



UNIVERSITY OF GOTHENBURG



The Benefits of Virtual Reality in Education A Comparison Study

Bachelor of Science Thesis in Software Engineering and Management

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Göteborg, Sweden, June 2015

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A Comparison Study

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Göteborg, Sweden June 2015

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Abstract

In education, new technologies are used to improve the process of learning. Mobile has been one these technologies offerings educators a way to communicate with the students by using suitable applications for learning. Virtual reality (VR) and its use in education has long been discussed, one of the main challenges is that VR was unaffordable for educational institutes. However VR has evolved since then, the technology is up to date, cheaper and more accessible than it has ever been.

This paper presents a qualitative study that examines the benefits of VR educational applications in comparison to the same application on the mobile. Xolius, an application for astronomy learning is presented and evaluated by 20 students and 5 educators through interviews. By analysing the results we have found that VR is especially effective in subjects where an interactive environment is needed. VR also offers an immersive experience, involvement and promoting active learning in comparison to the mobile application.

1. Introduction

With the advancement in technology in the past few years, new forms of teaching have emerged. Mobile applications are one of these new forms since smartphones and computer tablets are becoming a part of the student's daily culture. The process of learning can be a complex task for the students since it requires a lot of effort from them, which is why they need the motivation to learn [1]. Educational software for smartphones benefits the education process and makes it more interesting for students. Especially if it follows the computer game technology to render 3D graphics for the software and make it more amusing for the students while still deliver the necessary information [1].

But as technology advances, new technologies emerge and a new ways of learning are being introduced to us. One of these technologies that have been gathering headlines for

the past few years is virtual reality (VR). It is characterized as a medium just like telephones or televisions [2]. VR is a collection of hardware such as PC or mobile, head mounted displays (HMDs) and tracking sensors, as well as software to deliver an immersive experience. George Coates defined virtual reality as "electronic simulations of environments experienced via head mounted eye goggles and wired clothing enabling the end user to interact in realistic three-dimensional situations" [2].

The differences between modern VR compared to the concept of VR presented two decades ago is that the technology is finally at the stage where it can be adapted to any mobile phone. The introduction of Google Cardboard showed the public for the first time that any smartphone of this generation can be turned into a Virtual Reality machine with help of a HMD. It contains two optical lenses for each eye to have the perception of depth and suitable applications. At this point any student with a smartphone and a VR HMD can enjoy the immersive experience of VR applications, share their ideas and imagination through a whole new medium. By simulating the experience it encourages them to practice their skills in a safe environment [3] [4].

The literature covers many aspects of VR in education domain, but the comparison between a mobile educational application and the same educational application in terms of functional and nonfunctional requirements in VR is missing. The purpose of this study is to present a qualitative research strategy to identify the important characteristics, beneficial factors and suitable areas for using VR technology in comparison to standard mobile applications.

1.1. Research Questions

1. What are the important characteristics of VR technology in education?
2. What are the benefits of using VR technology in mobile education?

2. Background

A common definition of VR is "A technology that convinces the participant that he or she is actually in another place by substituting the primary sensory input with data received produced by a computer" [5] [6]. One of the key elements to VR is a virtual world, it is an imaginary space or a simulated environment. It's an illusion to illustrate a collection of objects in an environment that fulfil the imagination of the creator. Together with the virtual world there is the immersion of VR, the perception of being in an alternate world such as an imaginary world or another point of view of our world [7].

The immersion of VR is only limited by our imagination and how we decide to create the virtual world. In 1965 Ivan Sutherland stated "Don't think of that thing as a screen, think of it as a window, a window through which one looks into a virtual world. The challenge to computer graphics is to make that virtual world look real, sound real, move and respond to interaction in real time, and even feel real" [8].

It was not until late 2012 that Virtual Reality started to attract headlines again after over a decade of silence with the enormous success of Oculus VR kickstarter campaign, raising over 2.4 million dollar. This led to the development of the Oculus Rift, a wearable and affordable HMD with stereoscopic displays that is considered to be comfortable and lightweight. One of the key features of the Rift is the ultra wide field of view (100 degree) to create the immersion that is needed to experience virtual reality.

However, one concern that arose was how the general public will adapt to VR HMD, the companies are developing integrated HMD, which requires the consumer to buy new hardware. Solution to this problem started another trend of VR which surfaced during early 2014, where instead of an unfamiliar technology, one would utilise the power of the smartphones currently used by the general public. This was first shown by Google with their Google Cardboard HMD as a joke during the Google developer conference, where a piece of cardboard with optical lenses and an android phone could display VR wirelessly with the Google Cardboard application. This opened the way for affordable wireless HMD that could be used for the mobile platform. This solution is however not without its flaws; one major concern regarding Google Cardboard is the fact that the head tracking is using the built-in accelerometer of phones, this caused lag and headaches/motion sickness for many users.



