XR in Interprofessional Learning: Facilitating Engineering-Medicine Interactions

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Introduction

The field of biomedical engineering is constantly evolving, with new technologies and techniques emerging to improve patient outcomes and enhance the delivery of healthcare. One such technology is XR (extended reality), which includes virtual reality (VR) and augmented reality (AR), among others. XR has enormous potential in the field of medicine and can be used to visualize complex anatomical structures, train medical professionals, and improve patient outcomes. In this project, we explored the use of XR in biomedical engineering, with a specific focus on the segmentation of medical images.

The goal of this project was to utilize extended reality tools to promote interprofessional learning between biomedical engineering students and medical professionals. Currently, only a small fraction of Biomedical Engineering students get meaningful exposure to the clinic. This problem has been exacerbated by the COVID-19 pandemic, which forced many universities to shift to online learning, and clinical experiences to be limited or canceled altogether. This has resulted in a lack of meaningful clinical exposure for BME students, particularly those who are in their final years of study and preparing to enter the workforce.

The specific classroom challenges are as follows:

I. The performance problem is that BME students need clinical exposure to gain the knowledge required to design new medical devices, but it is difficult to physically access the clinical setting.

II. The learning problem is the gap in clinical knowledge and communication skills that are needed to interact with clinicians and to fully understand the clinical problem.

The use of XR will increase access to the clinical environment for BME students, and thereby will greatly enrich their training and their ability to be effective as engineers solving problems in medicine and healthcare.

The first iteration of the module was run in Dr. Stegemann's BME 599 class in Fall of 2022. This module was successfully completed by 28 students. In fall of 2022, we proved that XR was an effective tool for use in the Biomedical Engineering classroom; students in that cohort generally felt more comfortable using XR, interacting with clinicians as an engineer, and using XR to interact with clinicians once completing the module. In Winter of 2023, the module was run again Dr. Stegemann's BME 599 class, with some modifications.

The specific problems from version 1 of the module that were addressed are as follows:

I. Not related enough to the rest of the class; BME 599 is a design course, where students work in teams and with clinician mentors to solve a medical problem identified by healthcare professionals. In the first version of the module, students were given random datasets that didn't relate to their projects to work with.

II. Low resident and clinician involvement in the showcase day; On day 3 of the module, all of the residents and clinicians were invited to watch remotely with a VR headset. However, many were not able to participate due to technological issues and other responsibilities.

III. Not enough time to create a VR world using Unity; Unity is a very involved program with a steep learning curve. In the first iteration of the module, the students were only given 1 week to build a VR world in Unity after being introduced to the program, which was not sufficient time for them to create remarkable worlds.

This project plays to the strengths of XR by i) visualizing the unseen through use of VR to examine anatomy inside the body, and ii) immersing students in an authentic environment by teaming them with medical professionals and using real medical images for the simulation.

The main impact of this project is an innovative teaching tool that enables remote but lifelike VR-based interactions between engineering students and medical professionals. Achieving these interactions is difficult because of restricted access to the clinic, and these issues have been exacerbated by the pandemic. The proposed simulation modules enable cross-disciplinary experiential learning methods that could be applied across the College of Engineering and beyond.

Methods

The initial version of the XR module was designed to be piloted in the Graduate Innovative Design in Biomedical Engineering course in the College of Engineering in the fall 2022 semester. The main elements of the module and learning exercise were:

I. Segmentation of medical images to visualize anatomy using the Mimics Innovation Suite (MIS) medical image processing software. Segmented images (STL or OBJ) are brought into a VR environment for enhanced flexibility in viewing, manipulating and discussing the anatomy and pathology presented in the image sets.
II. Training and discussion on anatomy and surgical approaches in a virtual environment by student teams and surgical residents. Medical trainees will apply their knowledge to planning the surgery, and will explain the rationale for their approach to the engineering students. The VR environment allows manipulation of the anatomy and visual access to normally unseen structures.
III. Presentation and discussion of the segmented image and associate pathology with the rest of the class, and with clinical experts. The final showcase takes place in a virtual environment designed and built by the project team. The goal of the final presentation is for the team to articulate their approach to designing a therapy for the specific human pathology, and to discuss this with clinical experts.

