UTILIZATION OF VIRTUAL REALITY FOR ENGINEERING DISCIPLINE SELECTION

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Abstract
Fully immersive Virtual Reality (VR) has the ability to take students to remote locations or allow them to interact with a simulated environment without having to leave campus. This study investigated whether VR is an effective tool to help students increase their knowledge and understanding of various engineering programs and as a result increase their confidence when selecting an engineering discipline. Two purpose-built VR applications were developed; one for Mining Engineering and one for Engineering Chemistry at Queen’s University. The intention of the VR applications was to introduce students to the program of study by bringing them directly into the classroom or lab environment as well industrial sites where engineers in that discipline work. Each VR application took 5-7 minutes to complete and was intended to be interactive. To determine if the VR applications increased the student knowledge, understanding and confidence when selecting an engineering discipline, a series of questions were added to the annual first year engineering survey at Queen’s. Results from the study showed that the VR applications strongly or moderately increased the knowledge and understand of numerous students who attend the Mining Engineering and Engineering Chemistry discipline selection nights. Furthermore there were a number of students whose confidence when making their discipline selection was enhanced by the VR applications.

Keywords: Virtual Reality, Active Learning, Discipline Selection, Mining Engineering, Engineering Chemistry

1. INTRODUCTION
The Faculty of Engineering and Applied Science (FEAS) at Queen’s University has a common first year program. Students are required to select their engineering discipline during the second semester of first year. The importance and career ramifications of this decision are significant and it is important that students have sufficient information about the program of study and future employment. The goal is for students to feel informed and confident when selecting their engineering discipline. Numerous studies have been conducted to examine the elements that influence discipline selection which include factors such as student interest, input from social connections (teachers, friends, family), and employment opportunities. [1-3] Engineering schools continue to investigate methods to support students with their decision. [4]. Meyers showed that using innovative pedagogical strategies, which incorporated active learning had positive effects for an orientation course designed to assist students with discipline section [5]. The idea that active or experiential learning enhances students’ knowledge and understanding of an engineering discipline and therefore improves their confidence when deciding on a program is the basis of this study.

Experiential learning has been recognized as a highly effective method which “immerses learners in an experience and then encourages reflection about the experience to develop new skills, new attitudes, or new ways of thinking” [6-7]. Virtual Reality (VR) has the ability to provide high fidelity immersive environments where individuals can interact with the simulated environment. This interaction with the VR environment provides a means of enhancing, motivating and stimulating learners’ understanding, especially in areas where traditional instructional techniques have proven ineffective. [8-9]

At Queen’s each engineering discipline holds an information night where they use presentations, guest speakers, tours and other demonstrations to provide the students with a sense of what each discipline has to offer. The information nights are a vital part of the selection process, however it is often difficult to provide students with an in-depth understanding of the area and environments where engineers work in the discipline. The VR applications (VR apps) that were developed in this study were designed to provide an interactive tool that would help augment the information provided at the discipline selection nights.

In order to determine if the VR apps increased the students’ knowledge and understanding of the various engineering discipline and increased their confidence when
selecting a disciplines, a set of questions were added to the annual first year survey. The surveys are conducted near the end of the winter semester after the first year engineering cohort has completed their discipline selection. The survey was conducted in 2018 prior to incorporating the VR apps and then in 2019 after the VR apps were utilized.

2. VIRTUAL REALITY APPLICATIONS

2.1. General Design

The VR experiences were intended to improve the knowledge and understanding of a specific engineering discipline. Given the ability to provide experiential learning opportunities in VR the applications were designed to include interactive elements. Mining Engineering and Engineering Chemistry (Eng Chem) were selected as the first two disciplines for the development of VR apps. These two disciplines were chosen since they are specialized programs, which often make it more difficult for students to fully understand the different focus areas and employment opportunities. The content for the VR experiences was provided by faculty experts in the fields of Mining and Eng Chem. An undergraduate summer researcher developed the design framework for the VR apps and the initial code in Unity. A senior VR developer from the Engineering Teaching and Learning Team completed the VR applications and enhanced the user interface.

2.2. Mining Engineering

The Mining Engineering VR app was designed to showcase the three fields of expertise within the program; mining, chemical processing and mine mechanical. Upon starting the mining VR app participants find themselves in the main foyer of the Robert M. Buchan Department of Mining at Queen’s where they have the choice to select three interactive vignettes.

To provide students with the experience of being in a mine, the first vignette transports students underground and has them drive a large Load Haul Dump (LHD). The LHD, illustrated in Figure 1, is driven through a mine shaft which was created from LiDAR point cloud data obtained from a working mine in northern Ontario. While the students drive the LHD using their VR hand controllers they are directed by the narrator to look at key safety and mechanical systems in the mine such as ventilation equipment.