Figure 1. Google Cardboard [9]

Currently there are many other mobile HMDs in the market following the Google Cardboard idea. Simple and cheap wireless HMDs that work in combination with an android or iOS devices and use the stereoscopic display and the head tracking of the device. But Samsung had an idea of improving the wireless HMD experience that utilized mobile devices by introducing their own upgraded version building on top of the Cardboard idea. Samsung Gear VR is a wireless HMD developed by Oculus VR specifically for Samsung and their flagship phones, Galaxy Note 4 and Galaxy S6 devices.



Figure 2. Key features of Samsung Gear VR [10]

It has the Oculus Rift's head tracking module built in which greatly improves the motion latency; this reduces the chance for the user to get motion sickness caused by motion lag within the system compared to Google Cardboard. Galaxy Note 4 has very large screen using Samsung's latest

technology (AMOLED) and high resolution (1440 x 2560 pixels). This allows for an immersive experience and higher quality. For these reasons and the mobility that it offers compared to traditional VR devices, we have chosen to use Samsung Gear VR in our research study to deliver the best possible VR experience.

2.1. Applications

Astronomy was the theme for our applications, the goal of the applications is to teach about the planets in our solar system by visualising the planets and put them into perspective of one and another. The idea is to teach users by visual experience and immersion.

Due to time constraints we decided to include the 4 first planets closest to the sun. All 4 planets are selectable and have their own scene where it shows a model of the planet, a description and a summary. By making it as realistic as possible we made sure to calculate the distance and the rotation speed of the planets. When the user is in a planet scene they are still able to see the other planets orbiting around the sun to get a different point of view of our solar system. Both the VR and non-VR versions of the application have the exact layout, text, models and scenes.

We developed two versions of a mobile educational application; the first one is specifically designed to work with an android smartphone while the second one designed to work in a VR environment with the help of Samsung Gear VR. They were developed using Unity3D which is a game engine used to develop games and applications for many different platforms. Our goal was to have identical features for both versions to avoid any bias and not to favour either.



Figure 3. Main menu with the solar system

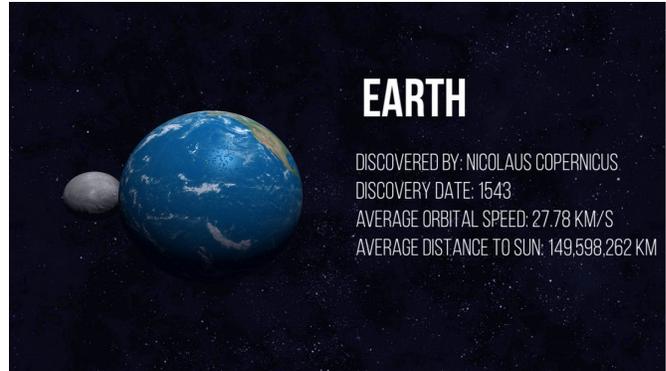


Figure 4. Earth's information page

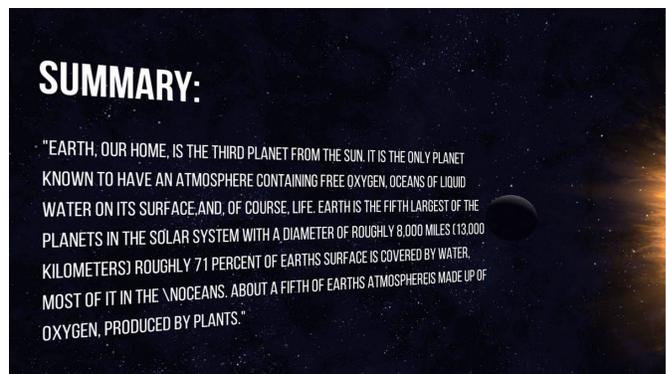


Figure 5. Earth's Summary page

The differences of the two versions are limited by the hardware. In the VR version the user needs to rotate his/her head in order to look around inside the scene while the non-VR version uses a simple swipe gesture on the touch screen. Worth to note the VR version works only with a Samsung Galaxy Note 4 and a Samsung Gear VR while the non-VR version works on any android device running android KitKat or higher.

3. Related Work

VR offers many unique benefits when used in education. First and foremost, by adapting VR into modern day education, it offers a new tool for educators and provides a new way of reaching out to more students [11]. The goal of VR is to enhance, motivate and stimulate students of certain events and at the same time also allows for students to experience hands on learning [12] [13]. But what is more appealing in regards to VR in education is the fact that it can be used to simulate and allow learners to practice procedures without the risk involved. This can be applied in experiments that have proven to be difficult to be carried

out in traditional instructional environments, teaching students regarding safety procedures and in medical education without involving the safety of a real patient [11] [14] [12].

