

Assessing the Desirability of Virtual Reality Exams

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Master of Science in Computer Science

by

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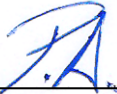
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Declaration

I declare that this thesis has been composed solely by myself and that it has not been submitted, in whole or in part, in any previous application for a degree. Except where states otherwise by reference or acknowledgment, the work presented is entirely my own.

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List of Abbreviations

VR	Virtual reality
E-exam	Electronic exam
3D	3 Dimensions
2D	2 Dimensions
VLE	Computer-based virtual learning
CAA	Computer-assisted assessment
EEG	Electroencephalogram
VRISE	Virtual reality induced symptoms and effects
HMD	Head Mounted Display
FPS	Frames per second
UE4	Unreal Engine 4
MVC	Model-View-Controller
UI	User Interface

Abstract

Technology and educational systems have been going hand in hand over the years, creating various digital examination platforms to further improve and digitize the pen and paper examination process in schools and universities. However, these improvements still offer the same stress and anxiety a student may experience during a pen and paper exam.

Virtual reality technology has been making its way to desktop computers and mobile phones and its use has varied between many fields including medical, scientific, and military. In this thesis, the use of virtual reality technology focuses on the education field. A virtual reality examination platform called VR Exam was created and assessed to see if it helps students stress less and focus more on their exams. The application requires a virtual reality headset and a mobile phone. During the exam, students open the VR Exam application and plug their phones into the headset, allowing them to see the exam in a 3D classroom environment where they can aim and click at answers and finally submit them.

The results showed that the majority of students found that the process enhances their focus and confidence. The results also showed that students are willing to use this system as a tool to conduct multiple-choice exams. However, 46.8% of the participants felt that the process did not reduce their stress as they felt this technology is quite new to them and needs practice on its own.

Keywords: virtual reality, e-exams, stress, education, technology.

Chapter 1: Introduction and Problem Definition

This chapter introduces the problem that is tackled in this thesis and specifies the objectives we aim to realize. The approach to achieving these objectives is explained and a summary of the results is given.

1.1 Introduction to the General Problem

Pen and paper is the most widely used format when conducting exams, which was set out to dramatically shift towards online assessment. A standard test format has been considered as an important measurement due to its plentiful forms of inquiry. For instance, a well-designed test paper including a range of question types such as multiple choices, true or false, and essay. These types of questions can evaluate the students' learning ability and knowledge from different perspectives. However, as technology is continuously evolving, so will educational systems.

Traditional pen and paper exams have advantages as well as disadvantages. The drastic amount of paper used as well as man effort and surveillance, along with different ways of cheating, has encouraged technology to improve examinations. Various types of software-based examination methods, e.g., tablet exams, have been adopted by some schools and universities. However, although online exams provide improvements, they also have disadvantages, vulnerabilities, and security issues.

1.2 Problem Definition

Online examination improvements vary between electronic exams, tablet exams, and other developed software-based exam types. On one hand, these improvements are proven to be quite practical and helpful especially for young learners who prefer anything related to technology in schools and universities instead of books and papers. On the other hand, these improvements are as stressful and vulnerable as pen and paper exams and do not prove to boost students' performance or results.

Virtual reality is a computer-generated 3D environment simulation that places the user inside a virtual experience that feels very close to reality. Virtual reality could help students in many aspects such as stress, anxiety, performance, and results, as well as helping the environment by reducing the production and waste of paper. The development of a virtual reality tool that allows users to take exams in virtual reality could achieve these objectives.

1.3 Research Objectives

The broad objective of this thesis is to study the technology-based examination techniques for educational systems, as well as the use of virtual reality in various fields. The specific objectives are as follows:

- To create a virtual reality examination tool called VR Exam for schools or universities
- To eliminate distractions and reduce stress towards exams
- To improve students' focus and performance

1.4 Approach and Main Results

The work performed in this thesis included the creation of a virtual reality examination platform called VR Exam. This platform is comprised of a 3D environment using 3DS Max, a VR application using Unity3D, and a fully working database and backend using HeidiSQL along with the Django framework. However, due to insufficient expertise with 3DS Max, the 3D environment was purchased from the Unity Asset Store. Several VR interaction methods were taken into consideration including gesture interaction and touchpad interaction. It was decided to go along with the touchpad interaction specifically the GoogleVR headsets due to its cost efficiency and the sole requirement of a mobile phone. The gesture or motion interaction requires more tools to be working such as a desktop computer which would cost more and would not help the cost efficiency of this study considering that each student would need a desktop computer. The exam format was set out to be a multiple-choice question format due to the limitation of the touchpad interaction of the GoogleVR headset that comes with a head motion detector and a click touchpad. The database and the backend server were developed on the localhost which the Unity VR application would then connect to and retrieve the questions and answers data from the database and display them in the VR headset. The user would then rotate with his head and click the touchpad to choose the answers, switch pages back or forth until finally the answers are submitted.

A study was conducted with participants to assess the desirability of VR Reality exams based on VR Exam. The results of this study indicated that the participants perceived several advantages of this method including an increase in the students' focus and elimination of distractions and seclusion. However, many participants did not perceive a

decrease in stress levels as an advantage. The results showed that almost half of the participants thought that using this new technology would be more stressful.

1.5 Thesis Organization

Chapter 2 presents the definitions of concepts, a review of the state-of-the-art examination techniques, and the motivation for this thesis.

Chapter 3 presents our virtual reality examination tool called VR Exam and the design and results of its end-user evaluation study.

Chapter 4 provides a summary of the contributions of this thesis along with possible extensions and future work.

Chapter 2: Background and Motivation

Many studies have compared pen and paper exams to e-exams (electronic exams), in terms of student's performance. This chapter discusses the studies that have been conducted and the strengths and shortcomings of different examination methods. This chapter also defines basic concepts and explains the research motivation.

2.1 Definition of the Basic Concepts

This section defines the concepts of virtual reality (VR), e-exams, and tablet exams, and it explains how each one affects the examination and learning process.

2.1.1 Virtual Reality

VR is the simulation of a virtual or created environment that can be experienced visually in the three dimensions of width, height, and depth and can let the user interact with the environment in full real-time motion with sound and tactile interaction and other forms of feedback [Moses & Felista, 2011]. Virtual Reality is an artificial environment created with computer hardware and software and presented to the user in a way that it appears and feels like a real environment [Baieier, 1993]. VR is based on a stereoscopic view that contains a left-eye and right-eye images of 3D object or a scene. When a user wears a VR headset, the brain transforms the information from the eyes to create the illusion of 3D space. With the illusion, objects seem to have depth and life beyond a flat image projected on the screen.

Viewers can then perceive distance and spatial information between the 3D objects more realistically and accurately [Moses & Felista 2011].

The virtual reality we know today has evolved from non-immersive VR to the current stage where it is possible to experience any environment in the virtual world, as well as making its way to education where computer-based virtual learning (VLE) are packaged as desktop VR. VLE has brought new ways for teaching and learning, practicing medicine and physical science, and conducting engineering tests [Moses & Felista, 2011]. VLE applications have emerged in schools and universities as tools to improve upon traditional teaching methods. These virtual learning environments offer a three-dimensional (3D) insights into the structure and visualization of the desired system. Students can then interact and learn the principles of the system in a fast, effective, motivating, and pleasurable way [Onyesolu, 2009a; Onyesolu, 2009b].

2.1.2 Electronic Exams

Electronic exams (e-exams) assess the knowledge, skills, and capabilities of students using computer-based systems instead of pen and paper. E-exams grew worldwide and are being adopted as open service in many universities including MIT, Stanford, Berkeley, and many others. E-exams make the creation and management of exams cheaper. E-exams can be set by any person who has the privilege to access the examination system such as teachers and admins. Examination sessions can be carried out online by a large number of candidates, and automatic results are immediately available after finishing an exam [Jannik Dreier, Rosario Giustolisi, Ali Kassem, Pascal Lafourcade, Gabriele Lenzini and Peter Y. A. Ryan, 2016].

An important part of the educational process is distance learning, based on interactive technologies. These types of distance learning methods usually use the Web to conduct e-exams that are also known as computer-assisted assessment (CAA). E-examinations may take place locally in the classroom, outside the main campus, or away from the examining institution. Students taking e-examinations inside or outside the classroom use the internet for communication and submission [Igor & Eva, 2006].

E-examinations are divided into two types: asynchronous and synchronous. In an asynchronous exam, students download the exam paper from the website, prepare their answers offline and then they reconnect to the examination web site and upload their answers. Synchronous exams keep all the candidates connected to a server for the whole duration of the examination period. With e-examinations candidates rising in number, the automatic grading of the exams promises faster, cheaper, and more accurate grading [Igor & Eva, 2006].

2.1.3 Tablet Exam

Using computer tablets within educational purposes has become more popular in recent years [Berque et al., 2006; Nakagawa et al., 2010; Manuguerra & Petocz, 2011; Wright, 2013], where the interaction via stylus pen, also described as `digital ink`, has become the most important feature in tablets [Maclaren, 2014]. The wireless connection support in tablets has given students the ability to access and post learning-tasks online from a wide range of locations [Smith & Cline, 2011; Anderson et al., 2013; Goh et al., 2013]. Additionally, pen-enabled tablets can bypass the limitations of online assessment (e-exams) and might replace traditional paper-based exams. The ability to draw equations and diagrams becomes easy with free handwriting via pen supported by tablets. It is also an

important aspect given that users can free handwrite on papers in paper examinations, while incorporating online submission to facilitate marking. [Matthew & Mary Louise, 2015].

All of these features give mobile devices the potential to replace pen and paper assessments, known as a tablet exam, which offers better accessibility for students and marking for teachers [Matthew & Mary Louise, 2015].

2.2 Related Work

This section provides a detailed review of previous studies that tackled paper-based and electronic exams and the current practice of VR in the educational field. Furthermore, section 2.2.1 and 2.2.2 present a comparison between paper-based and e-exams' students' performance and results, a discussion on the effectiveness of e-exams on students' grades, students' stress and motivation concerning e-exams, improvements that can be done for both types of exams, virtual reality in general and its impact and benefits in education, and finally virtual environments' contribution in decreasing stress and anxiety.

2.2.1 Paper-based vs Electronic exams

The study of Cheesman and Roy (2015) was set to evaluate a tablet-based examination that resembled the traditional paper exam. The exams that were completed were submitted and marked online with feedback. Their study's purpose was to indicate how students interact with the tablet under examination conditions as well as their performance by the technology compared to traditional paper-based format. The application was designed to be similar to the paper exam in all aspects of formatting and structure. The results showed that there was no significant difference in performance between each exam type. A key point in Cheesman

and Roy's study is that most students in category A found that the paper-based exam was easier and more comfortable to use than the TabExam. The same result could happen with VR Exam as students are not so much familiar with VR as they are with papers. However, every new technology needs practice to make perfect. There was also concern about phone battery dying out during the exam. Hence, all phones need to be charged fully before starting the exam. Other concerns were related to system crashes but that is very rare since most mobile phones and VR headsets are usually high quality nowadays. Students also said that *"A keyboard would have been helpful for short answer questions as my writing is huge on paper and even bigger on the tablet."*

This issue is handled by VR Exam by implementing a virtual keyboard inside the VR world that students will be able to look and tap upon characters to write their sentences. This feature could be somehow tedious but with practice, it should become usual and comfortable with time.

The study of Sindre and Vegendla (2016), was set to find process improvements with e-exams. Based on their study on various Norwegian learning institutions, the use of paper-based exam is still ongoing. Therefore, digitizing exams would yield improvements in many fields. There are still many problems that paper-based exams still face such as problem formulations errors, discrepancy between languages, copying errors, distribution errors, huge material costs for both question sets and student answer sheets, big number of man-hours needed to conduct collect and grade exams, unnecessary administration man-hours to type grade lists into the system. Sindre and Vegendla's study shows that going digital would eliminate most if not all of these problems since activities related to paper-based exams would no longer be needed. Flexible parallel grading, problem-oriented

marking of the answers instead of candidate-oriented and automated grading are benefits of digitization. Nonetheless, even if exams are digitalized, the ability to cheat is still present. Students can look at someone else's screen, or try to override their personal phone in order to access files that they are not meant to access.

VR Exam would eliminate these problems. The ability to cheat would almost be impossible given that the headset would be covering all your face. Tampering with the files does not offer any advantage, since the student must enter a VR application that sets apart all other active services, and since all the data is stored online rather than locally.

Alzu'bi (2015) conducted a research to find out if using electronic exams improves the students' achievement or increases their motivation in E101 at Ajloun University College. The results of the study showed a significant difference between taking an e-exam and a paper-based one. The paper and pencil exam had a more positive effect on students' achievement. The reason behind this effect is that the students lack computer experience and rarely review their answers before finalizing the test. Also, the time limits on e-exam tests are usually shorter than those of a traditional paper and pencil exam. As for motivation, the result did not show much difference. There is a higher degree of test anxiety when taking an e-exam than when taking a paper-based exam, because students may not be used to it or feel like they are part of an experiment that could affect their preparation. Students might feel the same way in VR Exam. Computers have existed for a very long time, and if students feel anxiety when partaking an e-exam, then there might be a higher degree of anxiety when putting on a VR headset and doing the same process. However, a VR headset offers exclusion from the surrounding, which could reduce the feeling of being in a closed room with other anxious looking students. All of these factors are hidden away

once the student sees nothing but a VR world and an exam to finish. In the long run, and with practice, this eventually could show less degree of anxiety and might even improve student performance.

Halbherr et al. (Halbherr, Reuter, Schneider, Schlienger, & Piendl, n.d.) explain how online exam environments can help improve the quality of examination by making them accurate and valid, motivating and meaningful [Tobias Halbherr, Kai Reuter, Daniel Schneider, Claudia Schlienger, Thomas Piend, 2014]. The results show that online exams offer better possibilities over paper-based examinations in terms of text, images, audio, and video formulation. The overall advantages of online exams are by far better than paper-based exams, where almost any kind of examination type can be performed through online exams. Performing closed and semi-closed task formats online results in flawless and immediate scoring, and students can change their answers as often as they want without repercussions compared to doing that on a piece of paper. Online tests are also beneficial for essay type task formats because typing eliminates poor handwriting problems that often make scoring error-prone and time-consuming. Online exams are also beneficial for competence-oriented tasks, open and closed book exams, technology (safe exam browsers), and others. The interesting part though is that a room equipped with VR headsets, ready to plug and play, costs and needs maintenance much less than the online exam room at ETH Zurich, which is a centrally managed university computer room. With all the reliability that these computers offer, constant maintenance needs to take place in terms of operating systems and runtimes. However, with VR Exam, such room could save up a lot of computer space because students can be placed near each other with no worry about cheating, which saves up a lot of room space and makes infrastructure cost less. Maintenance is also very occasional in

case there are any VR updates, but usually, it is rarely required. And with BYOD (Bring Your Own Device), the whole system could cost even less to implement because students can bring their own devices with the VR Exam application installed.

