last two periods in history, the time of *'world wars'* and *'television and computer'*, can be dropped out as well.

The four remaining time periods are: *'hunters and farmers'*, *'monks and knights'*, *'cities and states'* and *'explorers and reformers'*. Those four time periods also scored high when asking to which time periods the students wanted to travel in virtual reality. However, none of the four scored significantly higher than others. The last question in the survey was: *'Where do you want to learn more about?'*. Instead of letting the respondents choose from the ten time periods, they were asked to select a specific topic instead of the name of a time period. By doing this, a more specific historical event is presented and so it can be revealed what specific event the children find the most interesting. The possible answers can be found in the Figure A-4 in Appendix A. Surprisingly enough, the majority of the respondents wanted to learn more about the 'first people on earth'. This topic got eight votes, where the runner-up options — *Second World War and Cold War* — had a maximal of five votes. Therefore, this project's virtual reality application will focus on the time period of prehistory and in particular how the first people on earth lived.

Virtual reality device

An important thing to keep in mind is the financial aspect of this project. The client organisation is a small school with limited financial abilities, and thus is it of high importance to keep the costs at a minimum. In order to experience virtual reality, a headset is needed. These headsets come in different shapes and sizes, but they differ a lot in price. You have low budget solutions, like Google Cardboard, where you need an additional smartphone that functions as the screen. There are also high-class solutions, like HTC Vive or Oculus Rift where the screens are built-in. In the search for suitable headsets, the first headsets could be crossed out. The HTC Vive and the Oculus Rift are not suitable, because of the following reasons. These high-end installations come with multiple restrictions. The first thing is that a user can get tangled up in the wires that are connected to the headset. A supervisor can prevent this from happening, but that would make the application unsuitable for individual use, which was one of the requirements of the client school. However, many different headsets were found as well that ranked upon various specifications. Table 2 shows which headsets were considered and which one suits the client organisation the best.

Table 2: Comparison of considerable virtual reality headsets

	Google Card-board	Google Day-dream	Bobo VR Z4	Bobo VR Z5	Oculus Go	Gear VR	PS VR
Price	€10	€150	€35	€55	$199	€130	€350
Built in headphones	No	No	Yes	Yes	Yes	No	Yes
OnePlus 3 compatible	Yes	No	Yes	Yes	N/A	No	N/A
Available yet?	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Phones	All	Selection	All	All	N/A	Samsung Galaxy S6 and above	N/A
Lenses adjustable	No	Yes	Yes	Yes	N/A	N/A	N/A
External controller optional	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Developer accesibility	High	Low	High	High	High	High	Low

As Table 2 suggests, there is only one headset that scored well on all the criteria, namely the Bobo VR Z4. However, in the first comparison, only the Bobo VR Z5 was taken into account. The price was the only possible pitfall of this headset, and as the name suggests, there are multiple models released under the same name. Quickly, the Bobo VR Z4 was found and considered, as it met all the criteria. Some online reviews even suggest that the Z4 is outperforming the Z5 on price, comfort and field of view. Also, a Dutch virtual reality headset retailer advised this headset when asked which headset suited education the best. Therefore, it is decided to go with the Bobo VR Z4 headset, due to its high affordability and variety of options. It is, for example, possible to use other phones and eventually use an additional controller. The smartphone that will be used in this project is the OnePlus 3 by the brand OnePlus.

However, a few weeks into the project, the Oculus Go headset was released where it was still unavailable when purchasing the Bobo VR Z4 headset. The Creative Technology department decided to buy an Oculus Go to be made available for students to experiment with and use in projects. Due to its built-in screens and more advanced lenses, the decision is made to go with that headset instead of the Bobo VR Z4 in combination with the OnePlus 3. In fact, this Oculus Go headset is financially the better option, because you do not need to purchase an additional smartphone in order to experience virtual reality and the Oculus Go has a controller included. For schools, this all-in-one device is the best option, financially as well as practically, because this device is built for virtual reality, where a smartphone is not optimised for virtual reality usage.

Specification

Functional requirements of the educational application

The users to reach with this application are Dutch students who are in the final two years of their elementary education. In class 7 and 8 are students who are generally ten to twelve years old, who are being introduced to various multimedia sources in times of continual technological developments. For this project, the aim is to develop a virtual reality experience wherewith the children can travel back in time to taste the atmosphere and learning about how people lived in history. The perception of presence in a historical setting must rise the engagement levels of the children and boost their will of learning the new curriculum.

For this target group, a virtual reality application should be designed and tested upon the students. The application needs support for a tutorial scene wherein the basic principles of virtual reality will be explained. Afterwards, a historical scene will be presented to the user, who can interact with the world. The user should be able to walk and move around in the virtual worlds, as well as communicate with people in the world. These conversations should be done textual, to prevent the application from being noisy. Furthermoresince this application is more visual than the traditional textbook where reading is more dominant, texts should not be completely left out, and thus the textual conversation will stimulate the children to read texts. In these conversations, historical facts can be told and the world can be explained more elaborately.

The application should be made in Unity, industry-leading software for virtual reality application development. Photorealistic graphics are not pursued due to a higher chance of motion sickness, as stated by Tiiro (2018). The educational application should cover the history curriculum from Dutch teaching method *Wijzer!* by publisher Noordhoff. The selected period in history is the time of the first agricultural societies in the Netherlands, to be found in the first chapter of the textbook for class seven. In combination with the teacher's instruction manual, a selection of important topics can be made to be captured in the educational application.

Realisation

Fulfilling of functional requirements

Interaction in virtual reality

Interaction design is a very crucial part of a Creative Technology graduation project. This project almost fully focusses on the interaction with the virtual world and thus should be extensively examined. There are multiple virtual reality interaction methods known to developers, but they all differ a bit in use. If the user cannot use a controller, a gaze method can be used to handle the interaction. You can have a gaze-timer method, where you have to look for while to an object in order to select that object. Secondly, you have interaction with a controller, where you can either only use a button for selection making, but also a controller that can be used as a pointer.

As discussed in the previous chapter, at the first instance the project's go-to device was the Bobo VR Z4 virtual reality headset, but this later changed. After the release and purchase of the Oculus Go, this was the new target device for this project due to reasons that are mentioned in the previous chapter. One of the differences between the two headsets is the controller that comes with the Oculus Go, where the Bobo VR Z4 did not have an included controller. This makes a real impact on the project's approach, where the controller allows a new way of interaction with the virtual environment. A controller has buttons that need a finger press to perform an action. Without a controller, the user is only able to look around. Both interaction methods have their advantages and disadvantages. Let us take a closer look at the both.

