Virtual Reality Activities for Teaching Engineering Students Professional Development Skills

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***Abstract*—There has been a growing need to teach professional development skills to engineering students at Iowa State University. Students are often lacking these skills even though they are desired skills to have both for academic success and in the workplace. For our research, we are exploring using virtual reality to teach four professional development skills to students. These skills are leadership, teamwork, communication and ethics. We are using virtual reality as an innovative tool to teach students these skills in an interactive and fun environment. This work-in-progress paper will discuss the activities that are being developed to teach engineering students professional development skills at Iowa State University. In this paper, we will discuss three activities that are being developed to teach these four different professional development skills. Our framework for these activities is using Game Based Learning (GBL), which is based on Problem Based Learning (PBL). Each activity will be based on a problem that students must work together to solve. Through this interaction, students will learn one or more of the professional development skills outlined in this paper. The goals and learning outcomes of each activity will then be outlined and discussed in more detail. We will outline the execution of each activity and how the interaction between the students and the virtual reality system will be accomplished. In this paper, we will show our current work in progress of the development of the game environment used in these activities. This will include screen shots and other examples of the game environment for each activity. The development platform used for these activities is the Unity platform, a free game development software package that includes tools for working with virtual reality. The virtual reality headset that will be used with Unity will be the HTC Vive. This allows us to have an interactive environment where students can see and hear in the virtual space and use controllers to interact with objects in the virtual space. We are also adding physical props that can interact with the virtual space. The addition of these props is designed to allow multiple players to be involved while keeping costs low and increasing the portability of the system.**

***Index Terms*—professional skills, teamwork, leadership, ethics, communication, undergraduate, Multidisciplinary design**

I. Introduction

Professional development skills are important skills to have, but in the Make to Innovate program, it has been observed that these skills seem to be lacking [1]. In addition, engineering students are expected to have additional set of skills outside of the technical engineering skills they learn in the classroom [2]. Professional skills have been recognized by organizations such as the Accreditation Board for Engineering and Technology (ABET) as critical skills that students need to learn [3]. Because of that, many institutions, including Iowa State University, are now putting more emphasis on professional development skills and exposing students to these skills through a number of different pedagogies. 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.

II. Literature Review

A. Current approach to teaching professional development skills

The importance of teaching students professional development skills has been growing in many colleges and universities. Various groups have taken different approaches on teaching these skills to students. 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 [4], "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 [5].

While many institutions understand the importance of teaching professional development skills is important, there are different approaches to how these skills are taught. Many programs rely on these skills being taught in the students' capstone and design classes [6]. However, this may result in students not learning some of these skills until their last year in their education. There is a growing interest and push to have these skills taught at the freshman or sophomore level to not only allow students to develop these skills sooner but use them in other aspects of their academic career.

One approach to teach students these skills at different stages of the students academic career is with using Project Based Learning (PBL) in a course. The use of PBL in engineering courses is not new, and has been implemented in a number of courses to allow students grasp engineering concepts and reinforce what the students have learned [7]. Courses at Iowa State University also have used the PBL framework including the Make to Innovate program. Examples of using PBL in professional development courses include courses in engineering ethics [8], teamwork and communication [9] and even a course designed to improve students professional development skills overall [10].

In all of these examples, the authors noted that the use of PBL helped to increase the students learning and that this extended to learning the professional development skills taught in these courses. Warnock et al [10], discusses that

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the use of PBL resulted in the students being more engaged and interested in learning the skills. Kirkman [8] notes in his paper that feedback from students discussed how students changed their perception about engineering problems and in engineering ethics when he used PBL in his course. In his paper it is noted that students changed their approach to solving problems related to engineering ethics. Yosof et al [11] discusses that students can develop their own thoughts and it encourages critical thinking on these topics with the use of PBL in the course.

B. Game Based Learning Framework

In our study we wish to expand on the use of Problem Based Learning (PBL) for teaching professional development skills by using the Game Based Learning (GBL) as our framework [12] which is based on PBL. The difference with GBL is that a gaming environment is used. In the context of this research we define gaming 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.

The GBL environment further engages the student into the activity with the goals to keep them motivated to learn [13]. Because games can engage students in a more compelling and interactive method, some students tend to learn better in these scenarios [14]. This more interactive method helps to create additional motivation which in turn can help to improve the effectiveness in teaching skills to students [13]. We hypothesize that the use of the GBL framework will help students engage in the learning of professional development skills.

In the paper from Holmes [15], both Game Based Learning and Game Based Teaching are expanded on in four organizing frames which 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.