Washburn et al. (2017) conducted a study to evaluate the performance and results between traditional paper-based exams and electronic-based exams. Based on the examination formats prepared for a veterinary physiology course, the paper and electronic exams contained 25 similar multiple-choice questions. Survey and focus-group discussions were also conducted to know students' opinions towards the examination formats. The results show that scores for electronic exams were higher than those on paper, given that both had the same questions. Yet, based on the surveys and focus groups, results show that students still did prefer paper-based exams than electronic-based exams. Plus, students experienced more anxiety towards electronic exams than paper-based exams. The reason behind these results is that students were worried about technical problems, such that some students had to reopen and restart their exams, and others complaining about software being different on different devices. Additionally, students preferred circling and underlining keywords in the paper-based exam, which would help them eliminate answers and target their answers, whereas it was difficult to do so on the electronic version of it with the help of scratch papers.

Hillier (2014) researched what students think when using their own mobile devices and laptops for e-exams. The studies and surveys showed that students still prefer handwritten exams, even though they have no problem using computers for assignments or reports. The reason behind this behavior is that students are afraid of technical failures that might happen during their exam or poor typing abilities that might slow them down and

eventually run out of time. Another reason that drove students to prefer hand-written exams is that they can relate and remember better due to the handwritten notes that were taken in class. Some students who had a higher proficiency with a keyboard, claimed that they felt they were able to better compose their answers and thoughts with a keyboard.

However, in VR Exam, typing is less necessary and the experience is more engaging and fun, which will make students focus and enhance their performance. Although VR Exam is based on mobile devices, VR systems are robust enough to prevent technical failures during an exam. Additionally, students' proficiency with a keyboard is less needed in VR Exam, which brings fairness to students who lack typing speed and agility with a keyboard, since it is all more or less based on head rotation, aiming and clicking.

Sindre and Vegendla (2015) conducted another research to compare the threats and countermeasures against cheating at controlled exams with paper-based exams versus BYOD (Bring Your Own Device) e-exams. The findings show that the level of security for e-exams depends on each exam type, what countermeasures are in place, the skills of the proctors, and the types of questions asked in the exams. However, the countermeasures that are found to help improve the security of e-exams are mixed seating, non-uniform questions, leaving aside calculators and books, strict question/answer sequence, automated plagiarism checking, and biometric authentication. These countermeasures help bring the security level of e-exams and paper-based exams to an equal level.

Concerning VR Exam, cheaters will always try to find their way through an exam, but when a student's face is fully covered there is nothing much they can do. Cheating in VR Exam is almost impossible, due to being entirely covered by the VR headset as if the

student is blindfolded. Bringing in small cheat papers, notes written on hands or clothes or digital devices will not be of any help as students will not be able to see or interact with anything outside the VR environment. The only way to try and cheat a VR Exam is if there somehow exists a middleman trying to hack/access the connection between submitted answers and the database, which is impossible to do while you are doing the exam. To improve security further, no data is localized on the students' devices. Furthermore, all the answers are shuffled for each student and are submitted to a secure database.

2.2.2 Virtual Reality in Education

This section discusses virtual reality in practice and its use cases in various fields including exams. It also discusses the advantage and disadvantages of virtual reality concerning stress and anxiety.

2.2.2.1 Virtual Reality in Practice

Freina and Ott (2015) conducted a review of the use of VR and Head-Mounted Displays in education. Their findings show that VR can offer great advantages for learning by allowing a direct sense of physically unreachable objects. VR allows training in a safe area avoiding real danger and increases the learner's involvement and motivation. The increase in involvement and motivation is a very important criterion that will help students focus and convert stress and anxiety into motivation, thus allowing them to perform better during the VR Exam. Their findings also point out the intellectual advantages of disabled or impaired people can make out of VR. This technology allows easier learning transfer when learning in a virtual environment that reproduces almost a real one.

VR Exam can help disabled or impaired people to take their exams in the same manner as other people do. Sight and hand gesture is all that is required with VR Exam. This could be easier for many disabled people, in comparison to using pen and paper.

Hussein and Natterdal (2015) set out to test the differences between VR and mobile applications in the field of education. They have built two astronomy applications that cover the same features and were evaluated by participants. Their findings pointed out that most of the participants had no issues when using the mobile version of the application, as well as the VR version. An issue was encountered when users could not find the touchpad located on the right side of the VR headset. Another issue was related to the placement of the VR lenses, which made things blurry if left unadjusted. The important advantage that was found in their research is the immersive experience users had with VR. The users were part of a virtual world that offered a sense of involvement and exploration. The users saw objects in virtual real size; this allowed them to experience and feel the scale of the planets. Additionally, exploring such events that cannot be done in real life allowed students to be safe while achieving an experience that is the closest possible to real-life. It is also worth mentioning that based on the chart regarding the usability of both applications, VR had the most votes. This proves that students are willing to partake in new and interesting educational methods.

Hollister and Berenson (2009) conducted a study to test undergraduate student performance when doing an information system online examination in a proctored environment versus an unproctored environment. A thorough statistical analysis has been made based on multiple hypotheses regarding individual group performances between proctored and unproctored environments. Based on their findings, no significant difference was found in

students' performance in the exam. The overall course performance mean or exam performance between the two groups showed no difference. However, they found out significant variation in performance results with students taking the exam in an unproctored environment, and their best guess was because it is easier to cheat in an uncontrolled or offsite environment. But, there was no evidence of cheating behavior.

When performing an exam with VR, each student is placed in a virtual world of their own as if they are performing an exam in an unproctored environment. The significant variation in performance found could be related to the fact that the student is not tied to the same educational environment that may produce stress, but is somewhere offsite. The same performance variation could be observed within a virtual world because it is essentially the same, where the concept is to place the student in a virtual environment away from everything that may create stress and affect his exam performance, and that may lead to a reduction in the level of stress and an increase in performance results.

Schofield et al. (2018) created a new VR experience for the Yorkshire museum called Viking. The application consists of four 3D computer graphic scenes that were built around real artifacts found at a specific archaeological site, which gives a sense of realism and a legible link between the museum and its medieval vibe. The user would then virtually simulate how lifestyle used to be in medieval times and to also have a hint of how the environment used to look. The scenes were modeled, textured and animated using 3DS Max, and implemented using Unity3D. The chosen VR headset was Google Cardboard since it works with a large number of devices. Visitors' reaction towards this experience was generally positive (83%), with positive comments about immersion and real scale of the camp and environment. However, a lack of interaction was present in their virtual

experience where the user would only gaze from a fixed point of view, not allowing him to move and experience close situations due to the use of mobile/VR technology that does not support spatial tracking.

LeBlanc et al. (2004) compared virtual reality simulator-enhanced training with laboratory-only practice on the development of dental technical skills. By using The DentSim computer-assisted simulator, which is a clinical simulator providing real-time tactile feedback with 3D graphics and image processing, the students who practiced this method demonstrated better improvements in exam scores throughout the year than the students who followed the traditional laboratory way of training. The reason behind this result is believed to be caused by the ability to complete more preparations per hour than students in a traditional laboratory. In traditional operative dentistry instruction, students practice on mannequins in large groups and that limits the frequency of feedback offered by the instructors. Thus, students have to wait for a long time before getting any feedback. The laboratories are typically large ones, and the ratio of instructor to student is low. Thus, students often have to wait for a long time before receiving any feedback. Based on the research, it is best to provide external feedback for the students to achieve optimal instruction.

Koehler and Mishra (2005) introduced a new Learning by Design approach that can help teachers learn and develop a flexible and good understanding of technology. This new approach was designed for the teachers to know more about technology and be effective teachers in the information age. This approach was given in three case study examples: faculty development & online learning, making movies in Switzerland, and learning technology through re-design. All three case studies adopted the Learning by Design

approach, from which teachers learned more about educational technology by engaging in design tasks in small collaborative groups. Teachers need to get involved more into technology and develop pedagogical understandings if they are to integrate technology into their teaching methods. Here is a list of what teachers had learned through Learning by Design about the subtleties and complexities of technology in education: technologies have affordances and constraints, technologies are context-sensitive, technologies are social actors, technologies are malleable, technology means breakdowns.

Concerning VR exams, teachers must know about VR technology as they will be informing students on how to use VR Exam, allowing them to perform their exams with minimal questions about the navigation. Orientation can be useful to let teachers of all ages know more about the kind of technology they are about to use educationally.

Lin et al. (2007) used a dynamic virtual reality environment setup to study the Electroencephalogram (EEG) which relates to motion. The results show that the VR experiment did successfully induce motion sickness with syndromes that are identical to the syndromes of motion sickness in real life. The experiment consisted of subjects seated in a real car, with a six degree of freedom motion platform and a 360 VR scene with seven projectors. After analyzing the results, Lin et al showed that the parietal and motor area of the brain seen an 8-10 Hz power increase which induced motion sickness.

However, in VR Exam, giving the freedom of motion to the students will induce motion sickness. An exam with more than 10 minutes of VR experience can be pretty nasty with motion sickness. That is why freedom of movement will be restricted to minimize the

motion sickness that could potentially and normally be induced during the VR exam procedure.

Sharples et al. (2008) conducted experiments on virtual reality users to identify virtual reality induced symptoms and effects (VRISE). Based on three experiments, Head Mounted Display (HMD), desktop, and projection screen, 60-70% of users experienced sickness symptoms in the HMD experiment in comparison to all other experiments. A very important sickness contributor is the frame rate, where all viewing conditions averaged between 15-25 frames per second (FPS). Another contributor is the fact that users can control their movement inside the experiments, which may lead to increased sickness levels based on each user.

With VR Exam, no movement system will be implemented; this will prevent users from moving to avoid motion sickness during the exam. Additionally, an ideal VR frame rate experience should average 60 at all times, to avoid motion sickness and eye strain. This is why VR Exam will hit the 60 FPS mark as much as possible at all times and will be based on slight head rotations and aiming without any physical movement, to minimize sickness symptoms.

Llamas-Nistal et al. (2013) proposed a new e-assessment solution that would help the transition from classical pen and paper exams to digital. The tool provides assessment, result reporting, statistical analysis, and other activities in a digitalized way. Students still attend classrooms, perform pen and paper exams, and then submit their papers for scanning. Once scanned, their exams are transformed into a digital format (PDF) and are sent to the server for consultancy and correction over the internet. The tool also offers

correction features such as highlighting mistakes, annotating, imprinting grades, and others. The good thing about this tool is that it facilitates the exam process and grading, and provides instant access for students anytime and anywhere to check their grades. It is also a cost-effective alternative to computer-supported e-assessments. The downside however is that the use of papers is still present. Papers still need to be distributed, printed, and so on. The transition to the digital world is not quite complete.

On the other hand, no papers need to be distributed in VR Exam, as the students will be performing their entire exams virtually. Although equipment cost may be heavy to fill an entire exam room, the cost of this system, in the long run, could potentially be less compared to generated and distributed papers. In addition to purchased mobile phones and VR headsets, the BYOD could also be adopted, where students bring their own mobile devices and plug them into school offered headsets, which will also decrease the cost of the system.

Hochlehnert et al. (2011) assessed students' readiness and opinion, as well as performance results on computer-based examinations versus paper-based examinations. The results show that out of 98 students, only 37% of them chose computer-based examination and 63% chose paper-based examination. Based on the results, students were willing to stick with paper-based examinations more than participate in the computer-based one. The reason behind this behavior is stated where students are not able to write down notices and remarks in the computer-based exam. There was also the fear of PC-error and technical difficulties that made some students go with the paper-based examination. Additionally, students complained about loud keyboards that are making noises during the examination and should be taken seriously. The good thing is that a large portion of students 37% did

participate in the computer-based examination which proves the willingness of the students to try it out. The bad thing is that many of them complained about technical difficulties or loud keyboards, or were just unable to write down notes and remarks as they do in paper-based examinations.

However, in VR Exam, there are no keyboards attached to the headset and there are no loud noises that come out of the VR experience. This is why students will feel more secluded and focused especially when they are part of a virtual environment that no other student is in. As for the notes and remarks, it could be achieved with the HTC Vive controller but this is not what is aimed for in this research, as that would be very costly considering that each Vive headset with hand motion sensors requires individual computers.

2.2.2.2 Exam stress and anxiety

Barrows et al. (2013) conducted a study to find out the relation between anxiety and self-efficacy before and after an exam. A pre and post identical questionnaires were given out to students to fill, one to fill 3 days before the exam, and one after. The results showed that higher levels of anxiety before conducting an exam will negatively affect a student's grade. It was thought that self-efficacy would moderate the students' anxiety and thus lead to better results, but the results did not support that hypothesis. But, it was found out that if students had high self-efficacy, they are more likely to feel that they will do well and therefore actually help them do well in the exam. Their future work mentioned that there needs to be a way to lower students' anxiety or short-term anxiety because of the bad effect anxiety brings to each exam and possibly academic success.

This thesis tackles the problem of anxiety with the introduction of VR Exam. These exams transition students into a virtual world that is separated from their surroundings, to help them focus on completing their exams. The sense of involvement, seclusion, and virtual interaction VR brings will help in lowering the anxiety and stress a student accumulates before the exam.

Hashmat et al. (2008) studied the factors that contribute to exam anxiety in medical students in Pakistan. Their findings show that females have a higher level of anxiety than males. The main factors found start with lifestyle, which includes physical inactivity and improper nutrition due to the fact of having to study for more than 5 to 6 hours straight, skipping meals, and thus having a bad health impact. Another factor is related to physiological thinking, were irrational and negative thoughts, self-criticism, and the fact that they had no control over what is to come in the exam led to high levels of anxiety. Lack of preparation and memorizing, staying awake and studying all night, poor revising and reviewing were reported as factors that lead to high levels of anxiety. Another factor is the academic curriculum that contains extensive course loads and comprehensive information and material, which becomes daunting and leads to higher levels of anxiety.

Parsons (2008) investigated strategies that could be used to alleviate or reduce examination stress. The findings report that increasing a student's motivation by providing interesting content and useful complementary feedback does help in overcoming test anxiety to a certain level. Exam supervisors who are respectful and humorous instead of tense and serious play a major role in decreasing students' anxiety. Using the right amount of humor during an examination could help in relieving anxiety while using excessive humor could lead to distractions and an increase in anxiety. Background music has been confirmed to

decrease students' anxiety but only during the preparation stages before the exam and not during. There are examination formats that also prove to reduce anxiety such as the use of multiple-choice, putting easier questions first, and allowing students to choose from several alternative questions. Time or time pressure was also proven to be a major role in increasing anxiety.

With this information, VR Exam would benefit from many mentioned strategies such as background music before starting the exam, question formats and multiple choice answers, and many other aspects that VR helps when dealing with stress.

Riva et al. (2007) set out to analyze the possible use of VR as an effective medium and the relationship between presence and emotions. Three virtual environments were used on subjects: a relaxing, anxious, and a neutral view of a park, where they can roam around for 3 minutes. The results showed that the subjects' emotions did change based on the environment. The relaxing park increase quietness and happiness, reduced anger, anxiety, and other negative effects. The neutral park showed no difference in emotions, while the anxious park environment reduced happiness and positive emotions and increased sadness and anxiety. It was also found that the connection between presence and emotions is directly influenced by the characteristics of the experience, where the relaxing park had the highest positive correlation between presence and emotion.

With this information, a relaxing environment could be built inside the VR Exam to help reduce student's anxiety and increase their happiness and quietness, as those emotions will help in focusing on the exam and perform better.