No controller interaction

Not having a controller leaves the users only with the possibility to look around and gaze at objects. Many virtual reality applications are focussing on the broad public, who often have low budget devices without an included controller. This makes it that many virtual reality applications have a 'gazing interaction method'. This interaction method shows a small pointer in the centre of the screen. This can be compared to your mouse pointer on a computer. This small figure (often a dot) will change when the user looks at an interactive object in the virtual world. In many applications, a small radial bar will appear and fill after looking for a predefined time period at that specific interactive object. When the bar is filled completely, the object is selected. The gaze pointer for this application can be found in Figure 2 below. This interaction method allows a user to fully navigate in the virtual environment without the use of a controller or other button input.

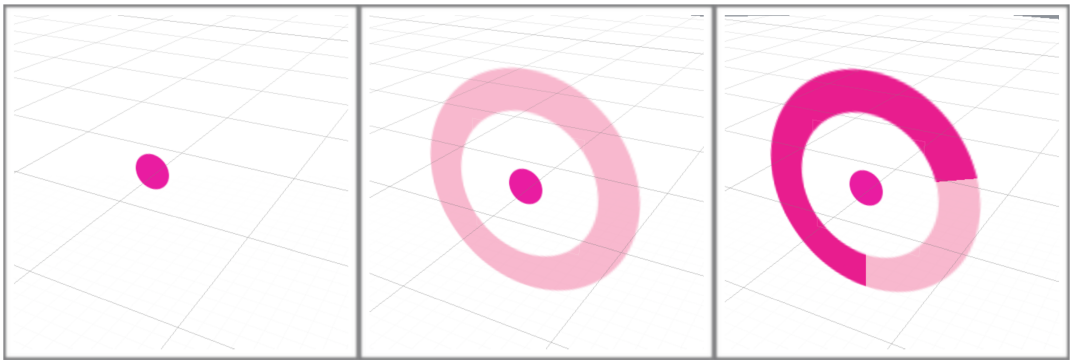

Figure 2: Normal gaze pointer (left), empty gaze-timer (middle), filling gaze-timer (right).

Controller interaction

Controllers give virtual reality a new way of interaction. When the user has a controller, buttons can be used for input. More advanced controllers, like the controller of the Oculus Go, is even able to detect motion and rotation, and thus can be used as a pointer in the virtual world. However, after introducing the client organisation to existing controller- and non-controller-supported virtual reality applications, they agreed upon the fact that the application for the elementary school should not use the controller as a pointer device. This pointer interaction is in the opinion of the client organisation not necessary if the gazing method basically gives the same functionality. Controllers can be easily lost in environments like the elementary school. Although the controller pointer is very convenient in the menu of the Oculus Go — where the menu buttons are placed relatively high and low — the controller pointer is not needed in the virtual reality application where most of the content is at vertical eye-level. The controller will be used, but only one button is needed to control the whole application. This is a very conscious choice, because of two reasons. The main reason to use only a single button is that it is the easiest to learn for new users. Everybody knows how to press a button and therefore no time is needed to learn how to use it. The biggest advantage of an external button is that the user needs to make the choice of pressing it. You either decide to press it or not to press it, and that decision-making is difficult to simulate in a virtual reality application. For this application, it can only be done by making use of a gaze timer. The favourable side effect of using only a single button is that the application is still deployable to other low-budget devices, like the Bobo VR Z4, that was previously mentioned.

Application design

The application consists of two scenes, namely an ‘tutorial scene’ and the ‘history scene’. Those scenes were designed in multiple iterations and the application has four important elements. The first element is the tutorial design, the second element is the teleport system, the third element is the conversation handling and the last element is the integrated history curriculum. In the first scene is the introduction scene, where the basic principles of virtual reality interaction are explained to the user. After the user has finished the tutorial, the

historical scene will be loaded, wherein the user can walk around in the environment. Additionally, the user had to be able to conserve with characters in the history scene. The history scene has the goal to educate the students, so there is history curriculum integrated into the application. The historical information is shared with the user via conversations and by visuals.

A. Tutorial scene

Tutorial design

First of all since the application was being tested on students who, overall, did not have any experiences with virtual reality, virtual reality had to be introduced to them. Therefore, a special introduction scene was made. In the first iterative round of the tutorial scene design, the user was introduced to the basic principles of virtual reality. They were introduced to the possibility to look around in the world, the possibility to select selectable objects, and the possibility to walk around in the world. The chosen selection method, the gaze-timer, was explained as clearly as possible to the users. This is done by making them select objects to go to the next step of the tutorial. Doing it way does not explain it only textually, but also practically. After the user has finished the tutorial, a button could be selected to load the scene that would take them back in time and educate them the history curriculum.

In the first version of the tutorial scene, the text was placed above the interactive elements in the scene. In the beginning, this did not cause any trouble for me, because I knew I should look at it, since that would trigger the selection. After showing the application to friends and family, it was discovered that the placement of the interactive items was problematic. The first text in the application welcomed the user and asked to look left. However, when turning left, the user immediately faded over the interactive cube which automatically triggered the gaze-timer. This was sometimes unnoticed by the user who is focussing first on the new appearing text. Therefore, in a second design, the text and interactive object were switched around, to prevent this from happening. The change is visible in Figure 3.

Figure 3: First version (left) and the second version (right)

Another problem that emerged was that when the application was tested by myself, I noticed that when I was moving around in the scene, sometimes I ended up in the middle of an object or wall. This is something that is a known problem by the developer of the application, but users can feel disorientated and do not know what to do if they end up in such a situation. Therefore, a hard-reset function was needed to make the user able to reset their position if they are feeling lost in the scene. This is implemented in a second version of the application, wherein the user can look straight up and select the 'reset' button. After the selection is complete, a sound will be played and the user's position will be reset to the initial starting position. When the position of the user is reset, a little sound is heard so the user knows that the selection is successfully completed.

Finally, the tutorial scene introduced the user to the mechanism of teleportation. Textually it is explained how to walk in the environment. The text ends with: "Now you can walk around, try it!" However, when testing the application on the students of the client organisation, it was noticed that just one or two students actually did what was asked for. Afterwards, in the history scene, the students did ask me how to move in the world. This should definitely be changed in a future release of the application. It must be made impossible to continue to the 'history world' when the user has not walked around yet. A simple implementation could be that the user is forced to move to certain targets in the environment. Only when the user has done this, the button for the next level is enabled and the user is fully prepared to go there. An example of the above-mentioned target can be seen in Figure 4 below.

