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Virtual Reality as an Education Tool in Biomedical Engineering

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University of Arkansas Honors College

Department of Biomedical Engineering

Abstract

Virtual Reality (VR) has become more accessible in recent years, both to experience and to create. Various studies have shown that incorporating VR in an educational setting can yield positive results. Virtual reality videos created using course-specific content could prove to be a beneficial educational tool. VR videos were implemented in a remote biomolecular engineering laboratory course. 180° VR videos of lab procedures were recorded and viewed by students using a Google Cardboard headset and their smartphones. After viewing all the VR lab videos, students were given a survey to report their experiences. The survey contained questions used to measure student engagement, video content, the potential for future use of VR videos, and the functionality of the VR equipment. The VR videos were very effective at allowing students to work at their own pace. A majority of students agreed that the videos contained enough information to understand the lab. Results were mixed regarding students' opinions if VR videos were an acceptable replacement for in-person labs, whether students would like these types of videos in future labs, and students' confidence in applying the skills learned virtually in reality. A majority of students felt viewing the videos, including nausea or discomfort from the cardboard headset itself. The videos proved effective in conveying the needed information of the labs but need to be improved. The quality of the headsets for viewing and the camera for recording the videos needs to be improved as it could be difficult to hear or see small details at times. In the future, if VR videos are to be utilized, they should be in combination with in-person labs if possible. They provided an adequate substitute but cannot fully replace in-person labs in their current form. More studies should be conducted with better equipment to further determine their potential as an education tool.

1. Introduction

Virtual Reality (VR) has become more accessible in recent years, both to experience and to create. A variety of VR headsets are available to consumers at various price points and quality. Similarly, there are many cameras with 360° recording abilities available to the public, bringing the ability to create VR videos to the public and non-professionals. VR simulations are already used in educational environments, such as flight and medical simulations, for students to train in high-risk scenarios [1]. These simulations provide students the opportunity to practice skills repeatedly when the real experience can be dangerous or require more resources than are available. Users can achieve a sense of presence in the VR environment when using immersive VR videos and headsets [2]. VR headsets, or head-mounted displays, allow the user to look around the VR or 360° environment as they would in reality.

Various studies have shown that incorporating VR in an educational setting can yield positive results [3]–[5], although others have shown that results are still mixed with respect to VR's effect on learning [6]. VR videos used for education should be designed carefully to prevent negative effects on student learning from extraneous details within the VR environment not relevant to the subject [7]. Additionally, complex systems to view VR environments may also affect student learning as it may take longer for students to acclimate to the system [8]. To produce effective VR videos for educational purposes, the videos must keep the student engaged and focused on the task or topic.

Engagement is the investment of effort and attention toward course material [9]. Student engagement in the classroom has been linked to academic performance with a correlation between student perceived engagement and test scores [10]. The development of more engaging teaching modalities could provide great benefits for students understanding of the material.

Laboratory courses are essential to STEM classes as they provide an opportunity for students to learn hands-on skills and interact with equipment they may use in their future careers [11]. Incorporating VR videos into lab courses could prove beneficial in the case if a student wants to experience the lab additional times or if a student cannot be present in the lab. Regular videos are a common tool in education as it provides a visual representation of concepts. Access to supplemental videos allows students to review concepts if they did not fully understand them or to fill in knowledge gaps [12]. Additionally, VR videos would allow each student to be at the center of the instruction whereas, during in-person regular labs, there are multiple students per instructor.

Virtual reality videos created using course-specific content could prove to be a beneficial educational tool. This study aims to assess VR videos as an educational tool by implementing 180° 3D VR videos in a remote Biomolecular Engineering laboratory course. The videos contain experiments specific to the course and performed by the course teaching assistants. Student engagement with the material and the videos' ability to adequately present course information were evaluated using student feedback through surveys.

2. Methods

The goal of this study was to determine if VR videos could be used as an educational tool and provide a substitute for in-person laboratory courses when lab spaces are unavailable. Students viewed the VR videos of the teaching assistants (TAs) performing the lab tasks before attending a Zoom lab session where they could discuss the lab with the TAs and begin writing a lab report. Students were provided a lab protocol in advance of the video and lab session to get an idea of the purpose and procedures of the lab before viewing the video. After viewing all the VR lab videos, students were distributed a survey to self-report their experiences with the VR videos. This study design was reviewed by the University's Institutional Review Board, protocol number 2012306663, and determined to be exempt.

2.1 Experimental Design

Students were provided with a lab protocol sheet, the VR videos, and data sets to analyze for a remote lab course. The protocol sheet and VR videos were made available a week before the students' scheduled Zoom lab session where they were able to discuss the lab with the teaching assistants and begin writing a lab report. All students were provided with a Google Cardboard headset to view the videos using their smartphones to ensure equal access to materials across all students. After viewing all the VR videos, students were provided an online survey through Qualtrics to report their experiences with the VR videos and headset. These survey responses were collected and analyzed.