Trifoni and Shahini (2011) conducted a study on test anxiety and the impact it has on learning, as well as the causes and effects on students. Based on a performed test followed by a questionnaire, the results showed high levels of anxiety when it comes to performing tests. The results show a great difference between genders where females experience more anxiety during tests than men even though they prepared better than them. Other results also show that lack of preparation, time limitation and pressure, number of items, and questions in the test, and the difficulty of the course also play a major role in anxiety. Furthermore, when there exists test anxiety, a student's physical and psychological state are also affected. More anxiety means less motivation and concentration, an increase in errors during the exam, a hard time to remember previously learned material and prevention of efficient study.

On the other hand, though, VR Exam directly targets anxiety where each student is placed in a private virtual world, away from everyone else, which is proven by previous studies to have anxiety and stress reduced.

2.2.2.3 Advantages of Virtual Reality

Pantelidis (2010) discusses the reasons to use VR in education and its advantages. The findings state that VR has the potential to make a big difference, lead to discoveries, motivate and encourage students and learners who can participate in the learning environment in a way that makes them feel present and real through interactions with the virtual world. It provides new ways of visualizing and presenting material or an object, which allows an accurate illustration of some features or processes and an extreme close-up examination of an object or area which may be unavailable to examine by other means. VR

also grabs and holds the attention of students who find it exciting and challenging to venture in and interact with a three-dimensional environment.

However, the advantages of using VR in an exam were not discussed. The use of VR for educational purposes engage and excite the students, and thus it could also be engaging and exciting to perform pen and paper exam through a virtual world in which students can interact with, leading to better performance and results.

Mantovani et al. (2003) discussed the main benefits of the use of virtual reality in health-care education and training. Active and experiential learning is one of the first benefits where students and trainees are simulating the real world through VR which allows them to learn context that needs to be practiced rather than learning without application. Visualization and reification of material can also be done through VR, where information is important to be visualized such as graphical symbols, abstract physics, and biological concepts. Another benefit of VR is the ability to learn in contexts impossible or difficult to experience in real life. For example, traveling inside a human body and moving around molecules allows an extreme close-up experience of the scene, or simulating an experience that is rather threatening and may lead to injury in the real world. Motivation is also a very important benefit from VR where students can make fun interactions with things that seem quite boring in the real world, such as game formats which is a good solution to make learning more interesting. Other benefits include collaboration, adaptability to student's characteristics and an easier way of evaluation and assessment since virtual environments can be monitored. It also mentioned that there are current VR applications for health-care professionals that are also very helpful such as open surgery simulations, orthopedic

surgery, a patient simulation system for teaching emergency response skills to U.S. Navy medical providers, and others.

Martín-Gutiérrez (2017) discussed the advantages of virtual reality in education. The results show that, based on studies, VR is motivating as well as provides a positive attitude in students learning process. It holds their attention and engagement since they interact, create, explore, and manipulate objects in a virtual environment. It allows a greater advantage because it adds precision and viewing objects that are impossible to show or experience in real life. VR allows a constructivist approach towards learning where students can navigate, experience, and obtain feedback, resulting in an experience that would improve their learning. Another important advantage is that VR is now affordable and accessible to almost everyone. Recent smartphones, tablets, and desktops offer easy access to VR a feature that allows students to share VR content through known platforms such as Youtube. Also, VR offers more interaction than traditional learning methods, where students feel immersed when virtually interacting with objects by using headsets, tactile gloves, and motion sensors. This experience allows the interaction with virtual reality objects that could not be accessed otherwise.

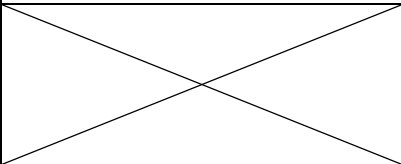
Boyles (2017) researched virtual and augmented reality applications in education, their advantages, and disadvantages as well as how to use those technologies to enhance teaching at the United States Military Academy. The results show the widespread use of VR in many fields such as medical education where they perform surgery simulations and allowing students to practice safely rather than on human or animal cadavers, science education such visualizing chemical reactions safely, engineering education such as displaying animations and instructions over electric machines to inform students how to use

those machines safely, and other fields like history and social sciences, foreign languages and distance learning. The advantages of VR allow users to understand objects or systems that are different in scale, as well as allowing them to learn abstract concepts because they can experience and visualize these concepts in virtual environments. A very important advantage stated is that the immersion of VR can help block out other distractions so the student can focus on the learning objective, where studies have been made and revealed that students are more focused and show better concentration when using VR. Furthermore, it is important to determine which course objectives benefit from a VR simulation, and what level of realism and type of immersion and interaction is needed to successfully integrate VR with education. In parallel, it is important to give instructors and students enough time to test and make themselves familiar with VR technology. It is also beneficial to give development classes in order to teach them the capabilities of virtual reality both in education or personal use.

2.2.3 Study Comparison

Table 2.1: Advantages and Disadvantages of Examination Techniques

Study	Advantages	Disadvantages
Cheesman and Roy tablet examination	Resembles paper-based in all aspects of formatting and structure.	Paper-based was found to be easier and more comfortable than tablet exam.
Sindre and Vegendla improvements in e-exams	Elimination of copying errors, distribution errors, material cost and man-hours for grading.	Ability to cheat still present.
Alzu'bi's research on e-exams and student's performance and motivation	No significant difference between e-exam and paper-based.	Higher anxiety due to lack of computer skills and no motivation difference.

Halbherr et al online exams in improving quality of examination	Offer better possibilities in terms of text, images, audio and video. Students can change answers without repercussions. Elimination of poor handwriting.	Constant maintenance needed in terms of operation systems and runtime.
Washburn et al study evaluating performance between paper-based and electronic-based exams	Higher score in electronic-based exams.	Higher preference for paper-based, higher anxiety.
Hillier's research on students' opinion about mobile and laptop devices for e-exams	Higher proficiency with a keyboard, and better answer composition.	Technical failures, poor typing abilities, muscle memory related to hand-written notes.
Hussein and Natterdal's study testing the differences between VR and mobile applications	Immersive experience, sense of involvement and exploration. Safe experience that is close to real-life.	Complex adjustment of VR lenses, inability to find touchpad on the headset.
Schofield et al VR experience named Viking	Immersion and real scale of environment, realistic and legible link between the museum and its medieval vibe.	Lack of interaction, inability to move and experience close situations.
Lin et al study about motion sickness		Induced motion sickness due to 8-10Hz power increase in the brain
Sharples et al identifying symptoms and effects induced by virtual reality	Ability to control movement.	Low frame rates, 70% of users experienced motion sickness.
Llamas-Nistal et al transition from pen and paper to digital exams	Facilitates exam process and grading, provides instant results access.	Use of papers still present, papers need to be printed and distributed.

2.3 Research Motivation

Virtual reality started in the entertainment area, but over time it became useful in other areas such as education. The main goal of Virtual Reality in education is to make the studying process more exciting and more effective. VR simulations provide a deep understanding of the material by a learner with its further application in real life. The strongest proof that virtual reality can make good for the education system is, in a way, the human brain. The fact is that the brain tends to remember 10% of what it reads, 20% of what it hears, and 90% of what it does or simulates. That is why simulations of virtual things in education are improving the students' knowledge and making them excited to know more about the subject due to this fun simulation experience.

It is known that the anxiety and stress a student goes through when taking on an exam is not a fun experience, which is why VR Exam is a great way of altering that experience into something enjoyable that the student will stress less about. VR could potentially alter the student's opinion about exams from a stressful experience to an enjoyable one. The students will not only interact with the exam in a new technological way, but there are also many benefits such as eliminating cheating, providing total seclusion, reducing the use of paper, speeding up exam correction through automation, reducing finger, hand, neck and back pain, and synchronizing grades to an online platform. Also, students' performance could be greatly enhanced using this new examination method, since it is proven by many studies that VR does reduce stress once you are engaged and interested. All of these benefits are a great motivation to implement and test this new way of conducting exams. It is always interesting and beneficial to test something new and creative that might improve traditional teaching and examination methods.

The main motivation of this new feature is the seclusion that the student gets from this method and the potential result enhancement as well as reduced stress. There exist many situations where students get annoyed and distracted from their exams due to some people whispering and trying to cheat and making noises, which creates anxiousness, nervousness, and distraction. This is a major motivation for creating VR-based exams. When putting on the VR Headset, there is absolutely no way of looking onto someone else's paper, and there is no way to make any noise with pens or papers. Everyone would have the benefit of seclusion and can focus better on their exam.

Chapter 3: VR Exam and its Evaluation Study

This chapter presents a new virtual reality examination platform called VR Exam. It also presents the design and results of an end-user evaluation study of the VR Exam platform.

3.1 VR Platform and Exam Format of VR Exam

VR Exam is a mobile application based on virtual reality for conducting school or university multiple choice exams through a virtual reality headset.

3.1.1 Virtual Reality Platforms

Bitner (2017) listed the eleven VR tools that are most commonly used by developers. These tools are split between those that are web-based and those that are not web-based. The tools that are not web-based include Unity3D, Unreal Engine (UE4), 3DS Max & Maya, Blender, and SketchUp. The web-based tools include Three.js, A-Frame, React VR, Vizion.io, JanusVR, and JanusWeb. Unity3D offers great features for building a VR application. It has a direct VR mode to quickly preview your work through a head-mounted display (HMD) and is becoming the default tool for VR development. Plus, the engine is capable of simulating real physics both in 2D and 3D mode for games, including augmented reality. Furthermore, the community, resources, and documentation available for VR and non-VR development as well as personal expertise have led to choosing Unity3D as the development platform for VR Exam.

3.1.2 Exam Format

The HTC Vive headset and the Samsung GearVR headset both can run a VR application, but each one has different features. The HTC Vive headset is capable of utilizing the motion controllers that allow users to use their hands in the virtual environment, giving them the ability to move around in 3D space as well as grab and throw objects within the virtual environment. This feature allows the VR Exam to have an essay or problem-type format, in which the user can use his hands to draw and write answers. However, the HTC Vive requires the connection of a computer to work. Knowing that there might be 10 or more students in a class conducting the exam, this requires having 10 or more computers for each headset. Therefore, this method is costly and requires high maintenance. On the other hand, the Samsung GearVR headset does not require a computer and instead, it only requires a phone. The headset is not capable of tracking hand motions done by the student nor does it offer motion controllers, but allows any student to plug their phones into the headset and dive into the VR experience without the need for a computer. The Samsung GearVR allows the user to rotate their head, aim, and click at certain objects. This makes pointing at multiple answers to choose from viable. Furthermore, this method also works with the BYOD (Bring Your Own Device) concept, in which students can use their phones to perform the exam using the exam application. Thus, it is less costly than the HTC Vive method and makes this new technology more appealing and applicable in reality.

3.2 Development of VR Exam

This section covers the development in Unity3D, along with the database and backend structure for VR Exam.

3.2.1 Database Design

A database is a necessity for many modern software applications. The advantages of a database are numerous including data security, integrity, and consistency. In VR Exam, a database is strongly required to securely store exam data. All exams and their answers are integrated into the database, from which the application sends a request to retrieve a specific exam question. Additionally, submitting the exam sends a request to the database to store the answers of the students, allowing for future data retrieval and confirmation through queries. The system also supports automatic grading, which saves a lot of man-hours needed by teachers.

Figure 3.1 showcases the database which is split into 7 tables, including student, exam, question, answer, exam_details, student_exam, and student_answer.

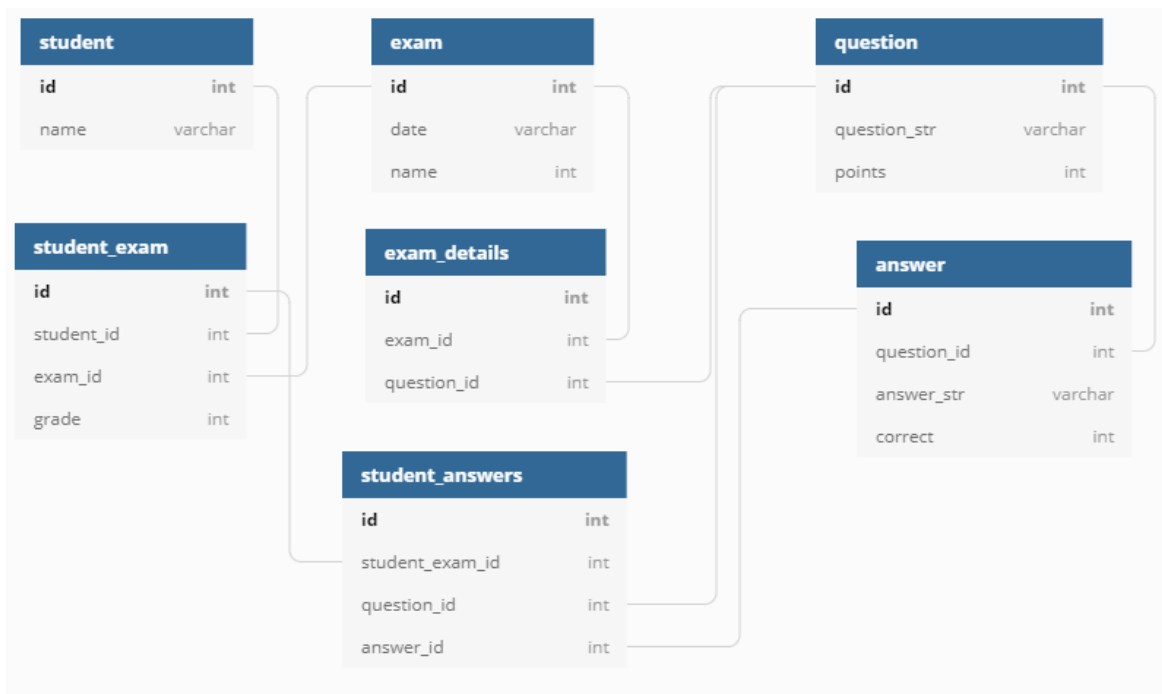


Figure 3.1. Database design diagram using dbdiagram.io

Using SQL language and a free relational database management system tool “HeidiSQL” (www.heidisql.com) shown in Figure 3.2, the tables are then implemented and ready for backend framework development.

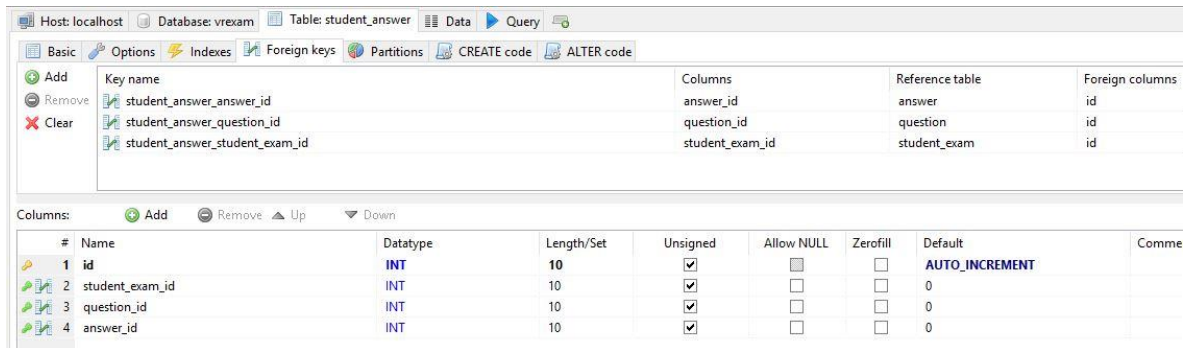


Figure 3.2. Example of student_answer table using HeidiSQL

3.2.2 Backend Development

Django is a high-level python web framework that contains a collection of python libraries that allow for efficient and quick creation of web applications. Django is suitable for both frontend and backend development. Django backend, also known as Django admin, is an auto-generated backend that allows for quick backend code generation without having to write everything from scratch. It is based on the MVC (Model-View-Controller) which consists of models containing business logic and directly related to tables in the database, views which in effect act as a controller, handling requests and returning responses, and finally, templates which handle presentation. Django’s main advantages are speed, security, and scalability. It was designed to help developers take applications from concept to completion as quickly as possible, avoid common security mistakes by using their built-in authentication classes, and has leverage on its ability to quickly and flexibly scale.