The revised version of the XR module was also run in the Graduate Innovative Design in Biomedical Engineering course in the College of Engineering in the winter 2023 semester. The revised version 2 of the XR module was created in order to fix the flaws of version 1 and to assess whether or not the module could be useful for biomedical engineering students in the future. The main elements of this module were:

I. Segmentation of medical images to visualize anatomy ***specific to the design project that the team has been working on*** using the Mimics Innovation Suite (MIS) medical image processing software. Segmented images (STL or OBJ) are brought into a VR environment for enhanced flexibility in viewing, manipulating and discussing the anatomy and pathology presented in the image sets.

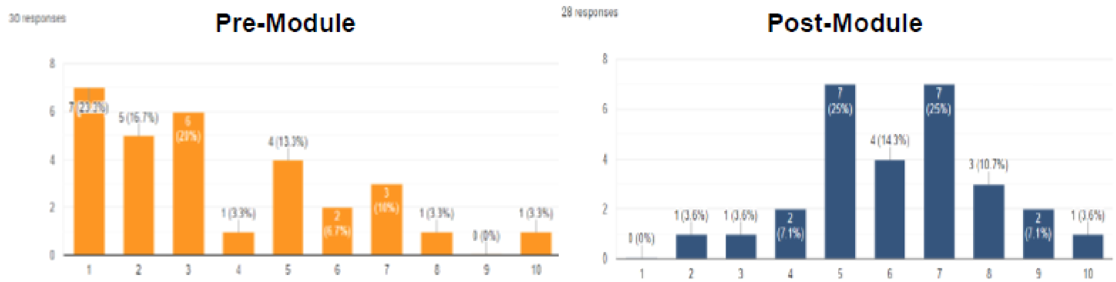
II. Training and discussion on anatomy and surgical approaches in a virtual environment by student teams and ***their previously established mentors from their respective design projects***. Mentors will explain their knowledge of the team's CT/MRI scan as it relates to their project, and students will be given the space to ask questions in order to gain deep understanding of their scan. The VR environment allows manipulation of the anatomy and visual access to normally unseen structures.

III. Presentation and discussion of the segmented image and associate pathology with the rest of the class, and with clinical experts. The final showcase takes place in a virtual environment designed and built by the project team. The goal of the final presentation is for the team to articulate their approach to ***designing their final product,*** and to discuss this with mentors and other clinical experts.

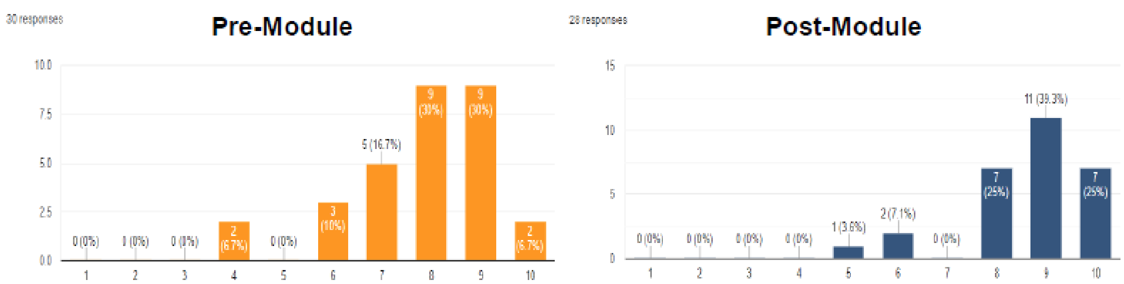
Both versions of the module spanned the same amount of total days, but version 2 of the module had a much more spread out timeline. During version 1, day 2 occurred 2 weeks after day 1, and day 3 occurred just 1 week after day 2. However, during version 2 of the module, day 2 occurred 1 week after day 1, and day 3 occurred a whole month after day 2. This change was based on feedback from module 1 - it didn't take very long to learn how to segment images in Mimics, but VR worldbuilding in Unity had a much steeper learning curve and therefore students requested more time to work with it.

