



Work in Progress: Developing Engineering Students' Professional Development Skills through Augmented and Virtual Reality Gaming Environments

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Abstract

Students working on hands on projects have a unique opportunity to exercise and learn engineering skills outside of what they learn in the classroom. However, students also need professional skills, or soft skills, that allow them to work effectively on their projects in a team environment. Unfortunately, these skills are often overlooked in the students' core classes and students are usually unfamiliar with these skills. Not having these skills in a project based program can lead to negative outcomes for the students. New technology is rapidly changing, and new techniques that can be used to teach engineering students these valuable skills have become easier to obtain. Advancements in virtual reality (VR) and augmented reality (AR) are one set of emerging technology being explored in education and engineering education. In this paper, we will examine the use of VR to teach engineering students professional development skills such as leadership, teamwork, and communication. This study will be used to examine if these tools can aid the students in learning these valuable skills. The Game Based Learning (GBL) theoretical framework will be used to guide this research. With GBL, we will use a gaming environment to teach these skills to students in an interactive environment and study on the effectiveness of using both VR and GBL to teach these skills. We will also discuss the activities that were developed and the learning outcomes from each activity. Finally, we will discuss preliminary results from students using the virtual reality system and the activities we have developed.

Introduction

This paper will discuss a current work in progress of implementing a learning module that uses virtual reality and a game environment to teach students professional development skills. We will use Game Based Learning (GBL) as our framework for this research and as a base for our approach in teaching these skills to our students. We will begin by doing an overview of our research including our motivation for this research, our theoretical framework and the use of virtual reality as a teaching tool. We will then discuss our current progress in developing both the lesson plan, hardware and software used for this learning module. Finally, we will discuss what our future work will be as we continue this research.

Research Overview

Engineering students are expected to have additional set of skills outside of the technical engineering skills they learn in the classroom [1]. Professional skills are increasingly becoming essential skills that engineering students should possess. Professional skills have been recognized by organizations such as the ABET as critical skills that students need to learn [2]. Because of that, many institutions are now putting more focus on professional development skills and exposing students to these skills. However, are there better ways to teach these skills to our students? Perhaps we can take advantage of new technology to expose our students to these skills.

A program at Iowa State University called Make to Innovate is a project based learning program that allows students to work on real world engineering problems. Over the six years that this program has been operating, informal information has been collected that has identified a potential issue with students lacking skills in key professional development areas, specifically in leadership, communication and teamwork. This information has been collected through monitoring of the projects progress (or lack of progress) through weekly reports and formal design reviews. Evidence of skills lacking in communication has been seen in reports and presentations made at the design reviews. Informal discussions and interactions with the students have also shown skills lacking in leadership, communication and teamwork. Students that lack these skills may struggle with accomplishing their goals or being productive in a team environment [3]. However, students that have these skills tend to perform better and accomplish their goals [4].

The lack of professional skills is not unique to this program, as other courses and programs at Iowa State University have also noted that students may lack these skills [5]. It is also not unique to our university. Other institutions have also noted a lack of professional skills and the impact it has on students [6],[7].

There are a variety of professional development skills and many skills will often overlap to some degree with each other. For the study we are currently conducting we are focusing on four professional development skills. These skills are leadership, communication, teamwork and ethics. We have selected these skills as they have been identified as skills that engineering students will benefit from and are often expected from employers. We also feel that these skills will benefit students in the Make to Innovate program. Finally, another reason for this selection was we felt that these skills can be taught using the virtual reality tools we wish to use.

Our framework for this study is the Game Based Learning (GBL) framework. Game Based Learning is rooted in Problem Based Learning (PBL) and uses games to enhance knowledge and skill acquisition [8]. For our research, we will define “games” and “gaming environment” to be that where we have one or more players that are engaged both mentally and emotionally in an interactive environment and are challenged to complete one or more goals.