Django backend development is an organized procedure. The Model.py script is firstly created, which is a class that represents a table or a collection in the database, and where every attribute of the class is a field of the table or collection. More detailed information regarding Django models is presented in Appendix A.

After creating the model script, the view script is then created. A view is a python function that takes a web request and returns a web response. This response can be the HTML contents of a Web page, or a redirect, or a 404 error, or an XML document, or any other type of response. A ViewSet class is a type of class-based View that does not provide any method handlers such as GET or POST, but instead provides actions such as list and create. The ModelViewSet is a class that inherits various actions, by mixing the behavior of various classes. The actions provided by the ModelViewSet class are list, retrieve, create, update, partial_update, and destroy. The ModelViewSet allows the Unity3D application to call GET and POST requests that retrieve and create data from and into the database. The ExamViewSet “*list*” function is responsible for retrieving a group of data from the database for a specific ViewSet. A modification of the endpoint is then done to return the data in a combined and tidy way, making all exam data retrieval from 1 endpoint only. The “*exam_id*” parameter is a variable passed through the endpoint to get the questions and answers of a specific exam, making the endpoint flexible enough to retrieve any exam data. Detailed information about the created viewsets can be found in Appendix B.

Serializers allow complex data such as querysets and model instances to be converted to native Python data types that can then be rendered into JSON, XML, or other content types. Serializers also provide deserialization, allowing parsed data to be converted back into complex types, after first validating the incoming data. A ModelSerializer class provides a

shortcut for creating serializers that deal with model instances and querysets, and the ability to control the output of the response. Detailed information can be found in Appendix C.

3.2.3 Unity Development

VR Exam was developed using Unity3D version 2018.3.4f1 along with the Oculus Unity VR package offered by Oculus.

3.2.3.1 Preparing The Scene

To start, a 3D scene is created to be able to import 3D models and use the VR feature in Unity3D. The Asset Store, which is an online store for Unity3D, holds many free or paid assets to use. And with its help, a school classroom is purchased and imported in Unity for testing as seen in Figure 3.

First, we start by dragging and dropping the classroom model inside the view scene and then adjust the lighting, scale, and the look and feel of the scene. Second, we import the VR camera from the Oculus package to enable a VR camera instead of the default one created by Unity. Other tweaks are performed on the camera such as position, scale, and rotation to get the right VR look and feel when launching the app. Throughout the tweaks, trial and error were essential for getting the VR environment scalability correct. Getting the correct look and feel is extremely important to make the user feel the immersion of VR and eventually assist in easing the stress and anxiety by looking at a beautiful scene. Third, the user interface is then created by using Unity's default UI Canvas with the setting of World Space instead of Screen Space. The difference between Canvas settings is that Screen Space does not offer any depth in the scene, whereas VR essentially needs depth which is why the World Space settings are used. The canvas is the main area where the user will be

interacting with the exam, through buttons and texts. The interface includes a welcome page, an NDU id page, question pages, and finally a thank you page. The welcome interface, seen in Figure 4, introduces the user to the VR Exam and invites him to proceed through clicking the proceed button. The NDU id interface, seen in Figure 5, prompts the user to enter his id through aiming and clicking on the numbers seen on the table, as well as informing him about the time that is set for the exam. The questions interface, seen in Figure 6, is where the exam will take place in which 10 questions will appear, each question having 4 different answers to choose from. The user can choose his answer by pointing at the answer and hitting the checkbox area of the answer. The user can switch his answer at any time. Additionally, the questions interface includes 2 buttons: next page and previous page, which lets the user go back and forth between the questions to double-check his answers.

Finally, when the user has answered all the questions, they can click on the submit button which will send his information to the server and submit his answers, leaving him with the thank you page, as seen in Figure 7. The “thank you” interface is the last interface the user will see in the experience, along with a restart button to exit the exam and go back to the welcome interface.

As for scene navigation, the user will find himself sitting in one of the seats in the classroom, looking at the interface in front of him as well as having the ability to rotate and discovering the virtual environment of the class. The user can follow the GazePointer, which is a blue circle in the middle of the screen for the VR camera that acts as a guideline to where the user is pointing at, in order to point at interfaces and interact with them. A classroom is the closest exam experience a student can have, where they will feel apart

from this world and yet familiar to the view. Moreover, being alone in a VR environment as well as being in a classroom makes the student feel lonely enough to avoid anxiety, yet triggering him to focus on the exam rather than get distracted.

Figure 3.3 showcases the 3D virtual environment from a back point of view.



Figure 3.3. Classroom Scene in Unity3D

Figure 3.4 showcases the welcome page when a user starts the virtual experience.



Figure 3.4. VR Exam Welcome Interface

Figure 3.5 showcases the student ID input page where the user inputs their ID.

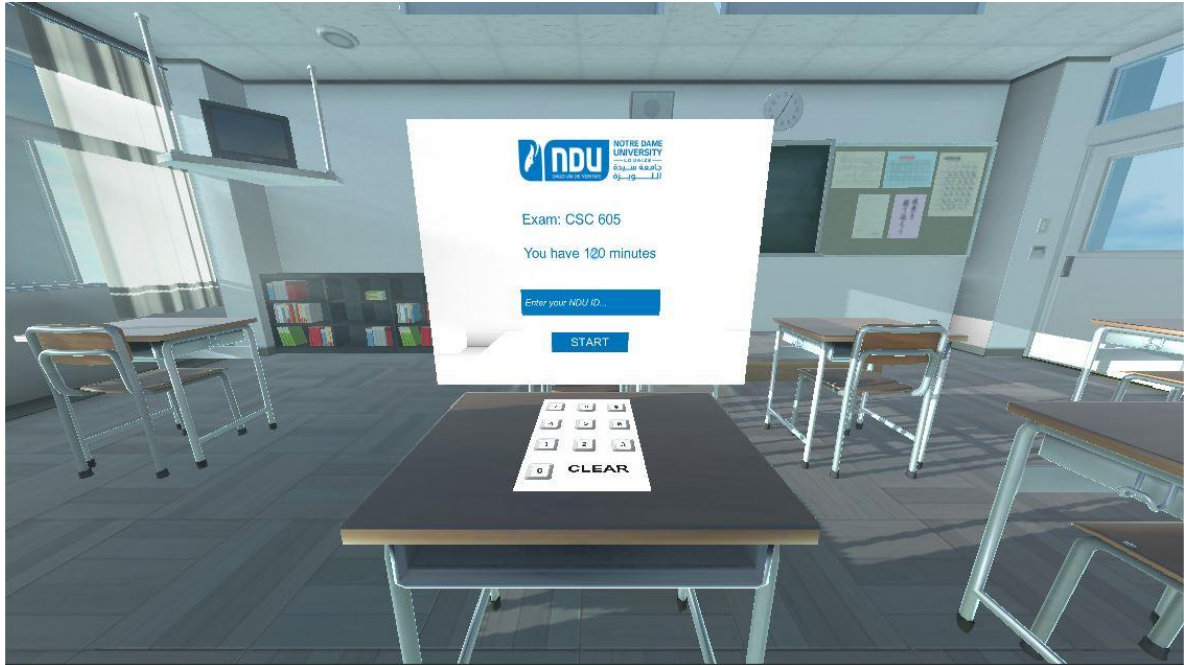
**Figure 3.5. VR Exam ID Interface**

Figure 3.6 showcases the first page of the exam containing 4 questions per page.



Figure 3.6. VR Exam Questions Interface

Figure 3.7 showcases the final page after submission.

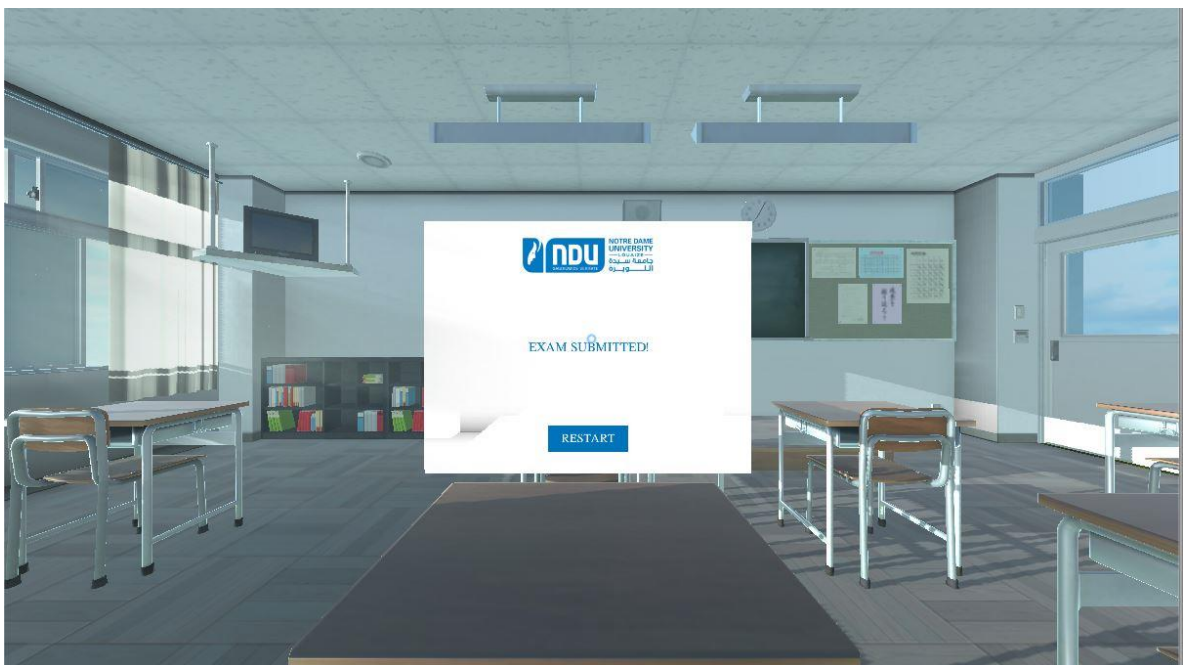


Figure 3.7. VR Exam Submit Interface

3.2.3.2 Preparing The Code

The main programming language used in Unity3d is C#. Several scripts are created to get things up and running, including one main script which is the Manager script. The Manager script, as seen in Figure 8, is responsible for almost all the behaviors in the application. The script handles retrieving all exam information from the backend server and transforms the received JSON data into readable models in Unity. These models are then used to populate questions and answers as well as set the exam name, timer, and all related information. The Manager script is also responsible for switching between interfaces, and the navigation between them as well as starting and tracking the exam timer. Additionally, when submitting the exam, the Manager script uses a function called “PostExamRequest”, which prepares all the answers in a list of models and transforms the list into JSON format, and finally sending it in a POST request to the server in order to validate and insert the data into the database. Detailed information about the Manager class can be found in Appendix D.

Other scripts include “Answer”, “AnswerModel”, “KeyboardScript” and “QuestionPrefab” scripts. The “AnswerModel” script is used to convert user answers into models to convert them again into a JSON format using the JSON library provided by Unity. The “QuestionPrefab” script is used to save information related to questions and answers such as question and answer ids, question and answer texts, question points as well as a chosen answer which saves the chosen answer for each question in an Answer script reference. Finally, the “KeyboardScript” script is responsible for tracking user’s touch events on the VR Headset when pointing and aiming at the numbers, in the NDU id interface, and displaying them in the text field of the canvas.

As per the design of the application, each question contains three answers to choose from, which is why the “QuestionPrefab” script handles toggling answers and setting the chosen answer. Additionally, the “AddAnswer” function adds the chosen answer to the final chosen answers list in the manager. More information about the scripts can be found in Appendix E.

The “AnswerModel” is the model of the Model-view-controller design pattern, which is responsible for managing the data of the application. It receives user input from the controller, which in this specific case is the manager, and is then converted into a JSON format using the JSON utility provided by Unity. The “answer” script is applied to every instantiated answer in the UI Canvas, which is used for determining whether the answer is correct or not, as well as setting its id from the database. Detailed information about the AnswerModel can be found in Appendix F.

3.2.3.3 Final Result

Figure 3.8 shows the final look of the information page. Figure 3.9 represents a view of the back of the classroom. Figures 3.10 and 3.11 represent the final look of the questions and answers section. Figure 3.12 represents the final page the user will be seeing after submitting the exam.