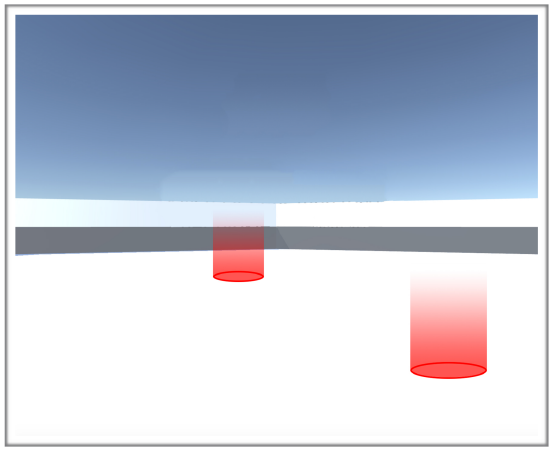

Figure 4: Example of targets that force the user to teleport in the tutorial scene.

B. History scene

When the user has successfully finished the tutorial scene, the user will go to the history scene. In this scene, the user is introduced to the history curriculum in a very visual way. To get an impression, two screenshots of the virtual world can be found below in Figure 5. In the history scene, the user can walk around freely, but there is also the opportunity to have a

conversation with a person in the world. In the developed application, you can talk with a little man who tells about the living habits of the tribe he belongs to. He tells about their way of building houses, gathering food, and about how they found out how to keep animals. After the conversation with the first person is over, he introduces the users to his brother, who will tell about the culture and rituals they have. All the information that is provided in the history world, is based upon the textbook of the students and the instruction manual of the teachers. These conversations are fully scripted. The users can gaze over the speech bubble (as seen in Figure 5 (right)) and that will control the conversation. The development of the three crucial elements of this scene will be discussed below, which are the teleportation system, the conversation handling and the integrated history curriculum.

Teleportation system

The first element that will be discussed is about how the user is able to move around in the scene. This was one of the more difficult parts of the project due to several reasons. First of all, the ground plane in the environment was not even, as shown in Figure 5 (left). This made the teleportation system complicated. Also, there was the possibility of teleporting into objects, which resulted in strange situations for the user. The user always sees a pink dot in the centre of their screen. This dot is not only used for selecting interactive objects, it also serves as the teleportation target indicator. When the user looks to a spot on the ground plane, an invisible line will be projected in forward direction. The point where the line goes through the surface, that will become the place the user can teleport to. This line is called a raycast. Once they trigger the button on the controller, the user will teleport to the destination.

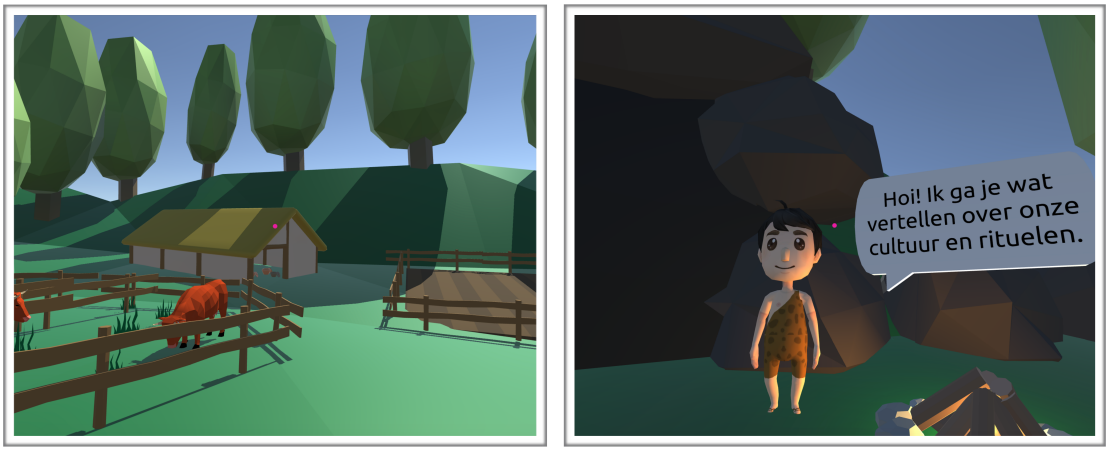

Figure 5: Two screenshots of the history scene of the application

The destination they look at is the point on the ground plane. If the user would be teleported to that exact same spot, he or she would end up in the ground. Therefore, a fixed vector addition should be applied to prevent this from happening. This may sound difficult, but can best be explained with the help of the figure below. On the left side, the first implementation is shown. There, onto the pink dot (destination target), a vector was added that would heighten the user to a suitable position. However, only heightening the target point can cause problems in some areas as shown in the left. When the user wants to teleport to a skewed point on the surface area, the user could potentially end up very close to the hill. It can happen that the user is positioned too close to the surface plane and thus look through the surface, into infinity. After discovering this, a slightly adjusted function is written for the teleportation system.

The problem is solved by not using a simple 'up-vector', but using the data of the ground plane itself. The new function works as follows. The point to where the user wants to teleport is stored in a variable. Every piece of the surface has a normal vector, the vector that is at right angles to the surface. This is called the normal vector of a surface. Now, the user is teleported to the point where it wanted to go plus a normal vector. Now, the user cannot be placed to close to the surface area and thus not look through the surface anymore. As seen in Figure 6, the normal vector of a flat surface is the same as an 'up-vector' that is used previously. Therefore, teleporting to a flat surface works exactly the same as before.

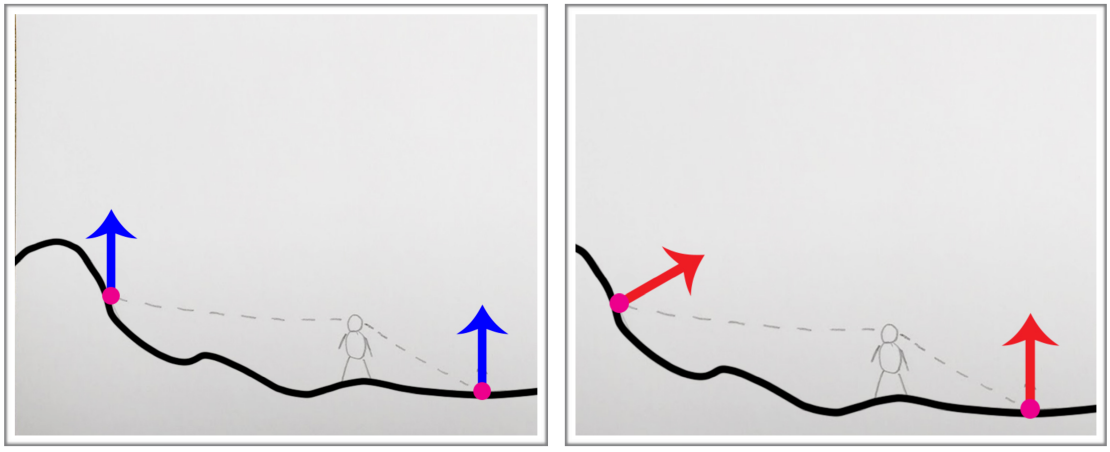

Figure 6: First (left) and the second implementation of the teleportation system.