Because GBL is based on PBL, it shares a similar framework. These similarities include engaging students in problem and where the instructor is in an advising capacity instead of lecturing to the students. In PBL, students are expected to develop a solution to the problem on their own. The instructor can provide assistance where appropriate but is otherwise not directly engaged with the

students.

GBL continues to enhance PBL by adding the game environment into the learning process. By adding this, students are now engaged in a more interactive environment. They are still expected to solve the problem, but there is more interaction through the game environment. In addition, guidance can now also be provided through the game framework and environment.

Encouragement and hints can be integrated into the game environment and provide additional feedback to the students as they work towards completing their tasks to solve the problem.

Literature Review

In this literature review we will examine three key areas to this research. We will begin by looking at why there is a need for professional development skills in the engineering curriculum. Next we will examine our framework for this research, which is the Game Based Learning framework. We will examine what GBL is and the use of GBL in other courses. Finally, we will examine research into augmented and virtual reality and what has been done with that technology as a teaching tool.

The Need for Professional Development in Engineering Curriculum

Students graduating from engineering programs today often go on to work in industry where they are expected to work, lead, communicate and collaborate in multidisciplinary teams. According to Siller [9], “the development of engineering students’ professional skills has gained national attention from Accreditation Board for Engineering and Technology, the National Academy of Engineering, ASCE, and other constituents” (p. 109). The inclusion of these professional or social skills in turn aid students to achieve more with the technical skills they have [10].

Additional research has been conducted to examine what other skills engineering students should be taught. According to Cox [1], leadership has been a skill that frequently comes up as a skill engineering students should have. This study used experts from both academia and industry to examine leadership skills and more in-depth levels of leadership that can be taught. It also examined two other skills, the ability to recognize and manage change and the ability to synthesis engineering, business and social perspectives.

Game Based Learning Framework

The use of games in education is not new, but the framework for the use of games in education has not been well defined. This is largely due to this type of framework being fairly new. In the paper from Holmes [11], both Game Based Learning and Game Based Teaching are expanded on in four organizing frames. These four frames are: action frame, structuring frame, bridging frame, and the designing frame. All four frames are different angles of both looking at and using Game Based Learning and Teaching (GBLT). By doing this, we can better organize and determine a

more specific way of implementing and using GBLT. They can be used in both the development and the analysis of using GBLT in the classroom.

Because games can engage students in a more compelling and interactive method, some students tend to learn better in these scenarios [12]. This more interactive method helps to create additional motivation which in turn can help to improve the effectiveness in teaching skills to students [13].

Since Game Base Learning is grounded in problem based learning it also engages students in developing their own solutions and thought process to solve the problem that is given [14]. It has been for these reasons that Game Based Learning has been explored and used to obtain higher-level abilities [15].

Use of virtual reality in teaching

In the article by Pantelidis [16], an argument is made that virtual reality can be used in education and more specifically in engineering education. As discussed in his paper, there are many reasons to use virtual reality in education. These reasons include more accurate illustration of some features, allowing extreme close-up examination of an object, and showing multiple parts not normally seen. This immersive and engaging system has led to additional research into virtual reality as a teaching tool because it can be a strong motivator for the student to continue in engaging in the learning process [17].

The paper from Hafner [18] discusses another application of teaching engineering students using virtual reality and also includes teaching of professional development skills. In this paper the authors' discuss a project based learning environment in which students not only learn in a virtual reality environment but also learn about virtual reality systems. Through this project based learning environment, additional professional development skills are also gained such as teamwork, leadership and communications.

As Abulrub [19] discusses, virtual reality can also lead students to more creative solutions to the problem that they are attempting to solve. By allowing students to explore different solutions in a fairly safe space, they are able to try different combinations and solutions that they may not do in the real world. This allows them to explore different solutions and try new things in a safe environment.

Virtual reality along with games has also been seen as disruptive technology that has been changing viewpoints on how they should be used in education [20]. This has been met with resistance or with lack of knowledge on how this technology can be effectively used in education. However, as Alhalabi [21] discusses in their paper, virtual reality can be an effective tool in teaching engineering students. The recent decline in cost for virtual reality and the increase in availability are now making virtual reality a more attractive option for engineering education.