In this work, we use these frames from Holmes to guide, inspire and give insight on both the activities we have designed and in the actual game environment. These frames are used from building the back-story for each activity, or using the structuring frame, to how we use and interact with game objects using the action frame. The designing frame gives us guidance on how we can teach these skills to students using games. Finally, the bridging frame is useful to not only bridge the learning between the objectives for the students but how these ideas can be carried to outside the game. In using both the GBL framework and these more specific points of the framework, we aim to develop a game environment that is effective in learning and engaging the students in each activity.

C. Why use virtual reality in teaching?

Virtual reality is a relatively new tool that is being explored as a teaching tool. 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 lead 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].

But how does VR stack up to other multimedia learning strategies? This was addressed in a paper from Parong and Mayer [18] in which a comparison was conducted between students learning in a VR simulation and with a multimedia slide-show on a desktop. In this study, the students that did the slide-show desktop performed better than those that did an immersive VR learning session. However, the motivation with the students were higher with those that did the VR learning session. Furthermore, students that did a written summary after a VR segment had similar test scores to those that did the multimedia slide-show. In other words, tools like virtual reality work, but the retention often has a shorter duration unless it is reinforced through another method such as writing a summary of what you learned.

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 his 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.

Continuing from the Game Based Learning (GBL) framework, we can see where the addition of virtual reality can further encourage students to be engaged in the learning process. The combination of interactivity and instant feedback encourages the student through the learning process. This allows for the student to immerse themselves into the environment and become fully engaged into the simulation. This differs from other methods where a disconnect can occur with the students since there is no direct engagement between the student and the learning environment.

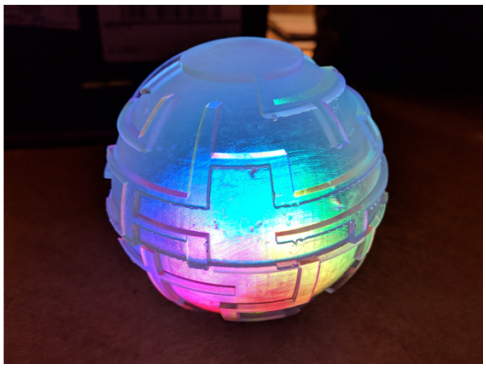

Fig. 1. 3D printed prop with electronics installed.

III. Activities

Three activities have been developed with the goal of teaching students professional development skills. For these activities, we used the Game Based Learning framework and designed the activities to be interactive games. GBL is based on Problem Based Learning (PBL) and uses games to enhance the acquisition of skills [12]. As such, we designed the activities to have a problem or problems that needed to be solved. As students progress through the activity, they will need to utilize problem solving skills to complete the activity given.

All three activities have a common space and science fiction theme to them and incorporate both virtual reality and props. These props allow for interaction between the virtual world and the real world. The goal of this approach is to reduce the overall cost of this system. While virtual reality has come down in price, the computer requirements and hardware can make the system expensive if you wish to have a large group work together. This concept allows for students to work together and interact with each other.

A. Activity One

The first activity is an original puzzle game set in a science fiction environment. It is designed to be a fairly simple puzzle and serves as an introduction to the players. This allows the players to learn how things work both the virtual reality workspace and with the props. In this activity there is a player that will be the engineer. The engineer is able to transport themselves as a hologram to the Mars station. This player sees a simulation of the Mars station in the virtual reality environment but they are limited in what they can interact with. A second player plays as the scientist. The scientist is actually on Mars and can interact with the props.

Learning objective In order to fix a computer problem, both players must work together to input the correct sequence into the prop. Some information is only available to the engineer and some information is only available to the scientist. Only the scientist is able to twist the sphere to input the sequence, but only the engineer can see the sequence that needs to be sent. Once complete, only the engineer is able to "upload" the data into the computer.

Fig. 2. 3D image of the Mars rover used in game.

This activity engages students to communicate effectively and work as a team. The faster they are able to complete the puzzle, the more points they will get. Using this GBL framework helps to encourage both students to solve the puzzle in an effective method. The key to solving this puzzle is communicate effectively and to work together. Through cooperation, teamwork and communication they will be able to solve the puzzle and the game will reward them with a score and good job. As this activity also presents a problem to be solved, students will also gain problem solving skills.

B. Activity Two

The second activity is inspired by the movie "The Martian" and is another puzzle game that uses a Mars rover. In this activity one student will be in the simulation and in this case will be transported to Mars. Three to five students will then be engineers that are located on Earth. Much like the movie, the objective is for them to communicate back to Earth, but the only way to do that is to use the Mars rover camera. The engineers on Earth will have a mock-up of the Mars rover that they can also control and will be equipped with servos, position sensors and a camera as well. They will be able to control the Mars rover camera and will be able to move it.