However, like any new technology there are always concerns regarding its usefulness and acceptance. In this case, concerns of incorporating VR in education have long been discussed. Bricken identified three challenges by comparing VR to pedagogical practice and theories: cost, usability and fear of technology [13]. Another important attribute to explore in order to understand VR within education is learner's attitude towards VR; this attribute considers the individual perception of the technology and the willingness to incorporate it in their learning [14].

Within technical education, VR provides a special feeling that will help persuade students to learn more on the subject [11]. In chemical engineering VR was used to develop virtual chemical plants to learn about the technology and how effective it is. The main goal of the project was to create virtual lab accidents to show users the consequences of not following the safety procedure [11].

Using VR technology in surgical educations can help the surgeons to determine their competence level before actually operating on a patient [15]. Medical education has shown a big interest in using 3D computer applications especially in the human anatomy field. A study was made to evaluate the use of 3D models to improve the learning process of human anatomy students, and it was shown that using such technology has a positive impact on the students [16].

Labs in engineering education are designed to improve the practical knowledge of the students and their ability to solve problems independently [17]. VR technology can help the students apply their theoretical knowledge into a real industrial problem. Autodesk Showcase software allow the students to create 3D models in CAD and use them in a virtual environment. This will reduce the cost of building the actual models and encourage the students to unleash their creativity and assess the value of their solutions. VR technology in this field will also reduce the risk of using hazardous materials in the teaching process and reduce the impact on climate by eliminating the wasteful materials or any harmful mistakes made by the students [17]. Some educational institutions are using this technology in their research and education purpose making it more affordable and effective [17].

In 1993 a virtual physics laboratory was modelled after traditional labs with a large room containing a table as a workspace to allow the students to experiment in VR [18]. The lab was used to measure the period of pendulum for different lengths and magnitudes of gravity, measure the average rate of energy loss of a ball dropped from different heights and to compare the trajectories of objects projected in two dimensions without atmospheric drag [18]. The lab

used a helmet-mounted coloured display and special gloves to register the gestures of the hand. The lab was developed using NASA's Solid System Modeller and rendering software [18].

4. Research strategy

To establish a common ground where applications from two environments can be evaluated fairly, it was important that an educational application that has same features and visuals. This is very hard to come by, where the VR application market is yet widely open to the public and the fact that we are at the same time looking for an educational application that fulfills these requirements. It made more sense that we would create our own application where we could make sure that both sides are represented fairly in the evaluation.

Therefore, we chose Design Research as our research approach. Design research is a problem-solving paradigm that evaluates and identifies problems with an artefact. In this case we would be creating our own artefact (Prototype Application) and evaluate it instead of evaluating an existing one and by doing so we will be able to answer our research questions. [19] [20].

To gather the necessary data from our interviews, we realised early on that a standard interview approach would not suffice to gather the data needed for the research. The reasons being the fact that the majority of the people has never had the chance of experiencing VR previously, nor have they had the chance of comparing two similar applications in the two environments to evaluate the differences. Therefore, it is necessary that we allowed the interviewees to experience similar learning applications in different environment first before giving us their opinion.

We chose to follow qualitative research approach over quantitative. By using interviews to gather qualitative data, this way we will be able to understand the users and delve deeper into discussion of the topic from different aspects of VR and Mobile applications in education. The qualitative research approach also influences the type of questions that will be used during interviews.

The scheduling of the interviews were conducted 2 weeks prior to the actual interviews. We contacted the interviewees to inquire their availability during the dates we set and to find a time slot to conduct the interview. We estimated each interview to be around 20-30minutes and booked around 25 people for our research. The population is divided into 3 different groups. First group of interviewees are the students of software engineering and management program at Gothenburg University. Second group are the students of Lagmans High School in Vara. Third group are teachers and researchers from university of Gothenburg, Chalmers and Lagmans High School. By having this group

diversity in our research, we will be able to assess how the 3 different groups responds to the technology. We will also be able to look at how programming students and non-programming students react to new technology and if there are any differences in adapting to new technology. And lastly whether if the educators are willing to use the technology in their teaching techniques.

In question formulation, questions have been divided into 2 parts. The first category of the questions is general information about the interviewees and their previous experience with mobile application for education and VR technology. The second category of questions is performed after the experiments. The majority of these questions are open-ended questions that give us the opportunity to gather the relevant data for the study. But there are also close-ended questions whether the user felt that the application used by us to evaluate mobile and VR platform was biased and if after trying out the application they would be interested in purchasing a VR HMD.

As for the actual interviews, each interview began by asking the interviewee for permission to audio record the session. If permitted, we would then set up one laptop and one audio recorder to record at the same time. This precaution is taken to ensure that the recording would be available in case any software or technical issues would arise. However, if the permission to audio record the sessions would be denied, the interview would then be recorded by hand. This way no information would be lost.