Another problem that arose was that the user could teleport into objects. For example, there are trees in the environment where the user could teleport into. When gazing at a point close to the tree, the user could end up at the same position as the tree and look therefore though it. This is unwanted and something had to be found to help this problem out of the way. A simple solution is found after a short time of thinking. When giving the objects a collider object in Unity, this problem is solved already. This works as follows: when the objects that you want to avoid have a collider, the raycast that is mentioned before will hit that

collider. When this happens, the line is invalid and therefore the user cannot teleport to that spot. So if all the objects that the user should not be able to teleport into have a collider, the user can never end up standing in an object.

As shown in Figure 5, there are characters in the scene with whom the user can communicate. When communicating, it is absolutely crucial that the user is not standing too close to the character. If this is the case, the text is hard to read. Therefore, a function had to be written. The first implementation of the function checks if the desired destination of the user is within a specified range from the character. If so, the distance between the desired destination and the character is calculated. This will be multiplied by a predefined value, so that the user can never stand too close to the character. After testing, this turned out to be not the best solution and caused even more problems. If the character is standing next to a hill, and the user wants to teleport between the user and the character, he will be moved into the hill and thus end up being in the hill object. This problem is comparable to the problem that was addressed above. Conclusion: another solution must be found.

The third implementation of the function is the easiest one. If the user wants to teleport close to the character, it can be assumed that the user wants to communicate with the character. If this is the case, the user will be teleported to a predefined location, that we determined to be a suitable position to have the conversation at. Therefore, if the user teleports within a specified range from the character, the user will be teleported in front of the character and the distance is specified as such that the text is pleasant to read.

Conversation handling

The user is able to communicate in the scene. This is done by a conversation with characters in the scene. An example of such a character can be found in Figure 5. The idea was to integrate a nodding system into the application. The conversations were scripted in such a way that the historical person asked the user if they wanted to know more about a certain topic. If the user wanted to know more, a nod should continue the conversation, a head-shake would end the conversation. Nodding seemed very intuitive, and this was implemented in an early version of the application. However, this turned out to be very awkward and uncomfortable. Nodding with a headset mounted on your head, makes it feel very uneasy and strange. Fast head movements in combination with the weight of the headset make it a very clumsy experience.

Even though it seems very intuitive and easy, it totally is not. This reason could be that the most important difference between head movement in virtual reality and head movement in real life, is that when nodding in real life, the eyes stay focussed on a fixated point. When someone nods in a conversation, the eyes keep making contact with the person they are talking with. When nodding in virtual reality, the total view moves up and down and it is nearly impossible to keep your eyes on the same point. Therefore, unfortunately, the tracking of head gestures are not possible with the current hard- and software. For future research, it is

very interesting to investigate if it is possible to solve this problem via smart software solutions or hardware additions, like cameras.

Because of the fact that head gestures could not be implemented, the conversation should completely be handled with the gaze timer. In the beginning, when the character is just standing in the environment, every time the user gazes over the character, it will say "Hello". After the user has selected the character with the gaze timer, a speech bubble will pop up and then the conversation is started. Every time the user selects the speech bubble, the next text will be displayed. In the first version of the application, the user could not walk away from the character he was talking to. However, this is a bit annoying when the character is talking about things in the environment. The user is inclined to walk away to have a closer look at the object where the character is talking about. Therefore, in the second iterative round of the conversation handling design, it is changed so that the user can walk away during conversations. Because the speech bubble remains visible, it is clear to the user to return to the character after walking away.

In the application, in the beginning, the user can start talking to a character who will, after a while, talk about the farm they have. When the conversation reached that point, the character is disappearing. In fact, it is moving to the farm to continue the conversation there. The students who tested the application were confused and often asked where the character had gone. The character could be far away and thus be hard to spot. The second character is far away and is even standing in the shadow, as seen in Figure 7, what makes it even more difficult to spot. This problem could be solved by marking the characters better. Therefore, exclamation marks were added above the characters after they have moved. This helps the users to easily spot the new location of the characters. Figure 7 below shows how this looks like in the application.

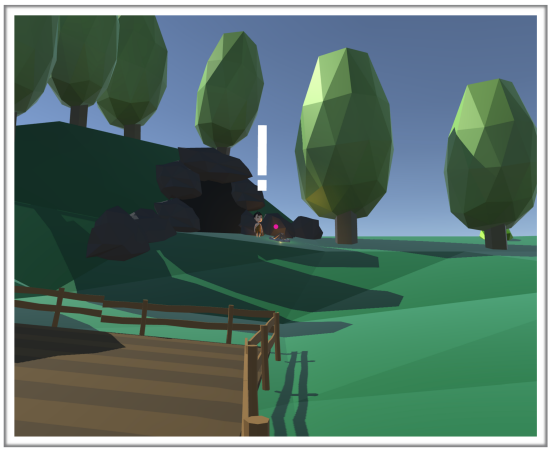

Figure 7: The moved character, clarified with an exclamation mark above it

For future development of the application, conversations must be revised. For now, the conversation can be boring after some time, where the historical figure is only telling information and the user is passively listening to the story. User tests have proven that the

second conversation, where the historical figure is telling many pieces of information, the user can get boring very easily. There should be more things where the user is involved in the world, to keep the attention of the user at the virtual world and the information that is being told. In the first conversation, this is done better. When the historic figure tells about the building process of the houses, he lets the user look at the house. This allows the user to actively check whether the information that is being told is visible in the world. This could possibly be expanded by practical tasks the user can do, by for example planted seeds in the field or having to feed the cattle. These slight and short interruptions form the conversation break the attention span of the user so that after the short break, the user can go back into the conversation with a fresh mind.

Integrated history material

The third element of the history scene is the material in the application. The client organisation demanded that the application should not only let the students taste a bit of the ancient times, it must also share information with the students. Most of the information is told in the conversations with the characters, but this is not all. Most of the information is visualised in the environment, just like the textbook does as well. In the textbook, there are pieces of text that describe how a settlement of the tribe looked like and a picture supports this. Visualisation of the material is a big part of the application. For example, the character says that the tribe has discovered how to domesticate animals. Simultaneously, the user can see those animals standing at the farm. Furthermore, the character says that they bury deceased tribesmen in so-called 'hunebedden'. Such a 'hunebed' is afterwards shown to the students. This visual way of learning should stick in the minds better. The decision of which material is implemented in the application is made with the help of two books, namely the instruction manual for the teachers and the textbook of the students.

In the history teaching method used at the client school, every chapter is divided into four lessons. Every chapter and every lesson has its own learning goals. These learning goals should be the fundament of the material that will be included in the application. This makes the application not only 'cool' or 'fun', but it will also be a useful teaching method for elementary history teaching. The first chapter of the book focusses on the hunters and farmers, but the application is designed to teach the students about the first farmers in the Netherlands. Therefore, the last lessons of the first chapter have more material integrated into the application than the first.