Figure 3.8. Final result of the info page



Figure 3.9. Side view of the VR classroom

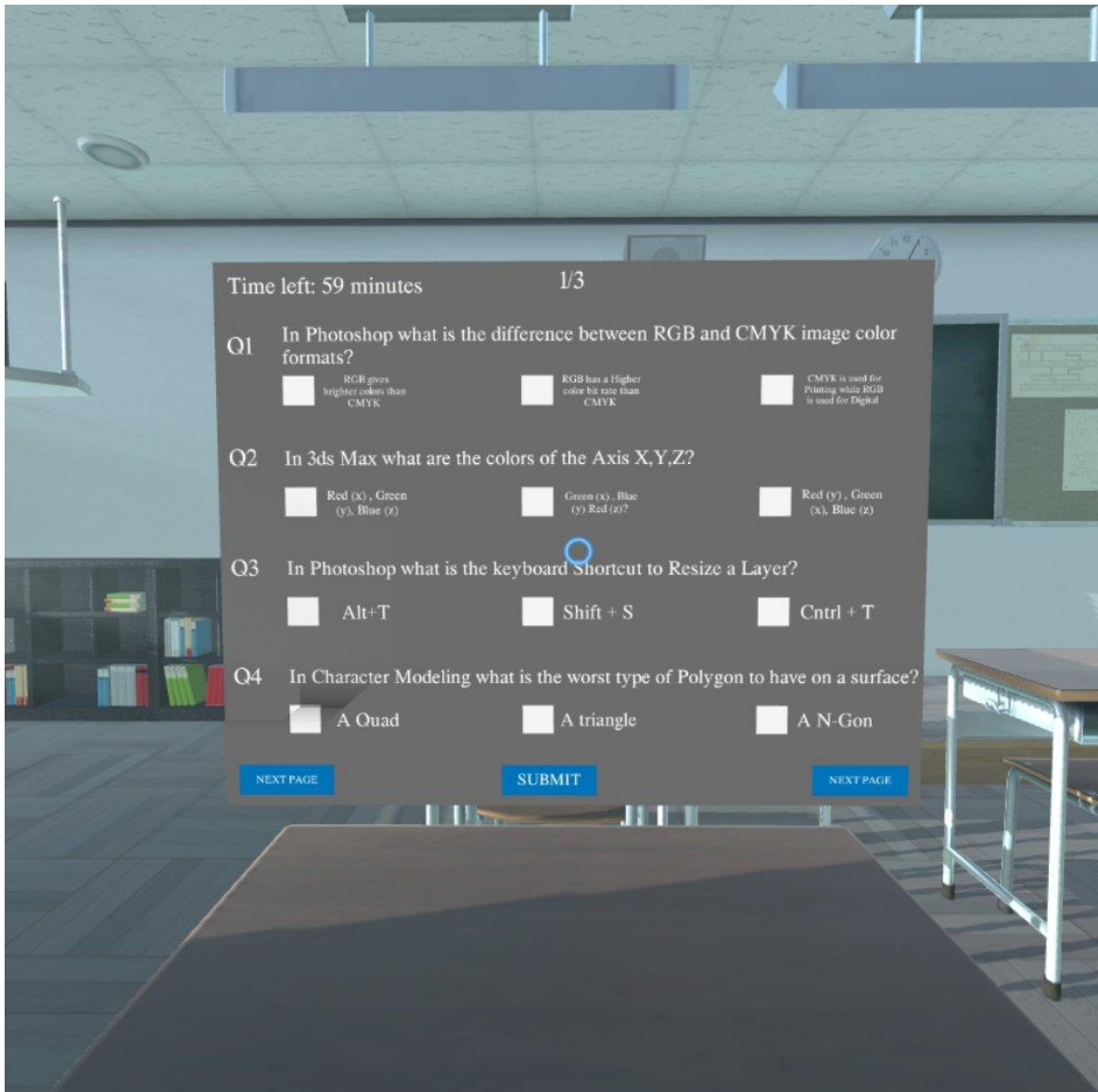


Figure 3.10. Page 1 of the exam

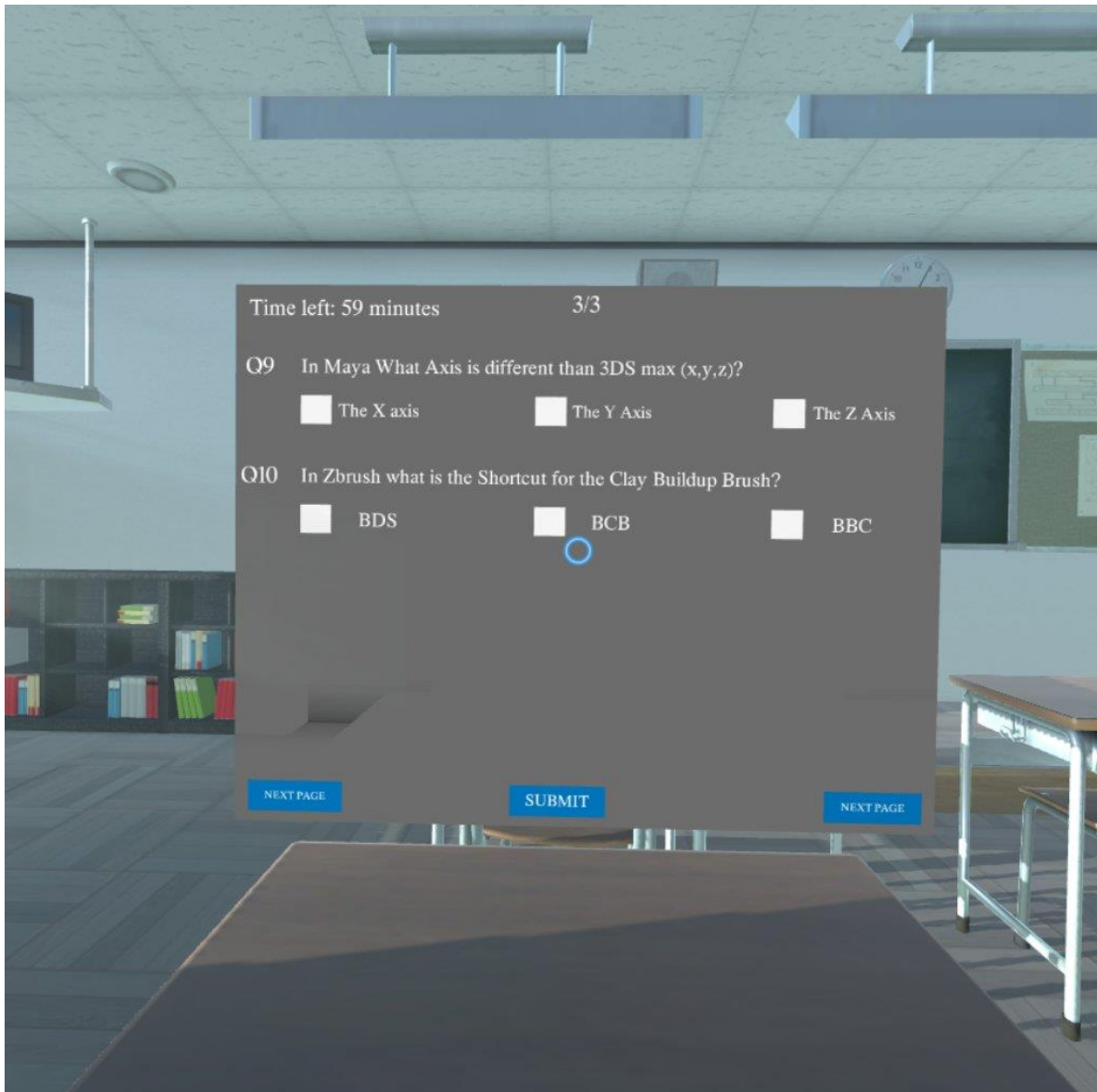


Figure 3.11. Page 3 of the exam



Figure 3.12. End of exam screenshot

3.3 Evaluation Study

This section presents a study that evaluated VR Exam with end-users. First, the participants' background information is presented, then the design and the results of the study.

3.3.1 Participants

A total of 32 students were recruited to conduct the study. Half of the students were friends enrolled at random universities in Lebanon and abroad. The other half were recruited through social media from university classes including Notre Dame University and others in Lebanon.

The background information of the students varies between gender, age groups, majors, and virtual reality use frequency. The ideal percentage that was sought for each gender is 50%. However, as seen in Figure 3.13, the numbers were 56% for Females and 44% for Males. The age groups for the participants are all quite young as analyzed from Figure 14 with ~22% of the participants vary between the ages 18-20 and ~66% between the ages 21-23.

The participants' majors varied between 10 majors (Figure 3.15), with Advertising and Marketing, Medicine, and Computer Science the most chosen majors. Luckily, it was beneficial to have Computer Science as the most chosen major, as Computer Science students can give out technical and detailed opinions around the technology.

Lastly, out of 32 students, 62% have used virtual reality whereas 38% have never used it before (Figure 3.16). As of the use frequency, 50% of the students never use virtual reality, 44% sometimes do use it, and only 6% of them frequently use it (Figure 3.17).

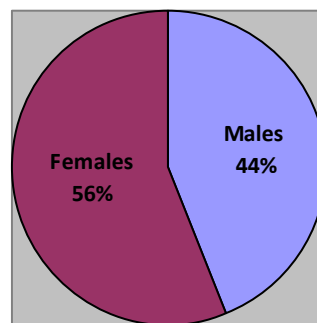


Figure 3.13. Gender of the participants

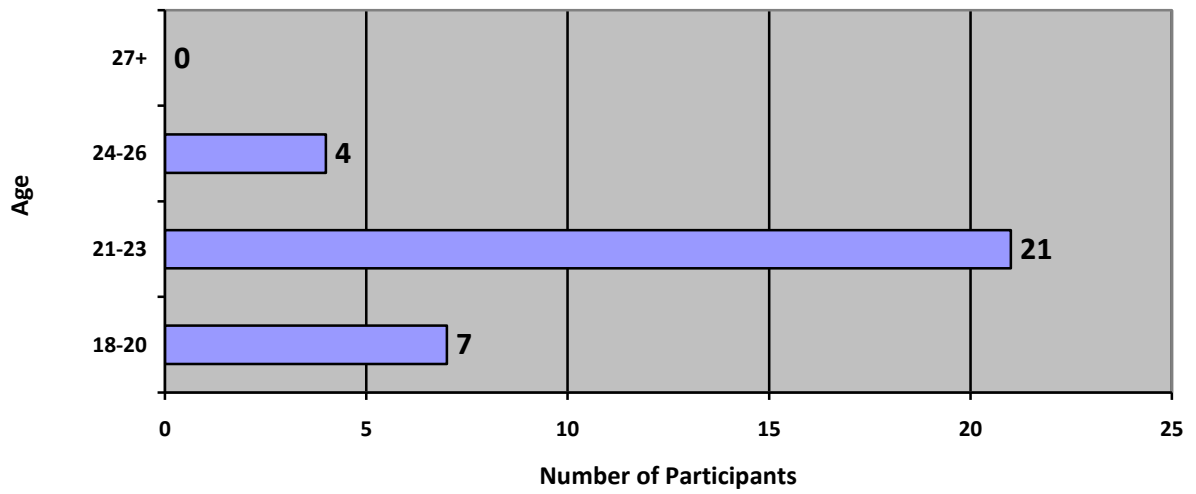


Figure 3.14. Age groups of the participants

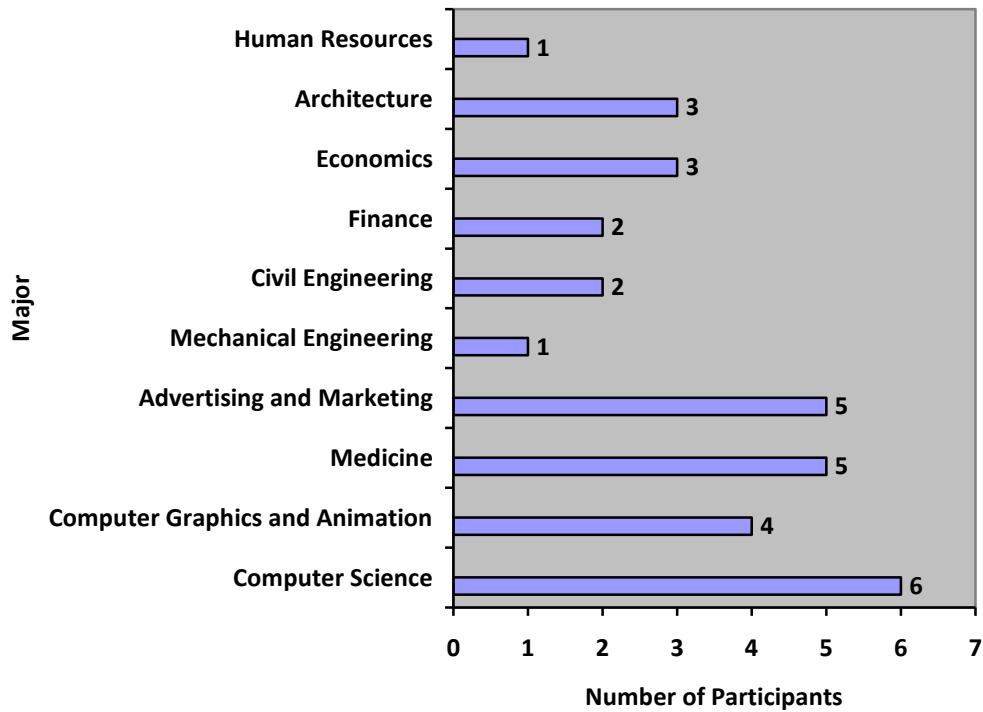


Figure 3.15. Majors of the participants

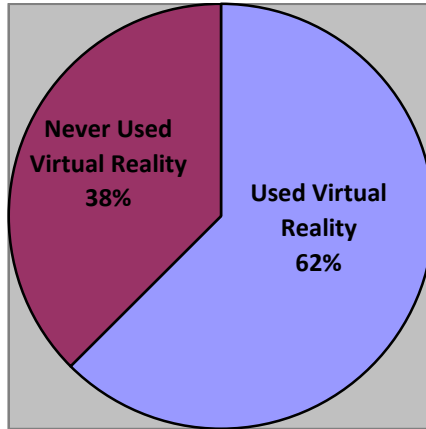


Figure 3.16. Virtual reality experience of the participants

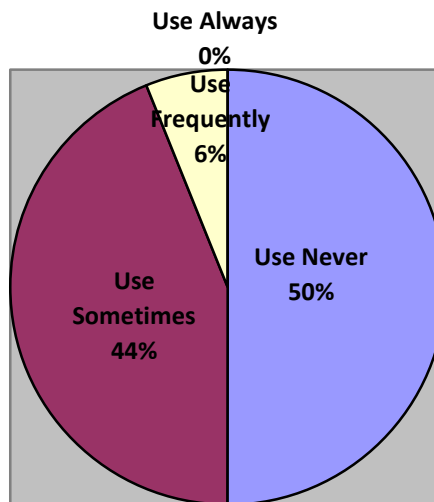


Figure 3.17. Virtual reality frequency of use of the participants

3.3.2 Design

The duration of the VR exam was set to be an average of 20 minutes for each participant to give enough time to answer some background information, conduct a VR exam, and provide feedback.

Initial design: The steps involved in the VR experience start with downloading the application on the phone. However, for testing purposes, a phone was prepared to be presented to the participants already containing the application. The participants then initiate the application and plug the phone into the VR headset. Then, they are prompted to enter their NDU id through pointing and clicking on VR keyboard keys and pressing the start button. Finally, the participants can choose their answers and switch to the next pages until they reach the end. Pressing the submit exam button will then submit their answers along with their NDU id to be checked, calculated, and inserted into the database.

The abovementioned design was initially intended for this study. However, due to the Coronavirus outbreak and the lockdown, students were sent a zipped file containing an introductory document, along with a video that showcases the whole VR Exam process. Finally, they were presented with a questionnaire containing all the feedback questions including those of the System Usability Scale (SUS) and Product Reaction Cards (PRCs). The System Usability Scale is a reliable tool for measuring usability. It consists of a 10 item questionnaire with five response options for respondents; from Strongly agree to Strongly disagree that allows the evaluation of products and services, including hardware, software, mobile devices, websites and applications (Brooke, 1996). Product Reaction Cards are descriptive words or phrases chosen from a large set of reaction cards that are used as a testing interface to understand the type and severity of emotional reactions throughout the interaction with a product. It is used to understand the emotions and behaviors of users (Benedek & Miner, 2002).

The feedback questions presented in the questionnaire are as follows:

Qualitative:

1. What is your first impression of this new method of doing an exam?
2. Would you prefer to do your multiple-choice exam on a piece of paper or using VR Exam? Why?
3. Did you find navigation (or process) simple or hard? If hard, please explain.
4. Do you think VR Exam offers advantages over paper-based exams? If yes, what are these advantages?
5. Do you think you would face any concerns when doing the exam? If yes, what are they?

Quantitative (on a scale from 1 to 5, where 5 is the best):

1. How much seclusion and involvement would you feel in the experiment?
2. How much would you be able to focus on the exam?
3. How confident do you feel about this new technology in terms of security, usability, and system robustness?
4. How stressed do you think you would be during the exam with this technology?
5. Will you be willing to use this technology in your exams?

As previously mentioned, the SUS questionnaire is also presented to the participants. The SUS questionnaire can be found in Appendix G. The participants were also presented with 12 negative product reaction cards (sophisticated, stressful, distracting, annoying, confusing, slow, not secure, not valuable, unconventional, unattractive, unpredictable, overwhelming) and 12 positive ones (creative, easy to use, time-saving, motivating, fun, secure, advanced, exciting, entertaining, attractive, professional, innovative). They were

asked to choose three cards that are either positive, negative, or a mixture of both. Additional comments were gathered based on their selection of the cards and were then analyzed.