We continued the interview by asking a few questions regarding the user. This is to establish a base understanding of our interviewee, where we get to know the participant and his/her previous interaction with VR and educational applications on the mobile platform. Once this is done, we present our two applications. Starting with the mobile platform, where we let the user interact with the application and guide them through the different aspects of it. When they have explored all the features we let them explore more if they want to. Once they feel that they are done with the mobile application we switch over the VR application and do the same process over again. During these experiments we encourage the user to utilise the "Think-Aloud" method to understand what the user is thinking when interacting with the system. [21]. By adapting the "Think-Aloud" method we can find interesting information regarding the mobile and VR applications. However, in our case we are not focusing on UI or the design of the applications. Rather we focus on what the user experience while using the app, so that we can investigate those areas by further inquire them regarding these problems to have a better understanding.

Once the interviewee has finished trying out both applications, we start with the second phase of interview. Semi-structured interview was applied during this phase, because the domain is still very young and there are many unex-

plored areas. Compared to structured interview, where you have to follow a strict guideline of questions and not diverge from the pre made questions. Semi-structured interview follows a predefined template but gives us the freedom to delve further into the questions and ask relevant follow-up questions that emerges from the answers of the interviewee. [22]. These can be can be interesting topics or areas that we did not mention in our interview. It is important while asking follow-up questions to avoid asking questions that only lead to yes and no, rather it should be questions that are open and have the possibility of following up with another question if needed [22]. By combining semi-structured interview with open-ended questions it will give us the opportunity to follow the interviewee when an interesting topic appears and lets us dig deeper into those areas by asking follow up questions to further investigate the domain.

After the interviewee has answered our questions, we also try to utilise an interview technique mentioned by Brusel called "Probing". Probing is a technique where the interviewer tries to prompt more answers from the interviewee [22]. There are many variants of probing, but the two that we found most useful in our case is the Tell-Me-More probing and Uh-huh probing technique. The Tell-Me-More probing is used in combination with the open-ended questions, where the interviewer inquire further regarding the topic that the interviewee brought up during the interview with the follow-up questions. Uh-huh probing on the other hand are used after the interviewee has given an answer to a question, by agreeing to the answer and sometimes stating a neutral agreement towards the response can lead to a more informative and longer answer. [22].

We chose to utilise grounded theory, it is one of the most popular data analysis techniques for qualitative research. It lets us to discover, generate ideas and explanations from our data. The data we collected from interviews were transcribed and analysed in parallel to the data collection procedure that is as soon as we did our first interview we started the transcription and the analysis of the data that allowed us to capture all possible relevant aspects to answer our research questions. The data was categorised as the following:

- General Findings
- Prototype-testing
- Quality Attributes
- Comparison of the application
- Comparison of the platforms

Once all interviews are done and data has been transcribed and divided into their categories. We look through each category to identify the common denominators, trends, analyse the cause of these trends and to explain what are the

underlying factors. This analysis will be introduced and explained in the result and discussion section.

5. Results

5.1. General Findings

According to the data we collected from the population sample regarding the use of mobile applications. The majority of people we interviewed have used an educational application before. Some used them in their free time to learn about different topics such as languages, geography and brainteasers while others used applications to help them with their studies in mathematics, programming and UML design.

When we asked them about their experience with the applications, 8 out of 15 subjects who used mobile applications for education said they had a positive experience. A student mentioned that it was a good way of killing time while learning. Others who did not find mobile applications useful mentioned that they rarely used it or could not learn anything from the applications.

Regarding their interest areas within educational applications, 8 out of 19 said mathematics, 7 out of 19 said languages, 7 out of 19 said computer and technology related subjects and 4 out of 19 said physics.

We also found that 11 out of 25 subjects have previously used a VR device, the responses of the experience with VR were mixed. One student who had a positive experience with VR mentioned that it was very unexpected; it felt real and has lots of possibilities. On the other hand a student who was not fond of the experience felt that it was only interesting for the first 30 seconds and that she ended up getting motion sickness and headaches. Another student felt that he was not fully immersed and it was lacking, which could have been caused by the resolution of the screen or the adjustments of the lenses as he explained. A particular student who previously has tried two different VR devices told us that he had a really bad experience with Google cardboard but had a better experience with the Oculus Rift even though the applications he tried were not fully optimised.

5.2. Prototype Testing

5.2.1 Non-VR

For most of the participants, there were no issues with the navigation and exploration of our mobile application. One student from Software engineering and Management (SEM) described the application:

"You feel like you are in the solar system yourself rather than just reading about it from a simple text."

another said:

"You get more sense of how it looks (the solar system) compared to just images or text. Feels like I'm already in a virtual reality."

During the testing we also asked the participants about the presentation of the summary text in the application compared to a website such as Wikipedia. Most participants found the summary text in the application more appealing, one student who preferred the app said:

"I prefer the mobile app, in Wikipedia there are a lot of links and irrelevant text that just confuses me and distract me from what I'm supposed to read."

while a high school student who did not prefer the app mentioned:

"I prefer Wikipedia, it has more text and more information. Something to grab and to know where the context comes from, references are important."