One of the learning goals of the chapter was to recall existing knowledge, it can be taken into account that the students are not uninformed about the history of that time. In fact, the client school teaches the whole history (from first people on earth to present-day) in class 5 and 6, whereafter they repeat the history again in class 7 and 8, obviously more in detail. That is why the application only shortly mentions the basics because the students have to remember these themselves.

A full overview of the learning goals of the chapter and the lessons is listed in Appendix B with a description of how and which goals were included in the application. Unfortunately, not all the learning goals were implemented in the application. This is because of the fact that there was not enough time in this project to create more content that would include the missing learning goals.

Evaluation

Users testing the application

User testing

As mentioned in the previous chapter, the iterative design approach is used to evaluate the prototype that has been developed throughout the project. Most of the design choices are made in the early stages of the project. Family and friends are overall not familiar with virtual reality, and therefore the application is shown to them. The issues that came known after exposing the application to those people, were reexamined and resolved. The reported issues were mostly about controlling the application and these were thus improved before testing the application upon the students of the target group, the students of the client school. Students of the client school were exposed to the virtual environment in the last stages of the project, were most of the problems have been solved. However, still some issues were found and resolved in the final iterative round of the project.

For example, the elements that the respondents had the most problems with, were the placement of the interactive cubes in the tutorial scene, the teleportation system and the possibility of ending up in objects in the virtual world. Those issues were revised and solved. The explanation of these processes can be found in the previous chapter, the realisation chapter. After solving all the popped-up issues, the students were exposed to the application. We wanted the children to get the best experience and provide feedback on the application so it was being understood by all age categories.

Consent regulations

Before the usability tests could start, the permission of participation in the research must be given by the parents of the children. In class 7 and 8 of the Mariaschool in Beuningen are nineteen kids. The group consists of 9 boys and 7 girls, however, for privacy purposes, all the participants will stay completely anonymous in this research. A consent form has been written by the researcher to inform the parents of the kids about this research and they were asked whether they objected to their child's participation in the research. The consent form can be found in Appendix C. To start conducting usability tests, the consent form was sent to the Ethical Committee of the Electrical Engineering, Mathematics and Computer Science (EEMCS) faculty of the University of Twente in request for acceptance. This research had been categorised as standard HMI-research and thus is approved.

Protocol

The protocol for usability testing in this project is as follows. One-by-one, the students were handed out the Oculus Go headset with the installed application. The supervisor told

them to put on the glasses and open the application. After that, only the trigger-button on the backside of the controller was needed in order to use the virtual reality application. The children were asked to speak out loud what they read in the environment, to let the supervisor know where the children were in the application. This think-aloud protocol is very useful to get insights in the thoughts and actions of the students. The supervisor is observing the student throughout the usability test and takes notes of the observation. When the students asked questions to the supervisor, they were in the first instance ignored. If the user poses the same question twice, the question will be answered by the observer. This way, the user is forced to try and solve the problem on his or her own, instead of being told how to do it. This stimulates an active attitude in problem solving.

When the user has walked through the whole application, he or she could return the headset to the supervisor who was then asking the user to take a seat. The user was posed multiple questions, to reveal information that was not yet discovered during the observations. The following, simple, questions were asked.

- What did you think of it?
- What did you find difficult?
- What did you find easy?
- What could be improved?
- What elements did you miss?
- Did you feel sick or dizzy?

The questions could not be too difficult, because of the age of the students. Therefore, there was chosen for simple, open-ended questions to let the student give an answer themselves. Also, by posing this questions, it was revealed what overall was found to be hard or difficult, so that these elements could be better or more extensively explained. The questions about what elements were missing or could be improved, resulted in very varying answers. Those were thoroughly taken into consideration in further iterative design rounds to improve the application where necessary.

Discussion

The goal of this project was to reveal the fundamental design-principles of an educational immersive virtual reality application for elementary history education. This was done in multiple iterative rounds, which has led to a step-by-step approach to the final design. In the final design, the user could freely walk and look around in a virtual world. This virtual world is not only giving the user an atmospheric impression of ancient times, it also provides the user with important and useful information via conversations with historical figures. These figures tell the user about their way of living and the culture they have developed. By telling the students information and letting them actively explore and check that information, the curriculum is presented in a very visual way. The immersive aspect of virtual reality is giving the users a perception of being present and involved in the world, which has proven to boost the intrinsic motivation of the students.

In the ideation phase of the project, multiple ideas were written down on paper to possibly implement in the application, like interaction via head gestures and interaction via voice recognition. The head gestures were implemented and tested by multiple test persons, but after all they were not implemented in the final application. The main reason for this is that it feels very awkward when the users are unable to keep their eyes on a fixated spot. The voice recognition is omitted, because this would be infeasible to implement in the short time of this project. Voice recognition can be used to let the user say; 'yes' or 'no', but other words and sentences would need some sort of machine learning to make the application anticipate on it. Additionally, this makes the user speak out loud, which detracts the demand of the client of making the application as quiet as possible. However, voice recognition would be a possible interaction method to investigate in future research.

One of the clients demands was to let the students individually use the application. When the application was tested by the children, the application was individually usable without problems. All other functional requirements that the client organisation demanded, were met, as the application is an immersive virtual reality application that is suitable for a single combination class where the material of the time period is fully based on the used history teaching method of the client school. The executed user tests with the new developed teaching methods have revealed that the students are highly enthusiastic and more interested in learning the history material. How effective the application really is, has to be tested and proven with statistical research.

Future recommendations

Now that the skeleton of an immersive virtual reality application for elementary history education is determined, time and effort are needed to generate enough and qualitative content to make immersive virtual reality teaching a meaningful addition to the traditional

teaching methods. New and more elaborated historical environment should be created to make this application work for different chapters in the history teaching method of the client school. The content that is implemented in the application should follow the learning goals of the existing teaching method to keep the application close to the traditional teaching lessons. Only when the learning goals are extensively taken into account, the application can be of great assistance during traditional history teaching methods.

To get an answer to the question if this application is equally useful as traditional teaching, further research has to be done with multiple groups. Statistical tests have to be done to reveal which history teaching method is outperforming the other. There could be two groups, where the first group solely gets traditional history lessons and the second group should be educated only with the newly developed application. Furthermore, there could also be three groups of significant size, where the first gets only traditional history lessons, the second group gets traditional lessons supplemented by the application, and the last group will be fully educated with the help of the new application. Statistical research can then reveal if there are teaching methods that work better than others.