Points for this activity will be based on how long they take to solve the problem and which actions they take to solve the problem. Some actions may have ill effects which may not only reduce the amount of points they have, but may even end the game early.

Learning objective. The learning objective for this activity is to work as a team through teamwork, communicate effectively, and build leadership. The team of engineers on Earth will have one person assigned as a team leader. The engineering team on Earth will then have to come up with a plan on how they can communicate using only the rover to do so. They will then need to communicate this plan back to the person on Mars. The engineering team will also be presented with an ethical problem. One or more actions would result in a shorter time but may harm or even kill the player on Mars.

The person on Mars will first need to initiate communication with the engineering team to tell them there is a problem. Once this is done, that person will need to follow the instructions from the engineers and be able to carry those out in the virtual reality space. This will require that they understand what they

are being told and carry those instructions out. That person will also need to communicate back to the engineers and provide them with feedback.

C. Activity Three

The third activity uses a space capsule and also pulls inspiration from the movie "Apollo 13". Like activity two, we will have students that will form an engineering team on the ground. In this activity however, we will have two students that are in the virtual reality simulation. The two students that are in the virtual reality simulation will be pilots on the space capsule.

An event will take place that will put the capsule in danger. The engineering team on the ground will need to develop a solution and communicate with the pilots on the capsule. Unlike the second activity, they will be able to communicate through voice communications. The engineering team on the ground will need to come up with a solution to fix the problem and get the pilots back safely. The pilots will need to follow the instructions from the engineers to return safely back to Earth.

Learning objectives The learning objectives for this activity will be similar to activity two. Students will need to communicate effectively, work as a team, and a leader will also be determined for the engineering team. Like activity two, there will also be ethical decisions that will need to be made that could impact the crew of the space capsule. The decisions that the students make will have an impact on the outcome of the activity.

IV. Future Work

Future work for this work in progress paper will include continued work in the development of the activities, the data collection methods to be used and the assessment methods to be used. We have implemented activity one in the software program Unity. Unity allows us to work in developing games and also virtual reality games. We have also developed the prop for activity one and used a 3D printer to print the prop. A Mars rover developed by a student team for a previous university competition will be used as the prop for activity two and will have the camera and servos. The prop and software for activity three is currently in development.

We will continue to develop both the data collection and assessment of the students as they learn these skills. Once these tools have been developed, we will then implement a test run in the Fall 2018 semester. We will use students enrolled in the Make to Innovate program and will focus on students that are in a leadership role for their team. From there we will evaluate the results and collect feedback.

A. Data Collection

Data collection will be an important portion of this research. Our research questions for this research is: 1) Can we use virtual reality in a gaming environment to teach professional development skills? and 2) Is using this method better, worse, or the same as teaching these skills using a self-learning module? To help answer these questions, we will be collecting both quantitative and qualitative data from the students. A control group will be used to compare how the students learned these skills between those using the GBL and virtual reality approach and those learning them by taking learning modules made available on-line. Data collection will be done by a survey and by interviewing a representative sample size of the students involved. Once this data is collected, we will use this to assess how well students learned these skills. These assessment tools are still being developed.

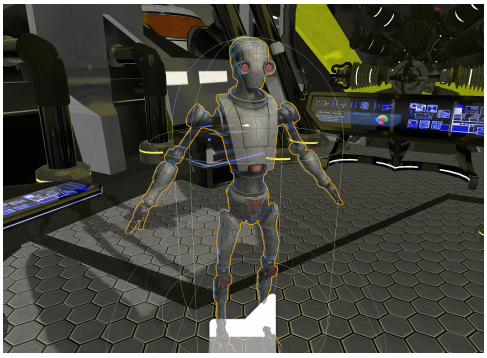

Fig. 3. The hologram avatar used in game for activity one.

V. Conclusion

This work in progress paper outlines a research that is ongoing at Iowa State University. We have outlined the need to have professional development skills to students. We have also shown that using new pedagogies and new technology may result in more engagement from students and the willingness to learn these essential skills. Finally, we have shared what our approach will be in collected data on this research and the plan to assess students on learning these skills.

Appendix A
Acknowledgements

Project/material is based upon work supported by the Iowa Space Grant Consortium under NASA Award No. NNX16AL88H. We would like to thank the Iowa Space Grant Consortium for their support of this project. We would also like to thank our collaborators, Dr. Tom Carstens at Loras College and Dr. Michelle Ruse at Des Moines Area Community College.

References

[1] M. E. Nelson and B. Ahn, "Improving engineering students professional development skills in the Make to Innovate program," in *2017 IEEE Frontiers in Education Conference (FIE)*, Indianapolis, IN, 2017, pp. 1–5.