We also asked whether the background elements and the surroundings were distracting while reading the summary text, the response from one student was as the following:

"I would say mostly I don't see the surroundings when I'm reading, but sometimes it can be a bit disturbing"

and a high school teacher said:

"I think it's not distracting, in fact it would help. I would use it as a teacher to introduce a subject to my students."

Overall, it was a positive experience and according to one student:

"I would prefer this way if the school was providing us with such applications, we would learn more and enjoy learning at the same time."

5.2.2 VR

The VR experience was pleasant for the most part, there were no issues for most participants to navigate and explore the application. The issues that did occur were mostly about not being able to locate the touchpad location on the HMD or the blurriness of the text. The majority of the participants found VR to be an interesting and enjoyable experience. One SEM student mentioned:

"I feel really concentrated compared to the mobile app, the main reason is that I don't get disturbed by the surroundings and just focus on what I'm supposed to do."

and another student who never tried VR before said:

"I'm amazed, I never used virtual reality before but I would love to learn more about our solar system now."

Another student compared to VR application with the mobile application and said:

"I didn't care to read on the mobile app but now when it's in front of me I just want to read it."

However, at the same time there were participants who did not find the VR application as appealing, one of them said:

"I don't know if I learn more on the VR application, because I'm so busy looking at everything else that I don't read the text."

and another mentioned that:

"It would be awesome to have an actor reading the text for you, it would be nice for kids to learn. Audio could improve it."

Regarding the learning aspects of the VR application, a female student told us:

"Since a lot of people learn better with emotions so here when you see the earth you can instantly associate it and might help you learn better, it's really nice."

It was also pointed out to us by a male student that:

"The VR app presented a different scale, more than what mobile ever could."

A teacher at Lagman high school also said:

"I would be a happy student if I used this technology, A happy student leads to good results."

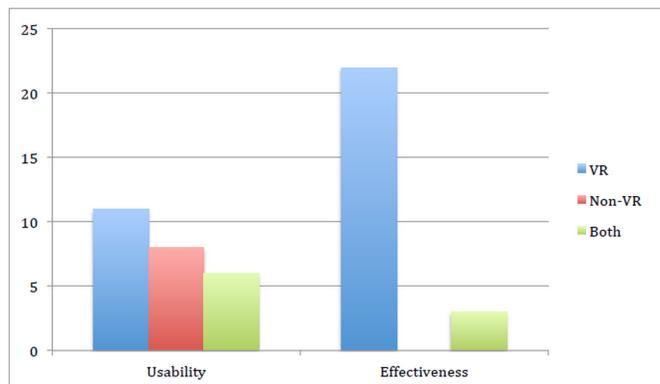
We also asked the participants whether they experienced any unpleasant feeling while or after using the VR application. One female student who previously had experience with VR application and got motion sickness from it said:

"I thought it would be worse, I feel no sickness, everything is moving slowly and I don't feel anything."

One concern that was raised by a few participants who at the time did not experience anything said that they believed longer exposure with the VR application would result in headaches. There were also a few other participants who experienced motion sickness, disorientation and minor headaches while testing the VR application. At the end 16 out of 25 participants had no sickness after using the VR headset, 6 out of 25 participants felt minor headaches and other minor unpleasantities. Only 3 out of 25 participants felt motion sickness after they used it.

5.3. Quality Attributes

We asked the participants about some quality attributes to see which versions of the application fulfil these attributes the best. Usability and effectiveness were the two main quality attributes in our research. The chart below shows the data we gathered from 25 participants after they have used both versions of the application:



The standard definition for usability is: "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" [23] [24]. We focused on the user performance and satisfaction and explained usability to the participants as: "The capability of the software product to be understood, learned, used, and attractive to the user, when used under specified conditions" [24]. We can see that 11 participants were in favour of the VR, 6 participants thought the two versions were equally easy to use and 8 thought the Non-VR was better in terms of usability. The general consensus among participants who preferred VR was the fact that they used their head movement to explore instead of their hand. The participants who prefer non-VR thought it was more natural to use since they are more familiar to the mobile phone and it felt like they are more in control of the environment.

Effectiveness is defined as: "the accuracy and completeness with which users achieve specified goals" [24]. We explained to the participants the goal of the application is to educate the user on our solar system and which of the applications they found fulfils the goal better. We can see that a majority of the participants preferred VR, 21 out of 25 participants said they preferred the VR to the non-VR application. 0 out of 25 participants chose non-VR for effectiveness and only 3 out of 25 students chose both as equally effective. Participants who chose VR mentioned that the VR application allowed them to be more focused. Mainly because they felt immersed and present in the VR world compared to the non-VR application where you are still a part of the real world and can be easily distracted by things

around you. They also felt that the content presented in VR was much more intriguing compared to non-VR, one student said:

"It feels like you don't want to take it off so it's like you really want to study if you have this."

a teacher at Lagman High School also mentioned that:

"In the VR, you get a different understanding of the subject, especially in lab simulations you don't need a text to read but you need to observe the situation and learn from it."