Methods

Through this study we wish to introduce students to four professional development skills. These skills are leadership, teamwork, communication and ethics. Students will be taught the fundamentals of these skills and how they can be applied. Because these students are involved in existing teams in a project environment, they will be able to utilize these skills immediately in this program.

The Make to Innovate program engages students in hands on learning through projects where students solve a variety of problems to achieve the projects goals. The program has between 270 to 290 students that are mainly engineering students from aerospace engineering, mechanical engineering, electrical and computer engineering.

To keep the study within a more manageable amount of students, we will focus on students that are in a leadership position within the program. Each project has a student project leader and each project has between 2 to 4 teams which each have a team leader. This will give us a sample size of approximately 45-50 students for this study.

This group of students will then be divided into two groups. We will select the students through a random selection process. One group of students will be taught professional development skills using learning modules and will be given a combination of materials to read with some instruction given. This will be the control group to examine the difference between teaching in a more common method compared to using virtual reality. The second group will be the intervention group and will be taught almost exclusively using virtual reality simulations and activities.

Procedures

Both groups of students will be given a short questionnaire and an interview will be conducted of each student before starting the learning process. Both the questionnaire and interview will be designed to determine what knowledge students currently have on the professional skills we will teach. The interview will be recorded, and transcribed along with the answers recorded during the session. This will establish a baseline of what each student knows about these skills beforehand. A similar questionnaire and interview will then be conducted after the lessons are completed to examine what the students learned from the experience.

Students will be put into a virtual reality gaming environment that will be designed to teach one or more professional development skills. Students will be monitored and recorded during the session that they are undergoing the game session. The virtual reality environment will be designed with a different scenarios that will have learning outcomes in teamwork, communication, leadership and ethics. Some scenarios will include multiple professional development skills. Some environments will include two players while others will be designed for up to 4 players.

After the students have participated in the gaming sessions, they will then be given another questionnaire and interviewed to examine what they have learned or didn't learn from the game sessions. Using students in the Make to Innovate program, we can also examine how they use these skills in leading their teams in Make to Innovate. This will be done by looking at the

success of the projects they are leading and in how they deliver their milestones and conduct their daily tasks. This information will also be collected from the cross evaluations given to students to evaluate their peers.

Once data has been collected both qualitative and quantitative data will need to be examined. This will include examining the scores from the questionnaire given to the students and coding the interviews from the students. To code the data we will develop a code book to look for key responses or keywords that show the students' understanding of these skills.

Materials

For this study we will be developing our own virtual reality environment. We will be using a freely available tool called Unity to develop the 3D interactive world that students will learn in. Figure 2 shows a screen-shot of the current work in progress of the virtual environment. In this screen-shot, the prop that is shown in Figure 1 is also shown in the virtual space.

An HTC Vive is currently being used as the hardware for putting the student into the virtual reality environment. Additional hardware that is being developed also includes props that students will use to interact with the virtual space. This creates a mixed reality experience for the student. This also has the benefit that allows multiple students to participate but does not require for all students to use the more expensive VR equipment like the HTC Vive.

With this being a mixed reality application, we are developing a system where students are interacting in both a real world setting and virtual setting. To do this, we will be using props that students will interact with. These props are able to influence and change props and interactions with the virtual environment. Currently, we have three props that are in development. The first is a sphere that can be rotated and the color changes based on rotation. The second is replication of a Mars rover that has a movable camera that as the camera moves, the change is shown in the simulation. The final prop will be

Figure 1 is an image of one of the props that was designed to be used for this purpose. The prop was 3D printed from a Computer Aided Drawing (CAD) that is the same model used in the virtual environment. This prop has a micro-controller that communicates to the virtual environment and vice-versa.