3.3.3 Results

The qualitative results point out great aspects of this technology both in improving efficiency and reducing complexity. The general impression of the students was mixed; those who found it innovative and helpful, those who would still prefer pen and paper due to some complexities, and those who saw this technology as a doorway to many improvements to exams and education. For instance, a student commented *“It has major advantages, especially when it comes to certain courses that no longer need pen and paper as an exam medium. The VR exam experience can tackle many solutions to regular exams (less cheating, more visual base questions, and interaction)”*, while another said *“Out of my comfort zone. It added more stress than what an exam already does. It rose a series of challenges of not being fully in control of what is in front of me.”*, and another student implied *“Really innovative, it’s fascinating to see the integration of technology in studies and for educational purposes”*.

The students’ preferability on whether to conduct their exams in VR or on a piece of paper was almost equally divided with 45% choosing pen and paper and 55% choosing VR. *“I prefer to do a multiple-choice exam on VR device because it lets the student manage his time and attention, reduce the usage of cumbersome material (pen, eraser, lot of papers) and make stressful situations and tasks easier like exams “, “I would prefer it to be on a paper; I focus more on paper.”, “I prefer using VR exam if the multiple-choice questions (MCQ) and straight forward and doesn’t require any analysis to be written. But if the MCQ needs*

something to be written down to help with the question then the paper will be better". The main concern for students is that VR may not be a practical way to conduct exams that include critical thinking and writing down notes. However, students stated that any exam that is focused on being only in a Multiple Choice format, then VR would be the platform to go with, given how easy to use it is and requires fewer materials to carry such as pens and others.

Regarding advantages and concerns, a small number of students thought that VR does not offer any advantages over pen and paper exams, whereas others saw great advantages as well as great concerns. Some of the advantages listed by the students were that VR is eco-friendly, cheat-free, helps in concentration, and adds engagement. For example, a student said *"it definitely helps the student concentrate more and avoid any distraction, and secondly there won't be any possibility of cheating."*, and another said *"Since it uses the cellphone and the cellphone is always with the student then it will save the students and the teachers some weight if there are VR ready rooms within the university"*, and another implied *"VR exam offers advantages over paper-based exams because using this method reduces distractions and stress, maintain attentional span, stimulate executive brain process, eliminate handwriting difficulties."* Given that the majority of the students had seen great advantages with VR, they also pointed out some concerns: *"The biggest concern would have to be motion sickness, some people are not used to Virtual reality and might face some discomfort while doing the exam especially if it's an hour long"*, *"The concern of writing something down is impossible without a keyboard or a paper. If we can implement a keyboard to work with the VR then we would benefit from adding more variety of question types to the exam and it has potential to become used in every exam type even*

written exams”, “One of the concerns is to face any technical issue with the VR while doing the exam.

For example, VR not turning on, batteries dying quickly, system error, error reading data, error submitting data, connection problems, keeping the VR up-to-date...”. The rest of the concerns were all related to the comments stated below; motion sickness, inability to write things down, and errors, or connection problems.

The quantitative results are analyzed in the following charts:

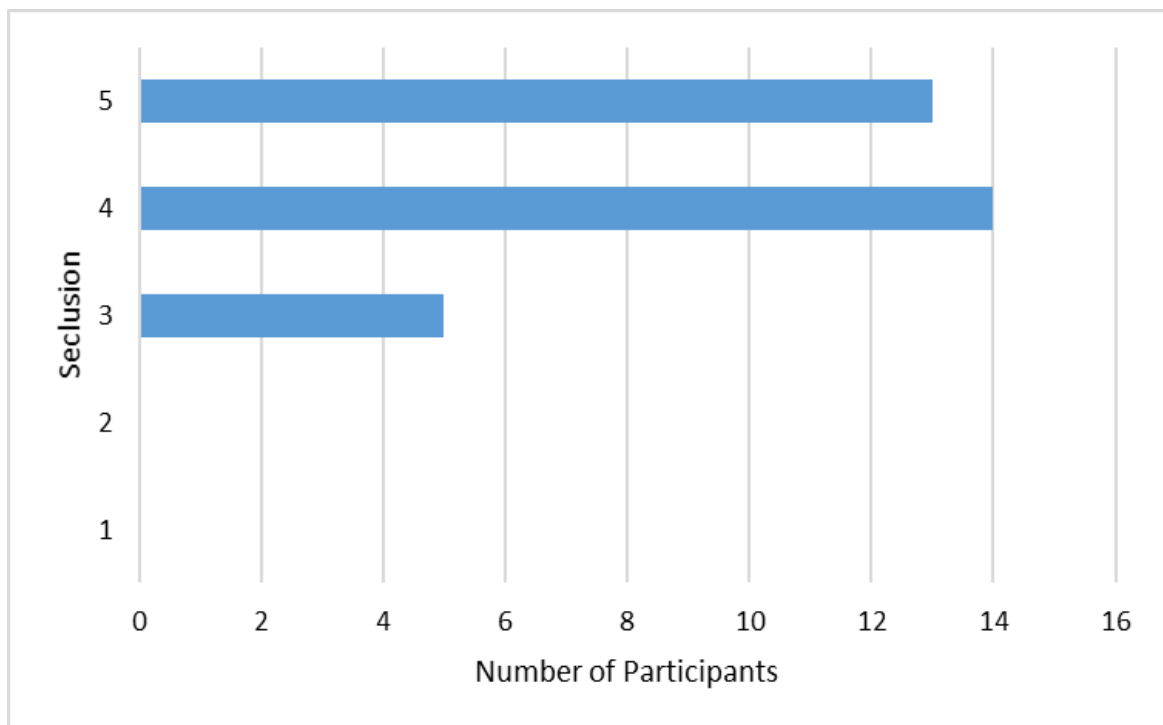


Figure 3.18. Participants seclusion range chart

Based on the seclusion chart (Figure 3.18), the median and the mean are 3. With a total of 32 students, the results show that 27 students are above the median which proves that 84.3% of them are above the average. This indicates that the students would feel secluded.

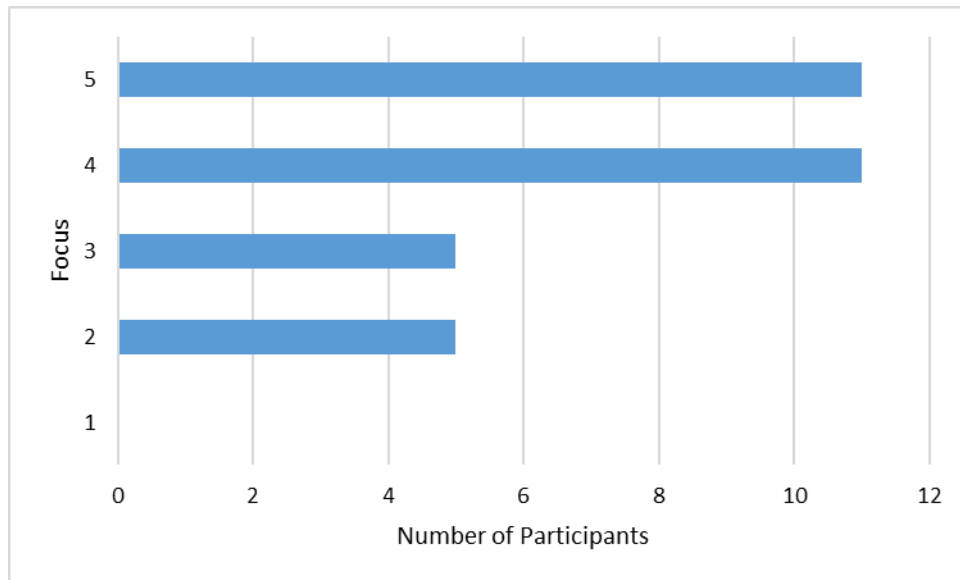


Figure 3.19. Participants focus range chart

Based on the focus chart (Figure 3.19), the median and the mean are 3. With a total of 32 students, the results show that 22 students are above the median which proves that 65.75% of them are above the average. This shows that the percentage tends to be higher than 50% which indicates that the students would feel focused.

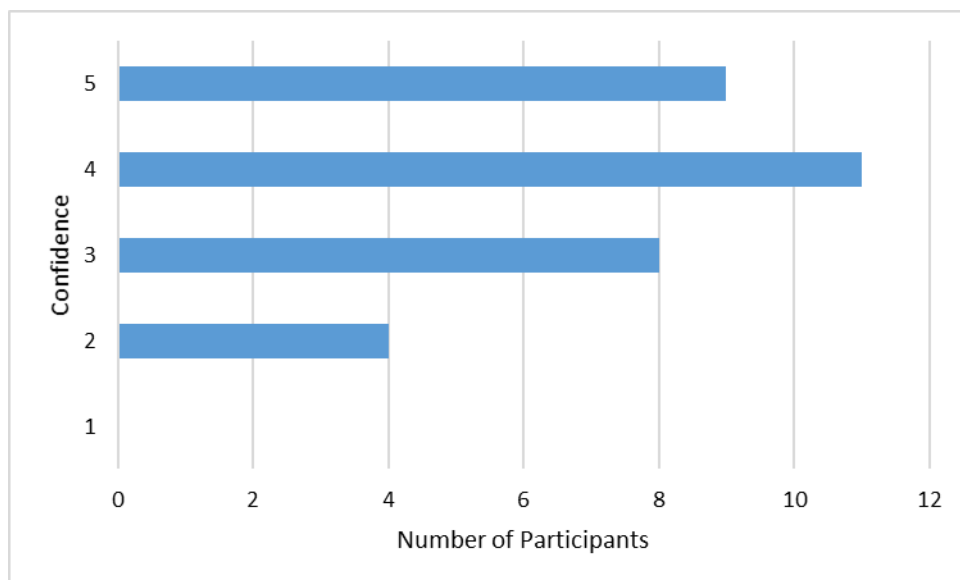


Figure 3.20. Participants confidence range chart

Based on the confidence chart (Figure 3.20), the median and the mean are 3. With a total of 32 students, the results show that 20 students are above the median and 12 students are at and below the median. This shows that 62.5% are above average which indicates that more than half of them would feel confident about the process.

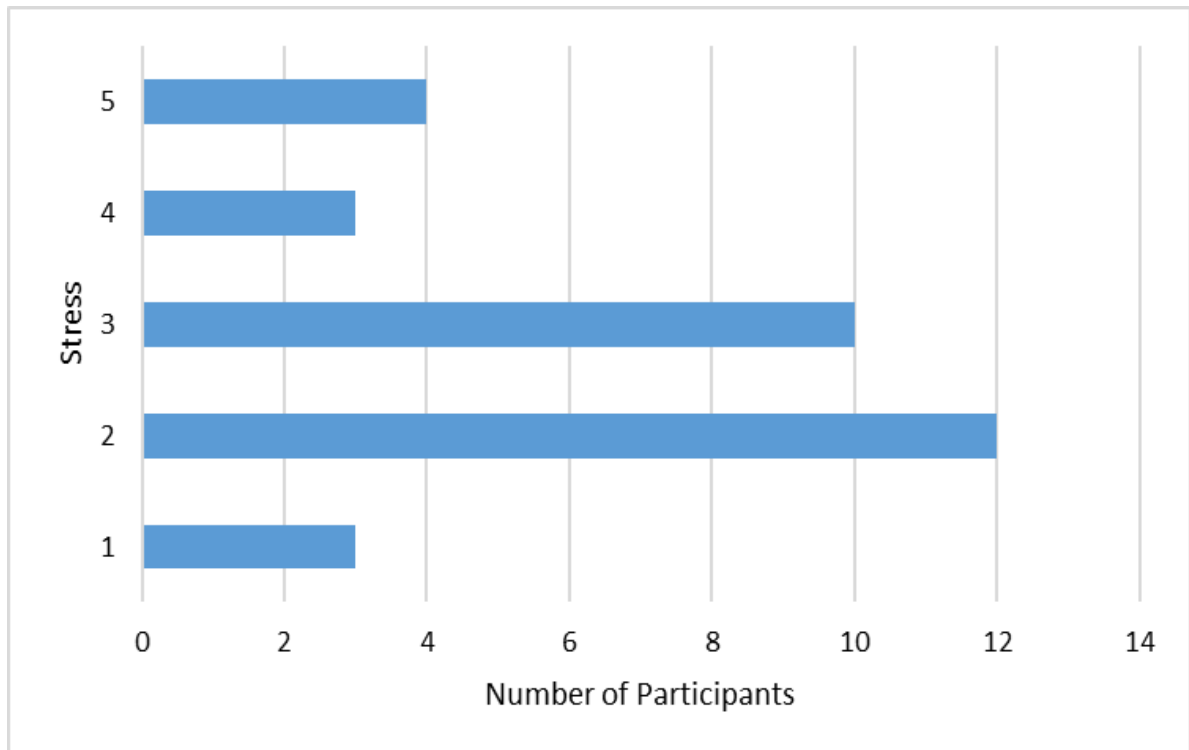


Figure 3.21. Participants stress range chart

Based on the stress chart (Figure 3.21), the median and the mean are 3. With a total of 32 students, the results show that 17 students are above the median which means that 53% of them are above the average. This shows that the result tends to be negative with more than 50% of the students would feel quite stressed during the exam.

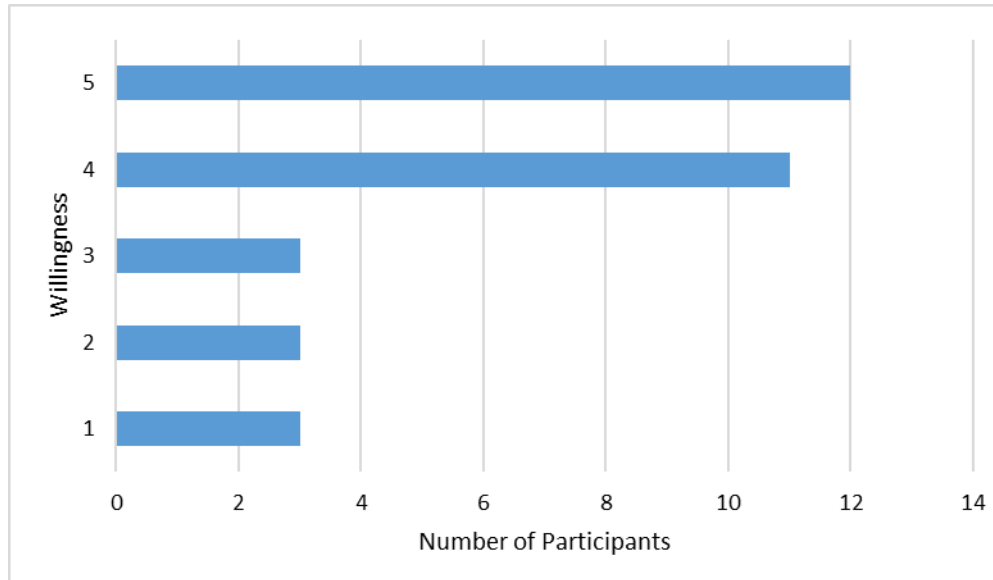


Figure 3.22. Participants' willingness to use VR Exam

Based on the willingness chart (Figure 3.22), the median and the mean are 3. With a total of 32 students, the results show that 23 students are above the median which means that 71.8% of them are above the average. This shows that the percentage tends to be higher than 50% which indicates that the students would be willing to use this tool as a method of conducting an exam.