However, participants who chose both in terms of effectiveness argued that there are positive and negative aspects of both applications. In VR they felt the text was harder to read compared to the non-VR application but at the same time VR managed to present the scaling of the planets in a way that mobile could not.

In terms of mobility, almost all participants choose the mobile platform. It was mentioned that compared to the VR HMD, it was less to carry around with and can be used in different environments while VR needed to have a safe environment to operate in. Same results were also found while asking about the safety of these two platforms. Majority of the students felt that mobile platform was safer due to the fact that VR is very immersive and you lose control of your surroundings in real life. One student formulated his answer like this:

"I would say the mobile, because you are not losing your eyesight and all the other senses."

5.4. Comparison of the Applications

We asked the participants about which versions of the application they preferred in the end as a means of education. A vast majority of the participants, 23 out of 25, voted for the VR as the most preferable choice. The main reasons that were given to us by the participants were that the VR offered an immersive experience. Being part of another world and it offers different perspectives on different subjects. One student said this regarding the VR:

"When it comes to education, it's a fun process to learn with VR. Especially for young people, it will spark their interest. Like in areas they consider boring, let's say math, simulation of equation they can interact with it in 3D compared to writing it on a paper."

another student mentioned:

"I prefer the VR because it's more interactive, if you want to learn something and it's fun you will learn it."

and a third student added:

"The experience was a lot better, I think with subjects as astronomy I can find it boring but VR makes it a lot more interesting and fun to learn. I really felt I was there and immersed."

Out of the participants who chose the mobile, described that they did not find VR as appealing due to the fact that they got headache/motion sickness with it and could not concentrate on learning while using it. One of the researchers at the University of Gothenburg told us:

"I prefer the mobile application because I get sick from those games, I don't like the 3D effects. For me personally VR gives me the same feeling of sickness."

5.5. Comparison of the Platforms

When asked about which platform is more intuitive as a learning tool, they explained to us the advantages of using both platforms for different subjects. A subject with lots of text to read would be most suitable for mobile while subjects that require simulations and 3D representations would be a better fit for VR.

One of the participants explained:

"I think the VR is a good way of experiencing things you don't have the capability to, like astronomy or other science fields, atoms or things you couldn't see with naked eyes."

and another one added:

"With VR you can show subjects you can't show in real life, you also get a sense of scale of objects. If we talk about atoms, an image says very little, a video might be better but in VR it would be the best way."

Participants also expressed concern regarding the different age group who would adapt to the technology. They believed that VR could be something that is being used in education, especially with the younger audience. They will have an easier time adapting to the new technology and more interested in new high tech gadgets than their older counterparts. But at the same time other participants believed that VR was very user friendly and only took a short amount of time to get used to.

One student mentioned that the mobile platform is already widely adapted by the public while the VR devices still has not been officially released. He hopes that it can be widely adapted in the future and that the older generation might have a harder time accepting it. Concerning this topic, a student told us:

"I think generally speaking, we are going into a more technological advanced age, this is the way of the future. We are getting more and more technological acceptance. I think the old generation can merge with the new one, we can teach them."

A physics teacher stressed the importance of correctly made applications on the VR platform in order to be effective in a school environment:

"I personally would use it in my teaching techniques if there is good software made for it."

and then he added that in some lab settings VR can help reduce the cost of lab equipment while at the same time offer the same experience to the students. A computer science teacher is also willing to adapt VR into his studies by integrating computer assembling in VR, where the student can see a 3D rendered tutorial before assembling a computer in real life.

A university researcher told us that it would be difficult to include VR in university level studies. But it could be used in order to communicate research results with the public or just as a tool to communicate complicated concepts. Another researcher told us he can see the possibilities of integrating VR into his course Model-driven Software Development. Where the students can interact with different domain models and classes dynamically to get a deeper understanding of the concepts.

We asked the participants whether they think that both applications are identical in features. 25 out of 25 said that the applications are the same in terms of features and nothing additional was added to promote either platform.

Lastly, we asked the participants after trying out VR whether or not they would consider buying one when it is released to the public. 25 out of 25 said they would buy it with consideration of the final price.

6. Discussion

6.1. General Findings

From our findings regarding the usage of mobile applications in education, we found that 10 participants have not used any educational applications on their mobile phones. The reason for this might be the fact that schools and universities are providing students with the materials needed in their studies. The ability to search the Internet for any topic provides faster access to information instead of downloading an application for a specific topic.

The students who did benefit from mobile applications were using it on the go and within the domains of languages and programming. Where we found that they can benefit from learning smaller amount of information, such

as words in languages, syntaxes in a programming language and quizzes.