Appendix A

Results of the historical time period selection survey

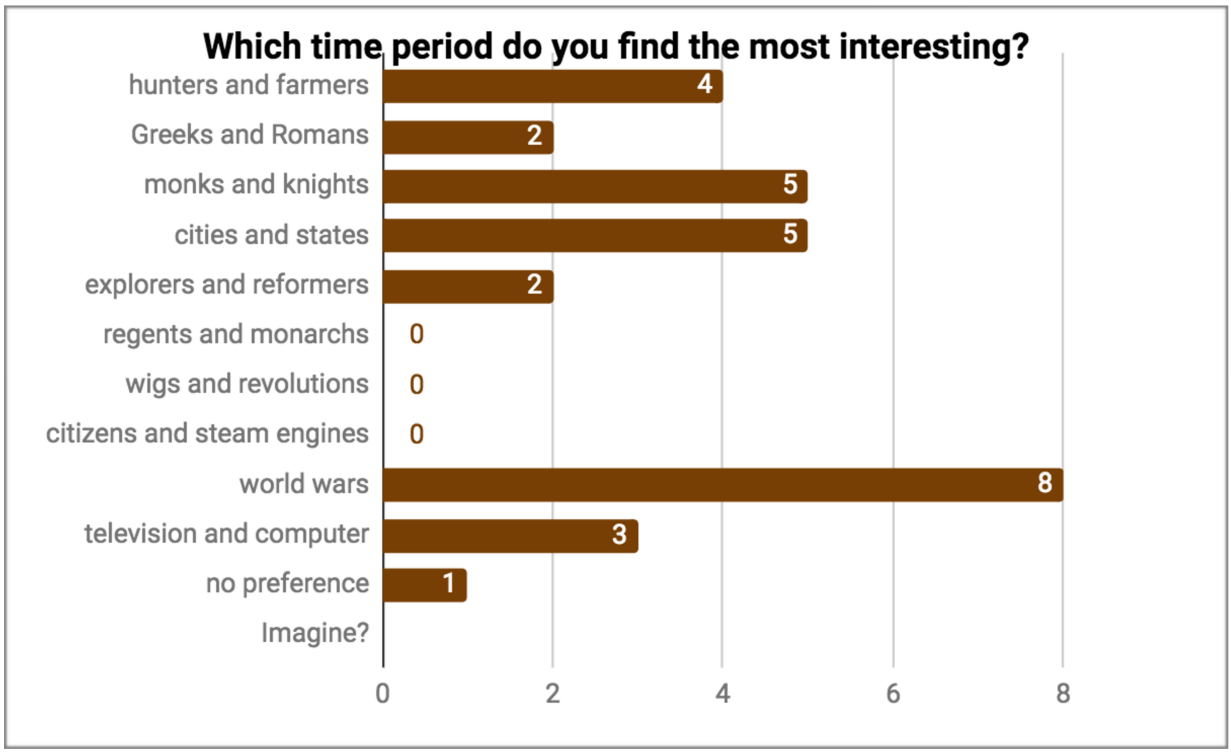

Figure A-1: "Which time period do you find the most interesting?"

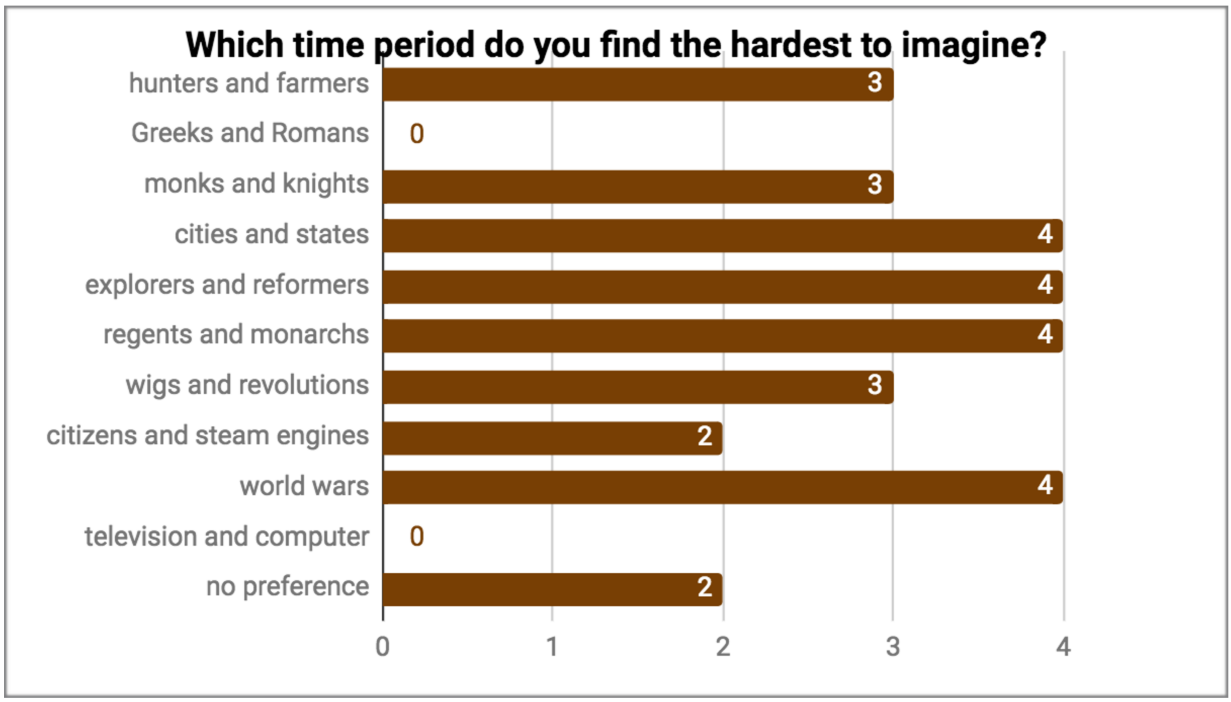

Figure A-2: "Which time period do you find the hardest to imagine?"