In the second experiential learning activity participants are taken to the Alan Bauer Explosives test site which is a 420 acres lab north of Kingston ON. In the VR app, students are required to use their hand controllers to mix Ammonium Nitrate (94%) and Fuel Oil (6%) to create ANFO, a bulk industrial explosive. The participants then enter a bunker at the test site and detonate the explosive charge. The participants initiate the explosion with their VR hand controllers using a plunge type detonator and watch the explosion out the bunker window. The explosion that is shown in the VR app is a video of an actual ANFO explosives test conducted at the site.

The final Mining Engineering vignette highlights the importance of environmental stewardship and sustainability. Students are taken onboard a boat which is anchored in a mine tailings pond. Participants use their VR controllers to test water quality. Following a description of the design of the tailings pond and the remediation process the VR app provides students with an image of the pond and surrounding area before and after completion of the remediation process.

2.3. Engineering Chemistry

The United Nations has identified the Water-Food-Energy nexus as the principal challenge of the next generation and is the theme used in the Eng Chem VR application. The program at Queen’s has three major focuses; pharmaceutical/agrochemical synthesis, energy conversion and storage, and chemical diagnostics. The focus areas and Water-Food-Energy nexus theme are combined in the VR app to provide interactive scenarios using Wolfe Island as a small-scale ecosystem. At the beginning of the VR app for Eng Chem the students are on board the Wolfe Island ferry where the narrator provides an introduction to the theme and instructions on how to operate the VR controllers. Upon arrival at the dock on Wolfe Island students can choose to enter three different interactive vignettes.

In the first vignette the students are teleported to a solar farm on the island. In the background large wind turbines are visible and the narrator discusses how the Eng Chem
Environmental monitoring, medical diagnoses, forensics and security systems require accurate and sensitive methods of detecting and quantifying trace amounts of target molecules. Eng Chem students study contemporary analytical chemistry as well as the engineering science needed to design devices for field use. In the third and final vignette, students tune a spectrometer to detect metolachlor the agrochemical herbicide used in the previous vignette. The participants find themselves on a bridge over a small stream where they interact with a replicated spectrometer to try to detect metolachlor in the water. This interactive activity is used to show students that the Eng Chem program involves the design of a wide range of devices to quantify analytes of interest to human health and public security.

2.4. Discipline Selection Nights

During the winter semester engineering students at Queen’s are invited to attend a series of discipline selection nights. Each engineering department has the opportunity to showcase their engineering program to perspective students. This typically involves the department providing presentations, guest speakers and tours. The VR applications were intended to augment the information provided at the discipline selection nights for Mining Engineering and Eng Chem. Following the official presentations made by the departments on discipline selection night, students were invited to network with faculty, current students and past graduates in attendance. It was during this networking time that students were offered the opportunity to go into the VR experiences. Three independent stations using Oculus Rift hardware and VR ready laptops were set-up in the room where the discipline selection nights were held. One of the VR stations was connected to a large TV to allow individuals not immersed in the VR app to see what others were experiencing.

2.5. Survey Design

The FEAS at Queen’s conducts an annual survey for first year engineering students near the end of the winter semester after they have made their discipline selection. The intention of the survey is to solicit feedback on the selection process and what factors played a role. The majority of the survey is focused on first year courses that had a positive or negative impact. In 2018 a question was added to the survey to determine student confidence when selecting their discipline. In 2019 several additional questions were added to the survey to investigate the efficacy of the VR discipline selection apps.

The survey question designed to evaluate confidence required students to indicate which engineering program they selected and then comment on the degree of confidence they had when making their decision. The survey questions related to VR were only asked to students that attended the discipline selection nights for Mining Engineering and Eng Chem. The questions focused on the degree to which the VR discipline selection apps increased
their knowledge and understanding of Mining and Eng Chem and their confidence when making their decision.

3. RESULTS AND DISCUSSION

3.1. Discipline Selection Confidence 2018

The plot in Figure 3 shows the results of the 2018 survey question used to determine the level of student confidence when selecting an engineering discipline. The data shows that in each discipline the majority of students are either extremely, very or moderately confident when making their decision. However, there is a smaller percentage of students in certain disciplines who are slightly confident or not confident at all when making their choice.

![Figure 3 - Level of Student Confidence when making engineering discipline selection 2018](image)

The results from Figure 3 helped inform which disciplines would be selected for VR app development. Ultimately Mining Engineering and Eng Chem were selected since both disciplines are smaller programs with unique features. The fact that several of the students who selected Mining and Eng Chem in 2018 were only slightly confident of their decision was also a factor for selection.