Overall, we can see that the current market for mobile educational applications is targeting a younger audience therefore it does not appeal to most of our participants in our study. Since they are mainly high schools and university students together with educators.

Understandably, most students we interviewed had never tried a VR HMD prior to the interview due to the fact that the technology is relatively new. From the students who had a positive experience, they have had the opportunity to experience VR through a HMD that is optimised (Gear VR, Rift) compared to the students with a negative experience and attitude who tried a cheaper and less optimised VR HMD (Google Cardboard). But this is not the only factor that affects the outcome of the experience, it is also important to have optimised software. Results suggest there is a correlation between the differences in the hardware, software and the acceptance of the technology. By providing the best possible VR solution to the participants, they will be more likely to have a positive experience and a better acceptance towards the technology.

6.2. Prototype Testing

From the results we gathered regarding the non-VR application, there was no issues with the navigation and exploration. Simplicity was the main focus while designing the user interface, by not adding complicated menu systems or complicated hand gestures.

Since we had the same concept and design for the VR version, most participants had no major issues with the navigation and exploration. However, for many first times Gear VR users, one small issue that arose was the fact they could not easily find the touchpad located on the right side of the HMD. This is however not a concern, once the user located the touchpad they had no issues using it. Another concern that we discovered was the blurriness of the text in VR. Lenses that are not adjusted to the user's eyes or the back head strap that is not properly fit can cause this. It can be either too tight, causing the eyes being pushed too close towards the lenses or too loose where the headset is angled down causing the eyes to not properly adjusted to the centre of the lenses. Another factor could be the eyesight of the user; some users removed their glasses before putting the headset on even though it was designed to support glasses.

This would not be an issue, the headsets are very personal and for each person they could easily spend some time and adjust the glasses in order to have a pleasant experience.

Most of the participants agreed that the presentation of the text in correlation with the environment in the app is more appealing than the traditional ways of displaying plain text. Mobile applications cannot take over the traditional

ways of finding information for a specific topic but rather used as a tool to introduce and help the users understand the topic in a different way. Visual effects and 3D objects can explain certain topics where text can't. A mixture of both can help the students achieve better results especially in science and engineering education. It can also increase the desire to learn for younger students with all the advancement in technology and the variety of educational applications in the market.

Concentration is a key for learning. Using VR application puts the user in a virtual world that simulate the topic, no distractions from the real world and the user is forced to focus and concentrate on what's inside that world. Scaling of objects in our example was very important and users could see the difference and compare the size of planets by using VR compared to the non-VR version of our application. Another key aspect that was brought up during the experiment was that many participants suggested adding audio on top of the VR experience. This would trigger the auditory system, which in combination with the visual experience can provide an even more immersive experience for the user.

6.3. Quality Attributes

Looking at the results from the chart regarding the usability of the application, even though VR did get most votes, the Non-VR was not far behind. Using head movements is a natural thing humans do to explore. Participants who preferred the non-VR app simply because they are familiar with it, and it's a valid point, we need to get familiar with technology before getting comfortable using it.

However, the effectiveness attribute in terms of learning had much more interesting result. Almost all students chose VR as the more effective platform and only a few students chose both as equal. For students who chose both, the argument was that both applications were lacking in certain areas while the other platform compensating in those aspects. But for the majority of students, there was no doubt in what platform they took. This really speaks for what areas VR shines in. While the liability of the participant choosing VR due to their first time is certainly possible, we had many participants who have previously experienced VR and as well as other educational mobile applications.

We think the novelty of VR is certainly a factor in our study and results, but we also believe that VR will be able to become more than novelty within education. As a new medium it offers something that other mediums used in education cannot. In our case VR allows for users to being apart of a virtual world and offers a 360 space around them to immerse the students in. Especially for school subjects that requires visualisation there are no other mediums that can compare with VR. As with any new technology, it might

seem appealing at the beginning, but the effectiveness can decrease over time once we get familiar with it. This is an area that requires even more studies over a period of time after the official release of VR.

As we expected, the mobile platform wins in terms of mobility and safety. For mobility the added hardware of the VR can be a hassle to carry around at all times. For safety the unawareness of the surroundings and possibilities of dizziness, headaches and disorientation makes it less safe to use compared to mobile platform. However, this is not an issue in areas of education such as school environments, library and at home.

6.4. Comparison of the Platforms

It is understandable for a subject that requires simulation and 3D models would fit better for the VR. Using VR is superior in many fields of education, in architecture the students get to see their design comes to live in a virtual world. In medicine it provide a better insight of the anatomy of humans and simulating surgeries to measure the confidence level of a surgeon. A subject that requires labs and real life experiments such as physics, chemistry, biology and nature science is a better fit for VR than a mobile platform. But using it does not replace the traditional means of conducting lab research or real life experiments but it should be used as a tool to help increase the knowledge level.