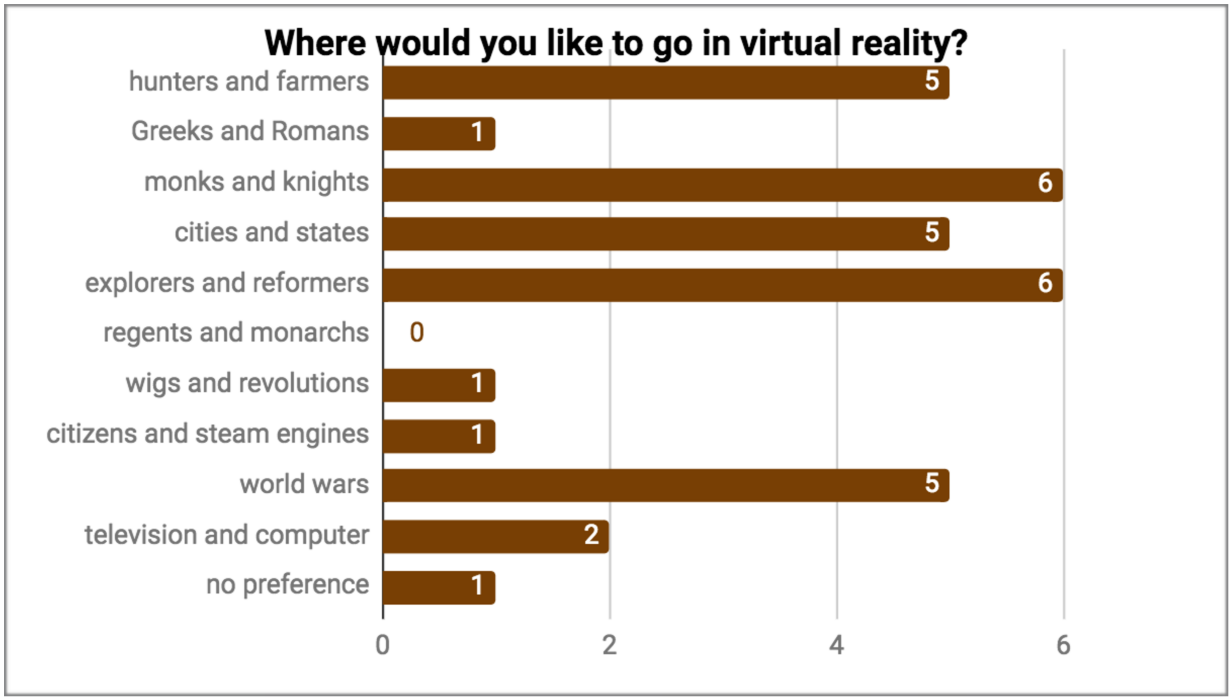

Figure A-3: "Where do you like to go in virtual reality?"

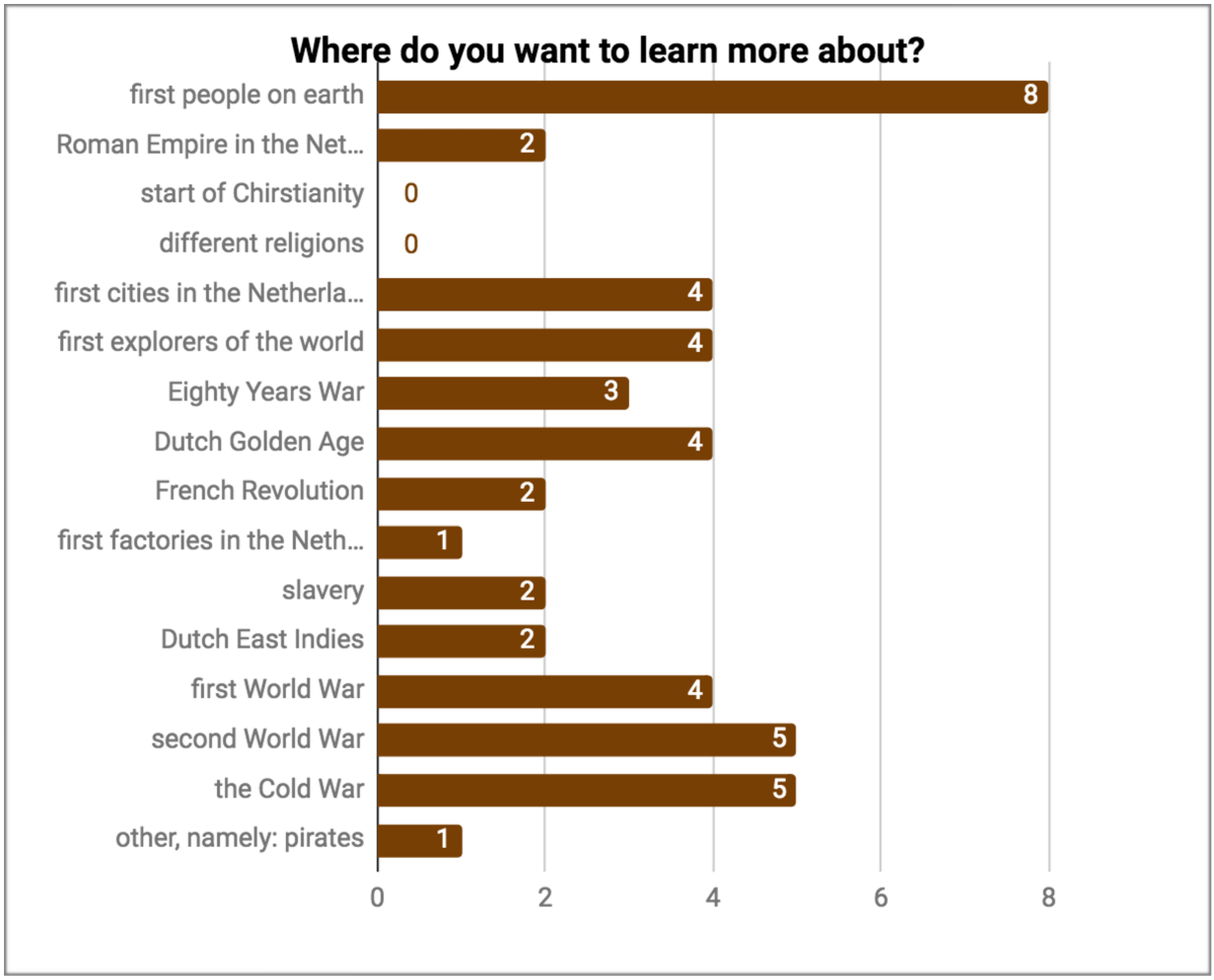

Figure A-4: Where do you want to learn more about?"

Appendix B

Integration of the learning goals of the chapter and lessons

Table X: Learning goals of the chapter and the individual lessons

	The students …	Implementation
Ch	… learn that the first people lived as nomads	"Our ancestors wandered around to get food…"
	… learn that afterwards, people lived in settlements	"… we live at one permanent place"
L1	… repeat relevant pre-knowledge	*This happens throughout the whole application*
	… develop an interested attitude	*The immersion makes the children very interested for the material.*
L2	… can describe how hunters lived from nature	*Not implemented*
	… can explain why hunters had no permanent place to live	*Not implemented*
	… can explain what changed when people had permanent places to live	"We have goats and cows. They produce milk and help us to work the land"
	… can explain how the first farmers lived	*The whole conversation contributes to this learning goal. It is also visually shown throughout the environment.*
L3	… can explain that farmers developed their own culture	"We believe in multiple gods who we have to keep happy. Therefore, we offer them food and goods"
	… can explain that there became differences between poor and rich	*Not implemented*
	… can explain that farmers had a religion and buried deceased traditionally	*The whole conversation contributes to this learning goal. It is also visually shown throughout the environment.*
L4	… can explain that people discovered materials and tools to make live easier	"We plow the land, this makes the grain grow faster"
	… can mention examples of materials and tools	*The application introduces plows, pots, food and the baking of bread.*