Table 3.2. Percentages of quantitative results

	% of students
Seclusion	84.3%
Focus	68.75%
Confidence	62.5%
Stress	46.8%
Willing	72%

The percentages in Table 3.2 show that participants felt secluded with the experience, were able to focus better, felt confident about the system, and are willing to use this system as a tool to conduct their multiple-choice exams. However, participants did quite feel stressed

with this technology with 46.8% of them thought that it adds stress more than it relieves. This behavior is predicted to be normal as this new technology is trying to replace pen and paper exams which they are familiar with since forever.

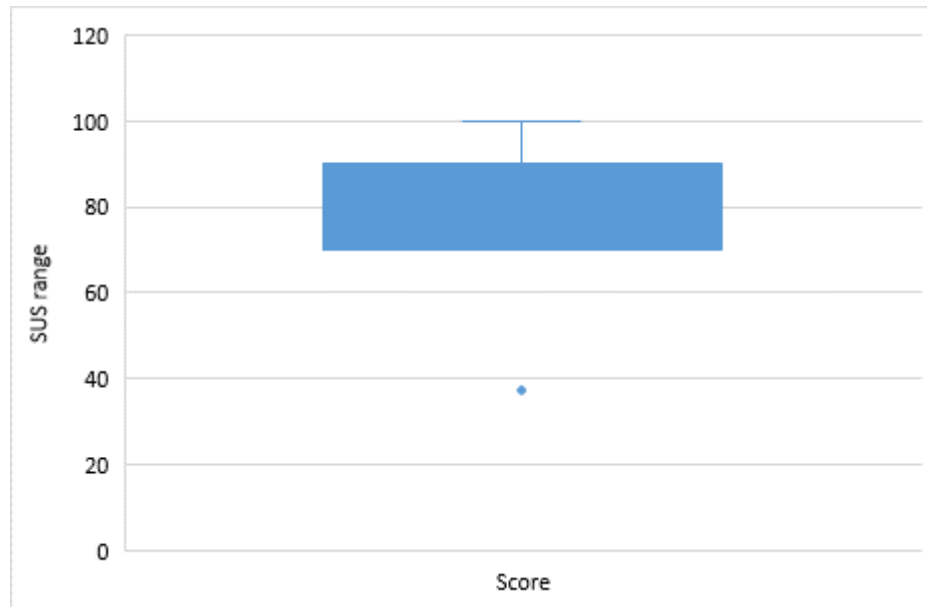


Figure 3.23. System Usability Scale participant scores

The SUS questions and can be found in Appendix H. The system usability scale results are presented in Figure 3.23, which shows the calculation of the minimum, quartile 1, median, quartile 3, and the maximum of the SUS whiskers box plot. The result shows that the box ranges between Q1 (70) and Q3 (90), with a whisker up to the maximum and an outlier at the value of 37.5. The SUS scoring system requires a result of 70+ to be considered good. A result of 80+ is excellent and 90+ is considered as best imaginable. Since the box range is between the values 70 and 90, with a mean of 78.2, this indicates that the results of the SUS score is considered good and the system is then valid.

The product reaction cards results are listed in the figures below:

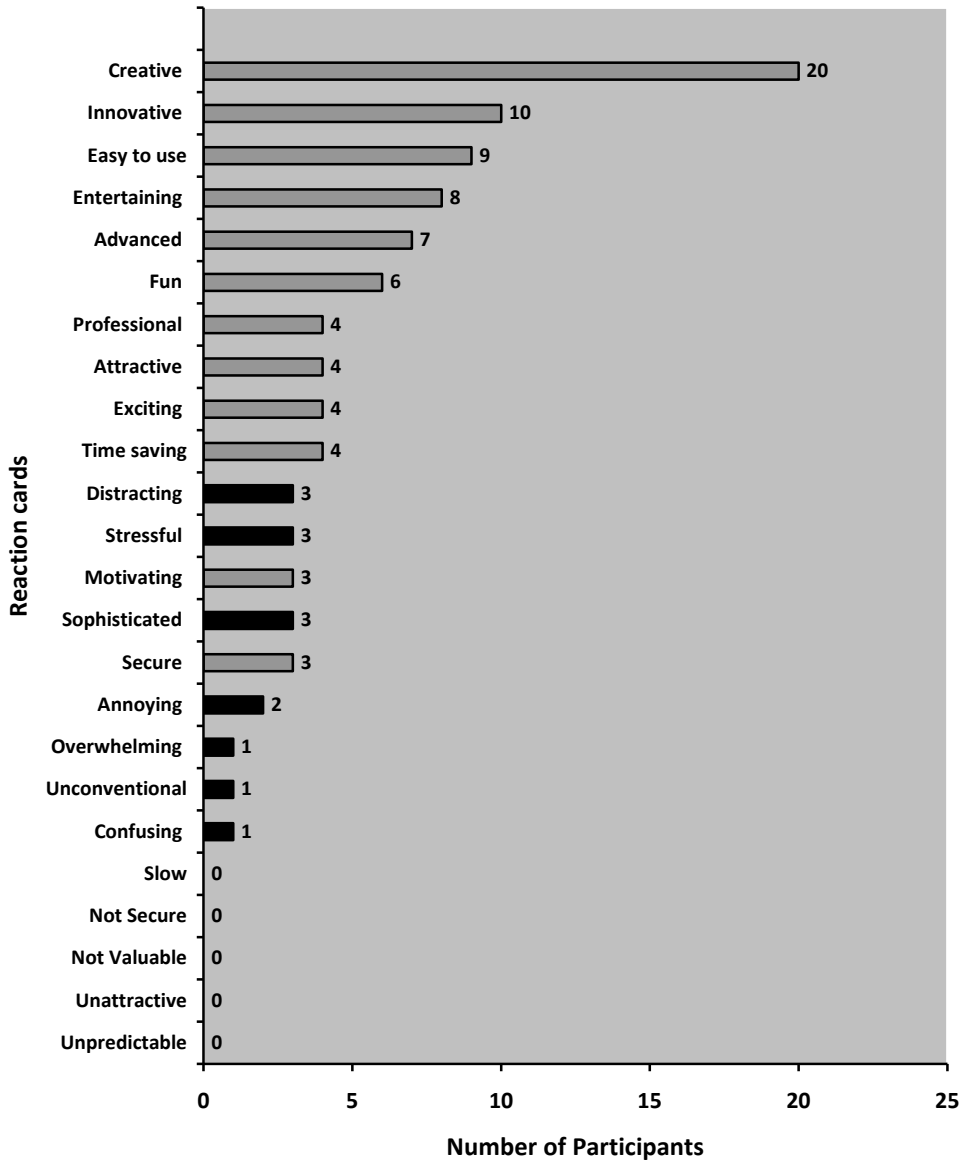


Figure 3.24. Product reaction cards selected by the participants

The product reaction cards in Figure 3.24 show that there are 82 positive cards and 14 negative cards chosen. The most widely chosen cards are Easy to use, Innovative and Creative. The creative card was chosen by 62.5% of the students which indicates that the system uses an original idea to create something new. The innovative and easy to use cards were chosen by 10 and 9 participants respectively. This shows that the system is quite clear

and easy for beginners to adapt to. Overall, 85.42% of the cards chosen were positive and only 14.58% were negative which proves the consent of the participants regarding this new method of conducting an exam.

3.4 Results Based on Participants' Background

The results based on the participants' backgrounds did quite differ based on their majors and ages. However, there was no significant difference based on their genders. Participants who are studying Computer Science and Computer Graphics and Animation gave much more insightful information regarding the new tool. Ideas for improvement and suggestions were mentioned by these participants due to the knowledge they have from their majors. On the other hand, participants of other majors did also mention suggestions but lacked detailed technical terms, which are very helpful to know exactly how to move forward or what could be missing from this tool. For example, when asked "Do you think you would face any concerns when doing the exam? If yes, what are they?" a participant studying Mechanical Engineering replied "No, unless the MCQ need critical thinking", while another participant from a Computer Graphics and Animation major replied "The biggest concern would have to be motion sickness, some people are not used to Virtual reality and might face some discomfort while doing the exam especially if it is one hour long". This insightful comment from the Computer Graphics and Animation participant helps in keeping an eye on motion sickness to keep the process as light and smooth as it can be for all students. Such comments show that some participants are more involved and knowledgeable in VR technology more than others, which makes the results different.

The results were also different based on age. The participants from the age group 18-20 gave good but very broad and general comments towards this new tool, such as “Cool” or “Very innovative”. However, participants from age groups 21-23 and 24-26 were the most involved and delicate to the comments they gave, mentioning suggestions, improvements, and advantages and disadvantages of this technology.

3.5 Threats to validity

The study was primarily set to be conducted in the Notre Dame University campus with an actual VR headset and a mobile phone handed to the participants. However, due to the coronavirus outbreak and the lockdown, a video was sent out with questionnaires to fill. This method poses a threat to the study as participants are not testing out this new technology physically, but are watching a video recorded in the VR headset. This method hinders the outcome of their answers as they are not experiencing how this new tool performs in hand. The general idea of the participants regarding this tool could be the same regardless if they are testing it or watching a video about it, but their opinions and answers could be more accurate and elaborate if they were experiencing it themselves. Nonetheless, it is possible to say that the study conducted in this thesis provided insights into the participants’ perceptions of virtual reality as a mechanism for disseminating exams. In the future, it is possible to conduct a lab-based study where the participants can interact with VR Exam by using a physical VR headset. The results of that study would complement the outcome of this thesis.

Chapter 4: Conclusion and Future Work

This chapter summarizes the main contributions of this thesis. It also points out possible extensions and future work that could be built upon or integrated into the proposed virtual reality examination system.

4.1 Main Contributions

This thesis presented a virtual reality examination tool (VR Exam) for schools or universities. This tool aims to eliminate distractions and reduce stress towards exams as well as improve students' focus and performance. It focuses on multiple-choice exams and requires a virtual reality headset and a mobile phone. The process requires a virtual reality headset and a mobile phone as well as the VR Exam application installed on it. It starts with opening the application and plugging the mobile phone into the headset, in the examination room of the university or school. The student then mounts the headset on his head and is presented with a screen to input his ID. Afterward, a series of multiple-choice questions appear where the student must aim and click on the answers until finally the answers are submitted. The answers are then automatically graded and inserted in the database which can be retrieved and shared by the professor or the teacher.

VR Exam aims to reduce shortcomings such as paper waste and cheating, which are present in exam formats such as paper-based and online exams. In comparison to paper-based exams, VR exam reduces paper waste due to its digital format. It can also benefit from the

seclusion that the VR headset provides to reduce cheating and the distraction created by fellow examinees (e.g., noise from papers, keyboard, and mouse). It is worth mentioning that virtual reality is the only method that offers total seclusion during an exam that is taken in the presence of other examinees. Based on the study with participants, it was indicated that this method of conducting an exam increases students' focus and eliminated distractions, offers seclusion, and contributes to better performance and results. However, this method did not decrease the stress levels of the students as the results showed that almost half of the participants felt more stressed when using this new technology. The shift from pen and paper to virtual reality does bring stress as students are not yet familiar with the technology nor with its navigation during an exam. It is believed that with practice and workshop sessions about this technology, students will be able to perceive this tool as a means to reduce their stress instead of increasing it. Plus, the negative results of the product reaction cards seem to be minimal in comparison with the positive cards that were chosen. Additionally, 84.3% of the students felt secluded, 68.75% felt focused and 62.5% felt confident which brings us to believe that when students become more familiar with this technology, it will relieve stress rather than increasing it. Moreover, the system usability scale results prove the system to be valid with a score of 78% percentile rank or a grade of B, which also means that the system was found to be easy to use, easy to learn, not complex, consistent, robust and most importantly a willingness to use it more frequently.

4.2 Possible Extensions and Future Work

It is possible to develop several extensions for VR Exam in the future. The need for typing or drawing inside the VR experience can shift VR Exam from being only related to

multiple-choice exam formats to becoming a fully-fledged exam with no limitations. The ability to type inside the VR or to draw gives users the freedom to answer written questions. It also allows users to sketch drawings or calculations on the side as it is usually done on pen and paper.

Another possible extension of this system could be to support remote exams. However, this could create a limitation concerning the ability to monitor and restrict cheating. However, if there was a way to prevent students from cheating whilst being at home or anywhere else, then this system could provide an innovative and helpful improvement on the way exams are conducted.

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Appendix A: Django Models

A model is the single, definitive source of information that contains the essential fields and behaviors of the data. Generally, each model maps to a single database table. Each model is a Python class that subclasses `django.db.models.Model`. Each attribute of the model represents a database field. In our case, the database tables are Student, Exam, Question, Answer, ExamDetails and StudentAnswer.

```
from django.db import models
from django.contrib.auth.models import AbstractBaseUser
from django.contrib.auth.models import PermissionsMixin
from django.contrib.auth.models import BaseUserManager

#CREATE YOUR MODELS HERE
class Student(models.Model):

    ndu_id = models.CharField(unique=True, max_length=255)

    class Meta:
        managed = False
        db_table = 'student'

class Exam(models.Model):

    name = models.CharField(unique=True, max_length=255)
    date = models.DateTimeField(blank=True, null=True)

    class Meta:
        managed = False
        db_table = 'exam'

class Question(models.Model):

    question_str = models.CharField(unique=True, max_length=255)
    points = models.DecimalField(max_digits=5, decimal_places=1)

    class Meta:
        managed = False
        db_table = 'question'
```

Figure A.1. Django models script

```
class Answer(models.Model):

    question = models.ForeignKey('Question', models.DO_NOTHING, blank=True, null=True)
    answer_str = models.CharField(unique=True, max_length=255)
    correct = models.IntegerField(blank=True, null=True)

    class Meta:
        managed = False
        db_table = 'answer'

class ExamDetails(models.Model):

    exam = models.ForeignKey('Exam', models.DO_NOTHING, blank=True, null=True)
    question = models.ForeignKey('Question', models.DO_NOTHING, blank=True, null=True)

    class Meta:
        managed = False
        db_table = 'exam_details'

class StudentAnswer(models.Model):

    student_exam = models.ForeignKey('StudentExam', models.DO_NOTHING, blank=True, null=True)
    answer = models.ForeignKey('Answer', models.DO_NOTHING, blank=True, null=True)
    question = models.ForeignKey('Question', models.DO_NOTHING, blank=True, null=True)

    class Meta:
        managed = False
        db_table = 'student_answer'

class StudentExam(models.Model):

    student = models.ForeignKey('Student', models.DO_NOTHING, blank=True, null=True)
    exam = models.ForeignKey('Exam', models.DO_NOTHING, blank=True, null=True)
    grade = models.IntegerField(blank=True, null=True)

    class Meta:
        managed = False
        db_table = 'student_exam'
```