Simulations in VR do not have the same impact on a person as in real life experiments. An example would be a chemical lab where using such technology would lower the risk of accidents and give the students a better control over the experiment. But it won't help them learn how to handle the chemicals and about the risks when they start their career in the real world [11]. At the same time, as one of the teacher mentioned: in order to successfully incorporate VR into the aforementioned educational environments, appropriate software must also be created in order to fulfil the purpose of the education.

From our results we can see the educators are willing to use VR as a teaching technique and setting up labs. Since the students will be unaware of their surroundings, constant supervision is needed to assure the safety of the students. The educators can control the experience and what the students are allowed to explore in VR with a tablet or computer. If the teaching scenario is to inform the student of facts, the teacher can use a main application to steer the lecture and broadcasts the scenario to the VR machines. This will deliver the lesson as he or she intends and allow the teacher to be in full control of what the students experience. On the other hand, if the lecture in VR is intended to be an interactive process such as a lab to be carried out by the students. Additional software on the computer will be provided to the teachers so that he or she can create the teaching

scenario according to the intended purpose. These apps in turn will be streaming back the content while performing a lab; this way the teacher can monitor the students through their main application and provide the necessary guidance when needed.

As for software engineering education, in subjects that requires visualisations, VR can be used to simulate the design models and different kind of diagrams with their different layers. One improvement VR will bring to modelling is the increased area to work on. It will be easier to fully visualise and have an overview of the models and diagrams in whole compared to computer programs. These programs has limited workspace where only a part of a diagram can be displayed due to the limitation of the screen size.

However, some considerations needs to be made while creating an educational application for VR. Focusing on simplicity and avoiding complicated menus by utilising the head tracking and the 360 view. This will give a natural feeling and an easy navigation while using the application. Low latency and slow movements of objects should be considered to reduce motion sickness and headaches while using VR for a long period of time. Since VR is heavily depending on the immersive experience in a 3D virtual world, it is important to model the environment with high quality textures and 3D models to deliver the best experience for the students.

The adoption or acceptance of VR depends on the age group it was aimed at. A younger audience will adapt faster to VR technology compared to older audience where they might consider the mobile platform to be a faster and safer way to use in education.

In the end, our results suggest the mobile platform is more suited for fast learning, where the platform itself offers mobility and allows the user to open up an app and quickly browse through some smaller pieces of information on the go. By analysing our result we found that VR platform is not as mobile and not suited in all environments. But very effective in subjects that requires immersion and deeper learning in comparison to the mobile counterpart.

7. Conclusion

We set out to evaluate the differences in VR and mobile applications within the area of education. In order to accomplish this task, we had to make sure that both applications are being evaluated on the same terms in order to reach the most trustworthy and unbiased results. To accomplish this we decided to develop two versions of the same application with identical features. With these two applications we gathered our data from interviews where we let the participants trying both applications and then provide their insight to the domain.

In RQ1, we found that the important characteristics of

VR consist of, first and foremost the immersive experience, where the user can be a part of the virtual world; this offers the user and sense of exploration and involvement into the VR. VR is also an active experience, where VR incorporates active learning. Because the user is so involved, this also makes the user more concentrated on the VR, but at the same time it also means that operating VR isolates the user from the real world.

In RQ2 we discovered that the benefits of using VR is that it paints a picture of the subject, in our case of astronomy, it allowed the users to experience the scale of the planets. In other fields such as medicine, it has been used to show the anatomy of a human body. At the same time it allows users to perform tasks that carries safety concerns or cannot be achieved in real life. In fields of architecture and design, it encourages users to be creative. We also discovered that VR technology could be used in a variety of educational fields, mainly the ones that requires a simulation or 3D presentation. From simple subjects like interactive environments to teach kids about basic science facts and small lab simulations to a more advanced higher education subjects like engineering in general, architecture and medical studies. History and geography are other fields VR can help improving, the ability to relive historical events or explore places in the world in a 3D virtual environment will be the closest experience a student can get.

With the cheaper cost and the accessibility of VR, it is a necessary tool in education in the near future. The unique way of delivering information with virtual experience is something that can not be reproduced with other types of tools used in education today and when used in right context VR can provide a great amount of help for both educators and students alike.

7.1. Future Works

We have found what benefits and characteristics VR offers in comparison to the mobile platform. But it would be even more intriguing if comparisons between VR and other educational tools such the computer or tablet could be evaluated to further understand the impact of VR in education. Furthermore, more comprehensive studies regarding the actual learning benefits should be deeply explored and recorded over a longer period of time in order to see what kind of effects VR has on education compared to traditional teaching methods. By doing so we can prove the effectiveness VR has as an educational tool.

Acknowledgment

The authors wishes to acknowledge and thank the students and researchers who participated in the research and

interview. The Software Engineering and Management Programme of the department of applied IT at Gothenburg University and Lagmans High School in Vara Kommun. A special thanks to our supervisor Morgan Ericsson for his advice and guidance and pointing us at the right direction.

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