[2] M. F. Cox, C. Osman, B. Ahn, and J. Zhu, "Engineeirng professionals' expectations of undergraduate engineering students," *Leadership and Management in Engineering*, vol. 12, no. 2, pp. 60–70, 2012.

[3] L. J. Shuman, M. Besterfield-Sacre, and J. Mcgourty, "The ABET "Professional Skills" - Can they be taught? Can they be assessed?" *Journal of Engineering Education*, vol. 94, no. 1, pp. 41–55, 2005.

[4] T. J. Siller, M. Asce, A. Rosales, J. Haines, and A. Benally, "Development of undergraduate students' professional skills," *Journal of Professional Issues in Engineering Education and Practice*, vol. 135, no. July, pp. 102–108, 2009.

[5] Y.-J. Chang, T.-Y. Wang, S.-F. Chen, and R.-H. Liao, "Student engineers as agents of change: Combining social inclusion in the professional development of electrical and computer engineering students," *Systemic Practice and Action Research*, vol. 24, no. 3, pp. 237–245, 2011.

[6] J. Mccormack, S. Beyerlein, P. Brackin, D. Davis, M. Trevisan, H. Davis, J. Lebeau, R. Gerlick, P. Thompson, M. Javed Khan, P. Leiffer, and S. Howe, "Assessing professional skill development in capstone design courses," *International Journal of Engineering Education*, vol. 27, no. 6, pp. 1308–1323, 2011.

[7] P. Dolog, L. L. Thomsen, and B. Thomsen, "Assessing problem-based learning in a software engineering curriculum using blooms taxonomy and the IEEE software engineering body of knowledge," *ACM Transactions on Computing Education*, vol. 16, no. 3, pp. 1–41, 2016.

[8] R. Kirkman, "Problem-based learning in engineering ethics courses," *Interdisciplinary Journal of Problem-based Learning*, vol. 11, no. 1, p. n1, 2016.

[9] K. M. Yusof, A. N. Sadikin, F. A. Phang, and A. A. Aziz, "Instilling professional skills and sustainable development through Problem-Based Learning (PBL) among first year engineering students," *International Journal of Engineering Education*, vol. 32, no. 1, B, SI, pp. 333–347, 2016.

[10] J. N. Warnock and M. J. Mohammadi-Aragh, "Case study: use of problem-based learning to develop students' technical and professional skills," *European Journal of Engineering Education*, vol. 41, no. 2, pp. 142–153, 2016.

[11] K. M. Yusof, S. A. H. S. Hassan, M. Z. Jamaludin, and N. F. Harun, "Cooperative problem-based learning (CPBL): Framework for integrating cooperative learning and problem-based learning," *Procedia - Social and Behavioral Sciences*, vol. 56, no. Ictlhe, pp. 223–232, 2012.

[12] M. Qian and K. R. Clark, "Game-based learning and 21st century skills: A review of recent research," *Computers in Human Behavior*, vol. 63, pp. 50–58, 2016.

[13] A. All, E. P. Nuñez Castellar, and J. Van Looy, "Towards a conceptual framework for assessing the effectiveness of digital game-based learning," *Computers and Education*, vol. 88, pp. 29–37, 2015.

[14] M. J. Mayo, "Games for science and engineering education," *Communications of the ACM*, vol. 50, no. 7, p. 30, 2007.

[15] J. B. Holmes and E. R. Gee, "A framework for understanding game-based teaching and learning," *On the Horizon*, vol. 24, no. 1, pp. 1–16, 2016. [Online]. Available: http://www.emeraldinsight.com/doi/10.1108/OTH-11-2015-0069

[16] V. S. Pantelidis, "Virtual reality and engineering education," *Computer Applications in Engineering Education*, vol. 5, no. 1, pp. 3–12, 1996.

[17] C. Dede, "Introduction to virtual reality in medicine," *Virtual Reality in Medicine*, vol. 9781447140, no. 1-2, pp. 7–9, 2012.

[18] J. Parong and R. E. Mayer, "Learning science in immersive virtual reality," *Journal of Educational Psychology*, pp. 1–13, 2018. [Online]. Available: http://dx.doi.org/10.1037/edu0000241

[19] A. G. Abulrub, A. Attridge, and M. A. Williams, "Virtual reality in engineering education: The future of creative learning," *International Journal of Emerging Technologies in Learning*, vol. 6, no. 4, pp. 4–11, 2011.

[20] J. Psotka, "Educational games and virtual reality as disruptive technologies," *Journal of Educational Technology & Society*, vol. 16, no. 2, pp. 69–80, 2013.

[21] W. S. Alhalabi, "Virtual reality systems enhance students achievements in engineering education," *Behaviour & Information Technology*, vol. 35, no. 11, pp. 919–925, 2016.