Figure A.2. Django models script

Appendix B: Django ViewSets

ViewSets are the controllers of the model view controller architecture. They provide default sets of behaviors such as create/retrieve/update/destroy actions. Moreover, ViewSets allows overriding any action should the system behave differently than the default one. It is responsible for retrieving query data, manipulating it, and returning it to the view via what is called a serializer.

```
from rest_framework import filters
from rest_framework.authenticators import BaseAuthentication
from rest_framework.authtoken.serializers import AuthTokenSerializer
from rest_framework.authtoken.views import ObtainAuthToken
from rest_framework.permissions import IsAuthenticatedOrReadOnly
from rest_framework.permissions import IsAuthenticated

from . import serializers
from . import models
from . import permissions

# Create your views here.
class StudentViewSet(viewsets.ModelViewSet):
    """Handles creating, reading and updating profiles"""
    serializer_class = serializers.StudentSerializer
    queryset = models.Student.objects.all()
    authentication_classes = ()
    permission_classes = ()
    filter_backends = (filters.SearchFilter,)
    search_fields = ('ndu_id',)

class ExamViewSet(viewsets.ModelViewSet):
    """Handles creating, reading and updating profiles"""
    serializer_class = serializers.ExamSerializer
    queryset = models.Exam.objects.all()
    authentication_classes = ()
    permission_classes = ()
    filter_backends = (filters.SearchFilter,)
    search_fields = ('name', 'date',)

class QuestionViewSet(viewsets.ModelViewSet):
    """Handles creating, reading and updating profiles"""
    serializer_class = serializers.QuestionSerializer
    queryset = models.Question.objects.all()
    authentication_classes = ()
    permission_classes = ()
    filter_backends = (filters.SearchFilter,)
    search_fields = ('question_str', 'points',)
```

Figure B.1. Django ViewSets script

```

class AnswerViewSet(viewsets.ModelViewSet):
    """Handles creating, reading and updating profiles"""
    serializer_class = serializers.AnswerSerializer
    queryset = models.Answer.objects.all()
    authentication_classes = ()
    permission_classes = ()
    filter_backends = (filters.SearchFilter,)
    search_fields = ('question_id', 'answer_str', 'correct',)

class ExamDetailsViewSet(viewsets.ModelViewSet):
    """Handles creating, reading and updating profiles"""
    serializer_class = serializers.ExamDetailsSerializer
    queryset = models.ExamDetails.objects.all()
    authentication_classes = ()
    permission_classes = ()
    filter_backends = (filters.SearchFilter,)
    search_fields = ('exam_id', 'question_id',)

class StudentAnswerViewSet(viewsets.ModelViewSet):
    """Handles creating, reading and updating profiles"""
    serializer_class = serializers.StudentAnswerSerializer
    queryset = models.StudentAnswer.objects.all()
    authentication_classes = ()
    permission_classes = ()
    filter_backends = (filters.SearchFilter,)
    search_fields = ('student_exam_id', 'question_id', 'answer_id')

class StudentExamViewSet(viewsets.ModelViewSet):
    """Handles creating, reading and updating profiles"""
    serializer_class = serializers.StudentExamSerializer
    queryset = models.StudentExam.objects.all()
    authentication_classes = ()
    permission_classes = ()
    filter_backends = (filters.SearchFilter,)
    search_fields = ('student_id', 'exam_id', 'grade')

```

Figure B.2. Django ViewSets script

```

class ExamViewSet(viewsets.ModelViewSet):
    """Handles creating, reading and updating profiles"""
    serializer_class = serializers.ExamSerializer
    queryset = models.Exam.objects.all()
    authentication_classes = ()
    permission_classes = ()
    filter_backends = (filters.SearchFilter,)
    search_fields = ('id', 'name', 'date')

    def list(self, request):
        if request.method == 'GET':
            exam_id = request.GET.get('exam_id')
            exam_details = models.ExamDetails.objects.filter(exam_id=exam_id).values()

            response_list = []

            for i in range(0, len(exam_details)):
                exam = {}
                exam["exam_id"] = exam_details[i]['exam_id']
                exam["question_id"] = exam_details[i]['question_id']
                exam["question_info"] = models.Question.objects.filter(id=exam_details[i]['question_id']).values()
                exam["answers"] = models.Answer.objects.filter(question=exam_details[i]['question_id']).values()
                response_list.append(exam)

            return Response({"exam": response_list})

```

Figure B.3. Django ExamViewSet script

Appendix C: Django Serializers

Serializers allow complex data such as queriesets and model instances to be converted to native Python datatypes that can then be rendered into JSON or XML formats, or other content types. Serializers also provide deserialization, allowing parsed data to be converted back into complex types, after first validating the incoming data. In the images below, each serializer is mapped to the respective model to determine which field should or should not be converted and rendered based on the content type chosen.

```
from rest_framework import serializers
from . import models

class StudentSerializer(serializers.ModelSerializer):
    """A serializer for our ProfileFeedItem objects/items."""
    class Meta:
        model = models.Student
        fields = ('id', 'ndu_id')

class ExamSerializer(serializers.ModelSerializer):
    """A serializer for our ProfileFeedItem objects/items."""
    class Meta:
        model = models.Exam
        fields = ('id', 'name', 'date')

class QuestionSerializer(serializers.ModelSerializer):
    """A serializer for our ProfileFeedItem objects/items."""
    class Meta:
        model = models.Question
        fields = ('id', 'question_str', 'points')

class AnswerSerializer(serializers.ModelSerializer):
    """A serializer for our ProfileFeedItem objects/items."""
    class Meta:
        model = models.Answer
        fields = ('id', 'question_id', 'answer_str', 'correct')

class ExamDetailsSerializer(serializers.ModelSerializer):
    """A serializer for our ProfileFeedItem objects/items."""
    class Meta:
        model = models.ExamDetails
        fields = ('id', 'exam_id', 'question_id')

class StudentAnswerSerializer(serializers.ModelSerializer):
    """A serializer for our ProfileFeedItem objects/items."""
    class Meta:
        model = models.StudentAnswer
        fields = ('id', 'student_exam_id', 'question_id', 'answer_id')

class StudentExamSerializer(serializers.ModelSerializer):
    """A serializer for our ProfileFeedItem objects/items."""
    class Meta:
        model = models.StudentExam
        fields = ('id', 'student_id', 'exam_id', 'grade')
```

Figure C.1. Django Serializers script

Appendix D: Manager Class

The Manager class is the main class responsible for the most important and data-driven behaviors of the application. The FillQuestions function is responsible for filling the questions and answers UI with the data retrieved from the database. The PostExam function is responsible for sending all the answers or data filled back to the server to insert it into the database. The manager class is also responsible for starting the exam timer as well as restarting the scene or the exam.

```

public class Manager : MonoBehaviour
{
    void FillQuestions(JsonData itemData)
    {
        int question_nمبر = 1;

        // Set exam title text
        ExamTitleText.text = "Exam: " + itemData["exam_title"][0]["title"].ToString();

        // Set exam timer text
        ExamTimerText.text = "You have " + itemData["exam_timer"][0]["timer"].ToString() + " minutes";

        // Set the timer
        timer = int.Parse(itemData["exam_timer"][0]["timer"].ToString()) * 60; // in seconds

        for (int i = 0; i < itemData["exam"].Count; i++)
        {
            // Set exam id
            exam_id = int.Parse(itemData["exam"][i]["exam_id"].ToString());

            if (Panels[CurrentPage].transform.childCount == 4)
            {
                CurrentPage++;
            }

            // instantiate question prefab and reparent it
            GameObject question = Instantiate(QuestionPrefab, Panels[CurrentPage].transform) as GameObject;
            QuestionPrefab _question = question.GetComponent<QuestionPrefab>();
            _question.Question_str.text = itemData["exam"][i]["question_info"][0]["question_str"].ToString();
            _question.points = double.Parse(itemData["exam"][i]["question_info"][0]["points"].ToString());
            _question.Question_nمبر.text = "Q" + question_nمبر.ToString();
            _question.Question_id = question_nمبر;
            question_nمبر++;

            // Set answers
            _question.Answer1_text.text = itemData["exam"][i]["answers"][0]["answer_str"].ToString();
            _question.Answer2_text.text = itemData["exam"][i]["answers"][1]["answer_str"].ToString();
            _question.Answer3_text.text = itemData["exam"][i]["answers"][2]["answer_str"].ToString();

            // Set correct answer
            _question.Answer1.correct = int.Parse(itemData["exam"][i]["answers"][0]["correct"].ToString());
            _question.Answer2.correct = int.Parse(itemData["exam"][i]["answers"][1]["correct"].ToString());
            _question.Answer3.correct = int.Parse(itemData["exam"][i]["answers"][2]["correct"].ToString());

            // Set ids
            _question.Answer1.id = int.Parse(itemData["exam"][i]["answers"][0]["id"].ToString());
            _question.Answer2.id = int.Parse(itemData["exam"][i]["answers"][1]["id"].ToString());
            _question.Answer3.id = int.Parse(itemData["exam"][i]["answers"][2]["id"].ToString());
        }

        // Reset current page to 0
        CurrentPage = 0;
        DisableAllPanels();
        Panels[CurrentPage].SetActive(true);
    }
}

```

Figure D.1. Manager class functions

```
// Get request to get questions of specific exam
IEnumerator GetExamDetails(int exam_id)
{
    UnityWebRequest www = UnityWebRequest.Get(server_url);
    yield return www.SendWebRequest();

    if (www.isNetworkError || www.isHttpError)
    {
        Debug.Log(www.error);
    }
    else
    {
        //json_result = "{\"questions\": " + www.downloadHandler.text + "}";
        json_result = www.downloadHandler.text;
        itemData = JsonSerializer.ToObject(json_result);
        FillQuestions(itemData);
    }
}

// Exam timer coroutine, reducing time to 0
IEnumerator ExamTimer()
{
    while(true)
    {
        yield return new WaitForSeconds(1);
        timer--;
        ExamTimerHUDText.text = "Time left: " + (Mathf.Floor(timer / 60)) + " minutes";
        if(timer <= 0)
        {
            TimeUpUI.SetActive(true);
            break;
        }
        yield return null;
    }
    yield return null;
}

// Restart the scene
public void RestartScene()
{
    SceneManager.LoadScene("school_morning");
}
```

Figure D.2. Manager Class functions

Appendix E: Other Scripts

The keyboard script is responsible for rendering the numbers clicked in the VR to the input field text on the UI. The QuestionPrefab script is attached to every question object that is created or instantiated on the screen and is responsible for adding and setting which answers are correct based on the data retrieved from the Manager.

```
public class KeyboardScript : MonoBehaviour
{
    public InputField inputField;
    public string text;

    public void KeyboardClicked()
    {
        if(this.transform.tag == "Clear")
        {
            inputField.text = "";
            return;
        }

        inputField.text += text;
    }
}
```

Figure E.1. Keyboard script and functions

```
public class answer : MonoBehaviour
{
    public int correct = 0;
    public int id;
}
```

Figure E.2. Answer script


```
public class QuestionPrefab : MonoBehaviour
{
    public int Question_id;
    public Text Question_str;
    public Text Question_nmbr;
    public answer Answer1, Answer2, Answer3;
    public Text Answer1_text, Answer2_text, Answer3_text;
    public double points;
    public answer chosen_answer;
    public int answer_id;

    Manager manager;

    private void Start()
    {
        manager =
GameObject.Find("Manager").GetComponent<Manager>();
    }

    public void DisableOtherAnswers()
    {
        if(Answer1.GetComponent<Toggle>().isOn)
        {
            Answer2.GetComponent<Toggle>().isOn = false;
            Answer3.GetComponent<Toggle>().isOn = false;
        }
        if (Answer2.GetComponent<Toggle>().isOn)
        {
            Answer1.GetComponent<Toggle>().isOn = false;
            Answer3.GetComponent<Toggle>().isOn = false;
        }
        if (Answer3.GetComponent<Toggle>().isOn)
        {
            Answer2.GetComponent<Toggle>().isOn = false;
            Answer1.GetComponent<Toggle>().isOn = false;
        }
    }

    public void SetChosenAnswer(answer _answer)
    {
        this.chosen_answer = _answer;
    }

    public void AddAnswer()
    {
        manager.AddAnswer(this);
    }
}
```

Figure E.3. Question prefab class and functions

Appendix F: Answer Model

```
public class AnswerModel
{
    public int exam_id;
    public string student_id;
    public int question_id;
    public int answer_id;
    public int points;

    public string GetStudentExamId()
    {
        return student_id;
    }
    public void SetStudentExamId(string s_e_i)
    {
        this.student_id = s_e_i;
    }

    public int GetQuestionID()
    {
        return this.question_id;
    }
    public void SetQuestionID(int _question_id)
    {
        this.question_id = _question_id;
    }

    public int GetAnswerID()
    {
        return this.answer_id;
    }
    public void SetAnswerID(int _answer_id)
    {
        this.answer_id = _answer_id;
    }

    public int GetPoints()
    {
        return this.points;
    }

    public void SetPoints(int _points)
    {
        this.points = _points;
    }
}
```

Figure F.1. Answer model script

Appendix G: System Usability Scale

1. I think that I would like to use this system frequently
2. I found the system unnecessarily complex
3. I thought the system was easy to use
4. I think that I would need the support of a technical person to be able to use this system
5. I found the various functions in this system were well integrated
6. I thought there was too much inconsistency in this system
7. I would imagine that most people would learn to use this system very quickly
8. I found the system very cumbersome to use
9. I felt very confident using the system
10. I needed to learn a lot of things before I could get going with this system

Appendix H: System Usability Scale Results Table

Participants	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	SUS SCORE
P1	4	1	5	1	5	1	5	1	5	1	97.5
P2	3	2	3	1	4	2	4	2	4	2	72.5
P3	3	2	3	3	4	2	3	3	3	3	57.5
P4	4	2	4	5	5	1	5	1	4	2	77.5
P5	4	1	5	1	4	1	5	1	5	1	95.0
P6	3	1	5	1	5	1	5	1	5	1	95.0
P7	3	3	4	2	4	1	4	2	4	3	70.0
P8	5	1	5	1	5	1	5	1	5	5	90.0
P9	5	1	5	2	5	1	5	1	4	4	87.5
P10	5	1	5	1	5	1	4	1	5	2	95.0
P11	3	3	5	1	4	2	4	4	2	1	67.5
P12	3	3	2	2	3	2	3	4	3	2	52.5
P13	5	1	5	1	5	1	5	1	5	1	100.0
P14	4	1	5	1	5	1	3	1	4	1	90.0
P15	4	1	5	1	5	1	5	1	5	1	97.5
P16	4	3	4	1	4	1	4	2	5	2	80.0
P17	3	3	4	2	4	3	4	2	4	2	67.5
P18	1	3	5	1	5	2	5	1	3	1	77.5
P19	3	1	4	4	4	1	4	2	3	5	62.5
P20	5	1	5	3	4	1	5	1	5	3	87.5
P21	1	3	2	4	4	3	2	3	2	3	37.5
P22	3	2	3	5	3	2	1	2	3	3	47.5
P23	2	1	5	1	1	1	3	2	5	1	75.0
P24	2	1	3	1	1	1	4	2	5	2	70.0
P25	1	1	4	1	5	1	4	1	4	1	82.5
P26	5	1	4	1	4	1	5	2	5	1	92.5
P27	4	2	4	2	5	1	5	2	4	1	85.0
P28	3	1	5	2	4	2	4	2	4	1	80.0
P29	3	1	4	1	4	2	4	3	4	1	77.5
P30	4	4	4	2	4	1	5	2	4	2	75.0
P31	4	1	1	1	5	1	4	1	4	1	82.5
P32	4	2	4	2	5	1	4	2	3	2	77.5