Results

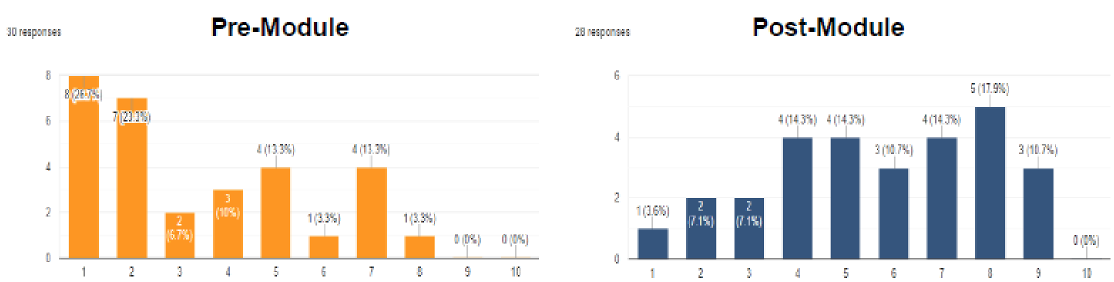
The first iteration of this XR Module was successfully run in Fall 2021. The module consisted of three class sessions that covered digital image segmentation and introduction to VR environments. Students worked on teams outside of class to prepare their VR project, and presented during the final showcase. Student teams demonstrated the ability to manipulate and discuss segmented digital models of human tissues in a virtual reality environment. All students completed both a pre-module survey covering their previous experience with XR and with interprofessional interactions, as well as a post-module reflection form that re-assess the pre-module questions and also allowed students to provide feedback on their experience with the module. Preliminary analysis of the pre- and post-module feedback demonstrated that the XR module increased the comfort level of students in using VR, and also increased their comfort in using VR to interact with clinicians (see Figure 1). Overall, the module was successful and impactful, though we identified several technical and logistical challenges in the first iteration.



Module assessment: How comfortable do you feel using XR (Extended Reality)?



Module assessment: How comfortable do you feel interacting with clinicians as an engineer?



Module assessment: How comfortable do you feel using XR to interact with clinicians?

Figure 1: Preliminary survey results from pre and post module surveys of iteration 1 of the module.

The second iteration of the project was successfully run in the Winter 2023 semester of the Graduate Innovative Design in Biomedical Engineering course in the College of Engineering. All 14 students successfully completed the VR module. Based on feedback from the fall 2021 cohort, most of the winter 2023 teams were assigned a scan that had relevance to their year-long design project. In addition to learning how to segment images with the Mimics software and how to create and navigate a virtual environment using the Unity game engine, the students in both cohorts were also asked to complete a pre and post module experience form. The pre module experience form collected information on the students' previous experiences using XR, interacting with clinicians, using XR to interact with clinicians, and with interprofessional learning. The post module experience form asked students these same questions, and invited them to elaborate on their experience with free response questions. The survey results from the winter 2023 cohort can be seen below.