For this activity, the players must work together to enter a color sequence. This involves both teamwork and communication between the two players. The sphere is actually in two pieces which allows the top part of the sphere to rotate. As it rotates, the color of the sphere changes. This color change takes place both in the real world and in the virtual world. The challenge however is the player in the virtual environment has the sequence that needs to be entered but is not able to rotate the sphere. The person in the real environment can rotate the sphere but does not have the sequence, therefore they must communicate and work together to solve the puzzle.

Three additional activities will also be developed for this study. All activities will use a mixed reality and combine both virtual reality space and augmented reality space. The second activity will be a continuation of the sphere but will utilize a device with additional sensors including an inertial measurement unit to determine orientation of the object. As with the sphere, use of this



Figure 1: 3D printed sphere used as a prop to have players interact with the virtual space.

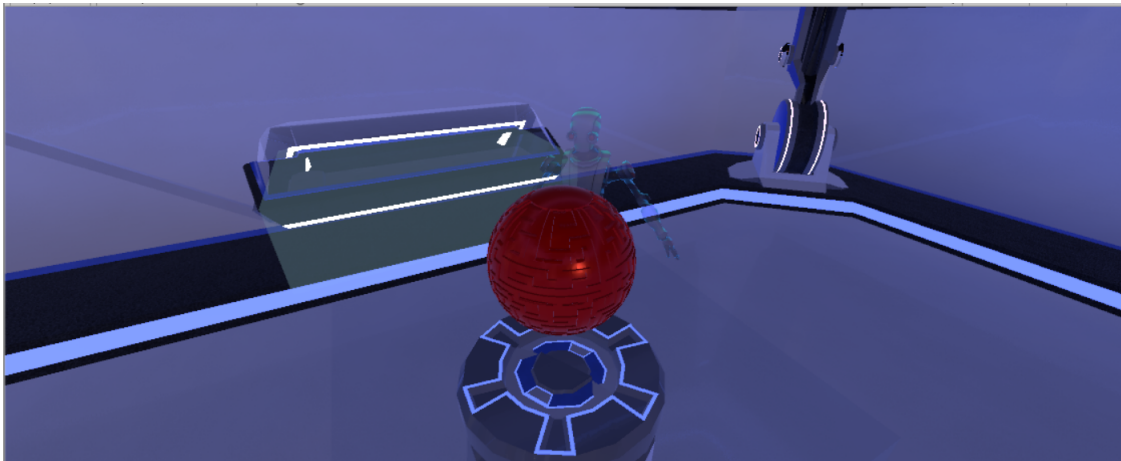


Figure 2: A screen-shot from the virtual environment developed in Unity.

device will have a direct impact to replica of the device in the virtual space. The third activity will recreate a scenario seen in the movie “The Martian”. Here we will recreate the scene where they need to communicate back to Earth but with only using the Mars rover’s camera and being able to point to letters or numbers. The last activity will utilize a scenario in which students will be faced with other students in distress as they orbit the earth in a space capsule. Students will need to solve the problem to get them home.

Conclusion

As this is a work in progress, work is on going in the development and refinement of both the lesson development and with the hardware and software that will be used. Additional work is also progressing with the assessment of how the students learn using these tools compared to other pedagogies. Finally, at the time of this writing IRB approval is being worked on and must be obtained before any data is collected.

Development of the virtual environment is currently an ongoing process. Current work has been in developing the environment and testing the environment as one that is easy to view and navigate using a virtual reality headset like the HTC Vive. As this will also include a mixed reality component, work is also on going in developing the hardware that communicates between the virtual environment and the real world device. While preliminary work has been completed and a rough proof of concept has been demonstrated, refining this to a more finished product is on going.

Additional work is also going into incorporating augmented reality as well. Using augmented reality tools such as Apple’s ARKit and Google’s ARCore are being looked to increase the other players engagement with the system. Augmented reality allows for the continued use of both physical objects such as the props described in this paper and further bring the student into the experience and engagement with the learning process.

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