3.2. Discipline Selection Confidence 2019

The survey question used to determine the level of student confidence was asked again in the 2019 survey, however the likert scale was adjusted. In 2018 a 5 degree scale was utilized and in 2019 this was reduced to a 3 degree scale. This change was made to increase the numbers of students in each category and to try and emphasize the lower range of the likert scale. In Figure 4 the plot shows that in each discipline the majority of students are either extremely or moderately confident when making their decision. However, there is a percentage of students in each discipline who are not confident when making their decision.

![Figure 4 - Level of Student Confidence when making engineering discipline selection 2019](image)

The results illustrated in Figure 4 are from 431 first year engineering students at Queen’s who completed the 2019 survey and agreed to the research study. The summation of the likert categories for the survey question on confidence levels is provided in Table 1.

| Level of Confidence | Total |
|---------------------|-------|
| Extremely Confident | 169   |
| Moderately Confident| 223   |
| Not Confident       | 39    |

The results of the 2018 and 2019 survey show that there were a number of students who were not confident when making their engineering discipline selection. In 2019, 39 students indicated a lack of confidence which accounts for 9% of the students who completed the survey. Although this is a relatively small percentage of students, the VR apps were developed to target this population and offer another tool to assist with their decision. It is important to note that for Mining Engineering and Eng Chem there was only one student who reported not being confident when making their discipline selection in 2019 following introduction of the VR apps.

3.3. Mining Engineering

It was estimated that approximately 100 students attended the 2019 Mining Engineering discipline selection night. Of those students who attended, 65 completed the survey. With respects to the VR application, 12 students
completed the VR experience, 19 students watched others in the VR app and 39 did not interact with the VR app at all. Figure 5 shows the result of the VR app for Mining Engineering. For a number of students the VR app strongly increase their knowledge and understanding of the discipline but did not strongly increase their confidence when making their decision. Similarly a number of students indicated that the VR app moderately increased their knowledge, understanding and confidence. Furthermore a portion of attendees at the discipline selection night indicated that the VR app did not have any effect on their knowledge, understanding or confidence in Mining Engineering.

![Figure 5- Effect of VR App on Mining Engineering Discipline Selection](image)

3.4. Engineering Chemistry

It was estimated that approximately 95 students attended the 2019 Eng Chem discipline selection night. Of those students who attended, 74 completed the survey. With respects to the VR application, 11 students completed the VR experience, 24 students watched others in the VR app and 39 did not interact with the VR app at all. Figure 6 shows the result from the VR app for Eng Chem. Similar to the data acquired for Mining Engineering there was a spread across the 3 likert scale range for knowledge, understanding and confidence when making a decision for Eng Chem.

![Figure 6 – Effect of VR App on Engineering Chemistry Discipline Selection](image)

One of the key findings for both VR apps is that for some students the VR experience strongly or moderately increased their knowledge, understanding and confidence when making their decision. The branching in the survey did not allow the researchers to determine if the individuals who completed the VR experience were the ones who indicated that it strongly increased their knowledge, understanding and confidence. This is important as the VR applications were specifically designed to be experiential and it is hypothesized that the students that interacted with the simulation were the ones most strongly affected. The ability to further discern the affects that the VR app had on those that completed the experience will be included in future surveys.

The number of students that completed the VR app at each discipline selection night was lower than desired. Despite having 3 stations it took approximately 45 minutes to have 12-15 students complete the VR apps at each discipline night. This included 5-7 minutes of time in VR plus set-up and change over. Given the up-front development cost of the VR apps and the goal to have it available to all students, the delivery mechanism for the VR apps will be altered in future years. In 2019 the VR apps were only available at the discipline selection nights. In future years the fully immersive VR apps, using the Oculus Rift hardware, will be available at the discipline selection night as well as on several designated VR stations before and after. Additionally the VR apps will be made available for download from the discipline websites as a VR executable and as a video. Students will be able to watch the video or use the VR app with fully immersive hardware or more passive VR hardware such as Google Cardboard. The optimal way to experience the VR discipline selection apps will always be using fully immersive VR hardware, however, making the apps more readily available will likely increase usage.

4. CONCLUSIONS

Selecting an engineering discipline is an important career decision and students should feel confident when making their selection. The results from the 2019 annual survey to first year engineering students at Queen’s showed that the purpose built VR applications strongly or moderately increased the knowledge and understand of numerous students who attend the Mining Engineering and Engineering Chemistry discipline selection nights. Furthermore there were a number of students whose confidence when making their discipline selection was enhanced either strongly or moderately by the VR apps. One of the drawbacks in the way the VR apps were deployed is that not all students had an opportunity to experience it firsthand. Deploying the VR apps in a multitude of formats including fully immersive VR, passive VR and video would help increase the number of students who utilize the discipline selection VR apps. The goal of the VR app development was to provide students with an experiential learning tool that would assist them
with their discipline selection. The results of the VR survey indicate that for numerous students this goal was achieved.

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