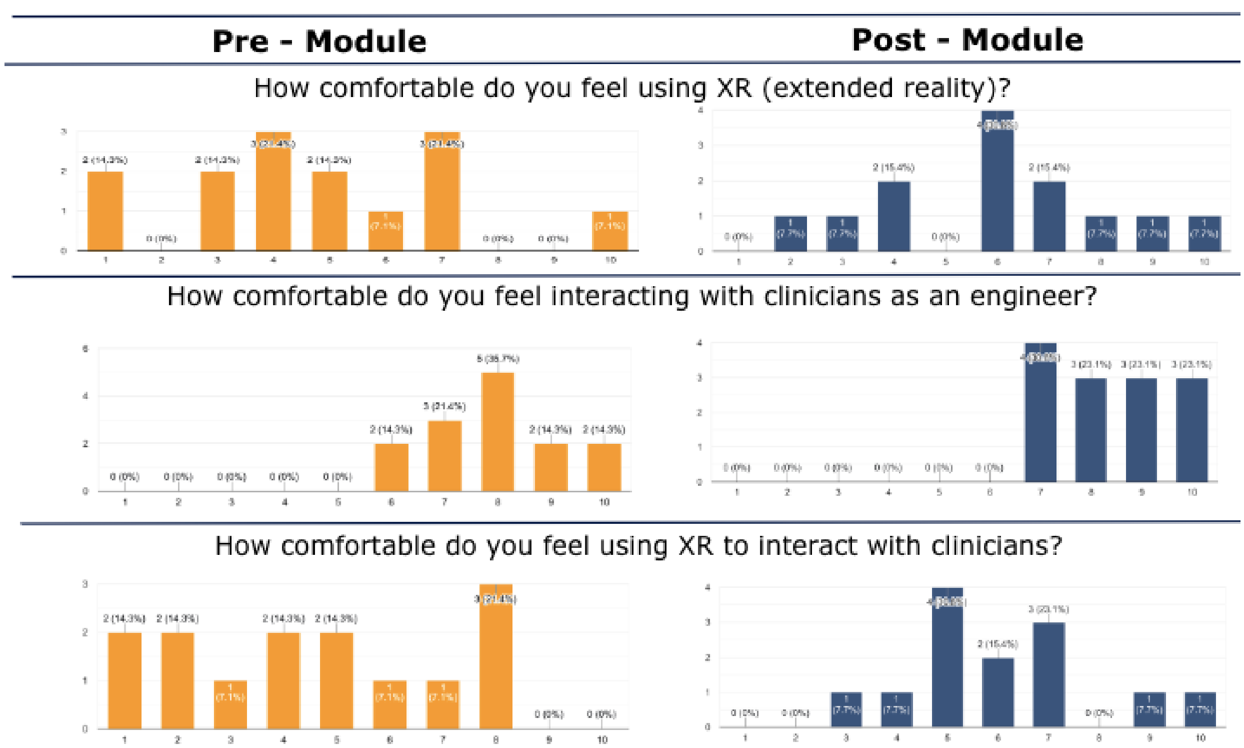


Figure 2: Preliminary survey results from pre and post module surveys of iteration 2 of the module.

Discussion

A main learning from the first iteration of the XR module is that student teams needed more time to create rich VR environments. The students were clearly enthusiastic about creating and using these environments, but technical complications occurred frequently and required time for troubleshooting. The final showcase was exciting, but also revealed some technical challenges in having several teams present remotely in a VR environment. In addition, the focus on technology and interaction with clinicians made it difficult to also assess the degree to which the module assisted with interprofessional communication. Finally, questions were raised about relevancy of the module to the class itself. Students in this iteration received datasets to segment that had nothing to do with their semester-long projects and residents to talk with that they had never met before, making the module feel like an add-on to the class instead of an integrated piece of it.

Modifications were made for version 2 of the XR module. To combat the issue of the time crunch, the module was spaced out more and students were given a month to create their VR environments, instead of just a week. In order to get more clinician interaction with the showcase, students were instructed to meet with the same clinicians that had mentored them throughout their year-long design projects. Additionally, their mentors were invited to attend the showcase in person or remotely via a headset. This in person option allowed clinicians that weren't comfortable manipulating the VR technology on their own to come in and get help from the teaching team during showcase day. Finally, student teams received datasets that complemented their year-long design projectto the best of our abilities. However, we were not able to find highly relevant scans for every team. For example, we received negative feedback from 2 teams working on skin related projects (skin can not be segmented in Mimics) that were given a shoulder and leg to segment. However, the team working on a modular leg splint received a broken fibula bone to segment, which paired nicely with their project.

Overall, this project has proved successful as a learning tool, but was difficult to integrate into Dr. Stegemann's graduate design course. Feedback from version 2 of the module mainly highlighted that the module felt important, but was so involved that it could almost be taught as a class in itself. In the future, we would like to explore the idea of creating a mini-course from this module, which would offer students enough time and instruction to fully grasp the ideas of segmentation and VR world building.

In conclusion, the use of XR in biomedical engineering has significant potential for improving biomedical engineering education and enhancing healthcare delivery. By combining the power of medical image processing software with XR technology, we can create accurate and detailed 3D models of anatomical structures and aid in the development of medical devices and implants. Additionally, the collaborative approach to problem-solving and design in a virtual environment allows for a better understanding of the patient's unique anatomical features and can lead to improved outcomes. We hope that this module has provided students with a comprehensive understanding of the use of XR in biomedical engineering and inspired them to continue exploring this exciting field.