Appendix C

Consent form for students' parents

Cis Sanderink

Oude Dijk 73
7588RV, Beuningen
telefoon: 06-81870524
mail: c.sanderink@student.utwente.nl

Beste ouder(s)/verzorger(s),

Mijn naam is Cis Sanderink, woon in Beuningen en ik studeer Creative Technology aan de Universiteit Twente. Ik ben momenteel bezig met mijn derde en laatste jaar en voor mijn afstudeeropdracht ben ik bezig om voor geschiedenisles een virtual reality applicatie te maken. Virtual reality is een techniek waarbij een gebruiker een bril op zijn hoofd zet, waarop een hele andere wereld wordt geprojecteerd. Je kunt rondkijken in een virtuele wereld waar je eigenlijk helemaal niet bent. U kent dit misschien wel van de reclame van KPN, waarbij een vader en zoon op het strand lopen, en het nieuwe kantoorpand bekijken met een bril op hun hoofd. (www.bit.do/kpnvr)

Ik wil deze techniek gebruiken om uw kind af te laten reizen naar een andere tijdsperiode in de geschiedenis. Dit is niet alleen leuk om eens te ervaren, het kan er ook voor zorgen dat de leerlingen zich beter een beeld kunnen maken bij bepaalde tijdsperiodes die anders lastig zijn om voor te stellen.

Hiervoor ga ik dus een virtual reality applicatie, maar deze moet wel getest worden. Hiervoor vraag ik uw toestemming om uw kind de applicatie te laten testen. Het onderzoek zal grotendeels bestaan uit korte, onschuldige, experimenten, waarbij ik bijvoorbeeld twee manieren van interactie met de virtuele wereld aan uw kind voorleg, waarna ze mij moeten vertellen welke ze beter vinden. De data van dit onderzoek zal alleen voor onderzoeksdoeleinden worden gebruikt en zal volledig geanonimiseerd worden.

Mocht u vragen hebben over wat het precies betekend, stuur me gerust een mailtje op bovenstaand e-mailadres en ik zal zo snel mogelijk uw vraag beantwoorden.

Als u geen bezwaar hebt tegen de deelname van uw kind, verzoek ik u vriendelijk om bijgevoegd formulier te onderteken en mee te geven aan uw kind. Mocht u wel bezwaar hebben, zal ik uw kind niet betrekken in het onderzoek. Ten alle tijden kunt u de deelname van uw kind aan het onderzoek opzeggen.

Alvast hartelijk bedankt voor uw tijd en moeite.

Met vriendelijke groet,

Cis Sanderink

Toestemmingsverklaring formulier

Titel onderzoek: *Geschiedenis les in virtual reality voor basisscholen*

Verantwoordelijke onderzoeker: *Cis Sanderink*

In te vullen door de deelnemer:

Ik verklaar op een voor mij duidelijke wijze te zijn ingelicht over de aard, methode en doel van het onderzoek. Ik weet dat de gegevens en resultaten van het onderzoek alleen anoniem en vertrouwelijk aan derden bekend gemaakt zullen worden. Mijn vragen zijn naar tevredenheid beantwoord.

Ik stem geheel vrijwillig in met deelname van mijn kind aan dit onderzoek. Ik behoud me daarbij het recht voor om op elk moment, zonder opgaaf van redenen, de deelname van mijn kind aan dit onderzoek te beëindigen.

Naam ouder deelnemer: _____

Datum: Handtekening ouder deelnemer:

_____ _____

In te vullen door de uitvoerende onderzoeker:

Ik heb een mondelinge en/of schriftelijke toelichting gegeven op het onderzoek. Ik zal resterende vragen over het onderzoek naar vermogen beantwoorden. De deelnemer zal van een eventuele voortijdige beëindiging van deelname aan dit onderzoek geen nadelige gevolgen ondervinden.

Naam onderzoeker: Cis Sanderink

Datum: Handtekening onderzoeker:
09-05-2018

Appendix D

Getting started with application development

When creating virtual reality applications, several things are needed in order to get started building applications. For the realisation of the prototypes, the following software programs are used.

Unity 2018.1.0f2 is used for creating the virtual reality prototypes as this is the industry standard. There is other software capable of creating virtual reality applications, but since Unity was used earlier in this bachelor programme, this was the software program to go with for this graduation project. Unity has a rich 'Asset Store' where all sorts of usable material can be downloaded and imported into new projects. In the beginning of the project, an older version of the Unity software was used, but since newer releases had improved virtual reality support, the newest version was downloaded and used to build prototypes.

For the creation of 3D models to be used within the virtual environment, the Maya 2017 software is used. This again is a program that has been used previously in the bachelor program to create 3D models with. The Maya software allows easy model exporting to Unity and thus connects seamlessly. Maya is a program with a big community, where solutions for problems can be easily found on the internet.

The Oculus Go is still a very new device and thus not much is known about it yet. However, Oculus has great developer tools available on their website as they have very much in common with the developer tools for the GearVR, a virtual reality platform owned by Oculus and Samsung. The developer tools contain handy and useful pre-programmed Unity objects to use in your project that give you a kickstart in creating your virtual reality applications. Problems with the Oculus Go developer tools often share their solutions with GearVR problems, due to its high resemblance in the package. Because the GearVR developer tools are much more used and investigated, more solutions can be found on the internet.

To export your Unity projects onto the Oculus Go, some software has to be installed on your computer. Connecting the Oculus Go to your computer via the standard included USB-cable is not enough and some additional steps need to be taken. First of all, you have to register on the Oculus website with a new account and make yourself a developer. This can be done in the account settings. When this is done, download the signature file that makes sure that the Oculus Go where applications will be deployed to, is actually the same as the registered one on the website. Afterwards, install Android Debug Bridge on a Windows or macOS computer to actually export the applications to the Go.

Tutorials on how to do this are easily found online. When the Android Debug Bridge is correctly set up, deploying applications to the Oculus Go can start. Installing and updating applications can be done via the Terminal window on your computer. It is impossible to

overwrite an application, therefore it is always obligatory to uninstall the application that needs an update before the updated version can be installed. The most used adb-commands for this project will be listed below.

`adb devices`	`Returns a list of connected devices`
`adb install PATH`	`Install app. PATH is directory of the exported .apk file by Unity.`
`adb uninstall PACKAGE_NAME`	`Uninstall app. PACKAGE_NAME is the identifier of your app. This is manually set up in Unity and looks like: com.CompanyName.ApplicationName`

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