2.2 Creating the Videos

The videos were created using an Insta360 Evo camera. This camera has the ability to record 180° 3D video. The course TAs were filmed performing the lab experiments as the students would have in an in-person lab. Each video was between 10 and 40 minutes in length depending on the content the lab covered. Insta360 Studio software and Adobe Premiere Pro were used to edit the videos. Images and text were added to highlight or depict certain concepts, for example, a diagram of the plasmid to be used in the lab experiment. These images were the same or similar to images that would have been used in an introductory presentation at the start of an in-person lab.

2.3 Distribution of Videos

The videos were uploaded to a course YouTube page labeled as unlisted, requiring a link to the video to view. This link was uploaded to the course webpage on the university's course management system one week prior to the Zoom lab session. The lab protocol for this lab was also available at least one week before the lab. Students were to view this video before attending the lab Zoom session. Students were given Google Cardboard headsets to view the videos using their smartphones. These headsets are constructed of folded cardboard and a pair of lenses that provide the VR effect. Students would navigate to the video on their phone, select the VR setting to enter their phone into VR viewer mode, and inserted the phone into the viewer compartment of the Google Cardboard. This setup allowed students to view the video in 180° 3D VR where they were able to look around the 180° environment. If students were unable to use the headsets due to technical issues with their phone, if the phone did not fit in the headset, or due to discomfort with the VR or headset itself, YouTube provides a desktop viewing option that provides a partial VR effect. The video is presented on the desktop as a normal YouTube video would be, however, the user is able to click and drag the video to look around the VR environment.

2.4 Survey

A survey was used to collect data. This survey was adapted from questionnaires used by Goehle (2018) [3], Sultan et al. (2019) [13], and Singh et al. (2020) [14]. Students self-reported their experiences with the VR videos. The survey included 11 5-point Likert questions (where 1 = Strongly Disagree, 3 = Neutral, and 5 = Strongly Agree) and 7 open response questions. These questions evaluate four aspects of the videos: engagement, video content, the potential for future use, and functionality of the equipment. Student engagement with the material was measured as it can provide better learning. The video content questions evaluated whether the videos contained enough and appropriate information for the students to understand the purpose and procedures of the lab. The potential for future use questions evaluates if VR videos, for this class specifically or in general, could be used in future lab courses. The equipment functionality questions related to any technical issue the students may have faced including if their phones fit in the viewer, if they had trouble accessing the videos, if they felt discomfort from the headset or the VR effect. This survey was distributed online through Qualtrics and provided to students through email or a link on the course webpage. These survey questions are listed in Table 1.

Table 1. Survey Questions

Questions	**What is being measured**
5-point Likert Questions	
The use of VR helped me feel more engaged with the lesson.	Engagement
The use of VR allowed me to learn at my own pace.	Engagement
The use of VR technology eliminated or reduced auditory and visual distractions from the environment.	Engagement
The use of VR technology helped me understand the material.	Video Content
The VR videos increased my retention of the course material.	Video Content
The videos provided enough information to understand the task.	Video Content
The use of videos met my expectations about this lab.	Video Content
The videos provided an acceptable alternative to in-person labs.	Potential for future use
I would feel confident applying the skills/techniques from the videos in person.	Potential for future use
I would like to use this kind of video in future labs.	Potential for future use
I experienced some kind of discomfort (e.g. claustrophobia, nausea, dizziness) while using the VR technology.	Functionality
Open Response Questions	
Was the length of the videos appropriate for the material covered? Please explain your answer.	Engagement
Did you watch any of the videos multiple times? If so, why?	Video Content
Did you experience any problems using/viewing the videos for the lab? If so, which ones?	Functionality
Did you use the headset while watching the VR videos? Please explain.	Functionality
What aspects of the VR lessons were helpful and/or effective?	N/A
What aspects of the VR lessons were not helpful nor effective?	N/A
Suggestions or comments.	N/A

2.5 Data analysis

Data was collected using a student self-reported survey. Percentages were calculated for the response distribution for each Likert question. These distributions were graphed using Excel, graphing questions together for each aspect they were measuring. Responses to the open response questions were sorted into categories of similar remarks and percentages were calculated.

3. Results

3.1 Engagement

Three Likert questions were asked regarding the students' engagement with the material, as shown in Figure 1.

Many students, 29%, agreed that the VR technology eliminated or reduced environmental distractions, However, a greater portion of participants disagreed, 34%, or strongly disagreed, 13% with the statement. 25% responded neutral. Regarding the statement, "The use of VR helped me feel more engaged with the lesson," 16% of students strongly disagreed, 30% disagreed, 25% responded neutral, 23% agreed, and 5% strongly agreed. The VR videos proved effective at allowing students to work at their own pace with 48% of participants strongly agreeing, 41% agreeing, 7% responding neutral, and only 4% of students disagreeing with the statement.

The open response question, "Was the length of the videos appropriate for the material covered?" was included in the survey. 64% of participants responded that the videos were an appropriate length, 21% thought only some of the videos had an appropriate length, and 14% responded that the videos were not an appropriate length.

Student comments included,

- "The 20-30 minute ones were too long to focus on. The 15-minute videos seemed to be a good length to include all necessary information while also keeping my attention."
- "Yes, some of the labs themselves are quite long so the length of the videos is appropriate."
- "The videos that were nearing an hour were in my opinion a bit too long - I would prefer something more around 30 minutes on the upper end. A video longer than that becomes very difficult to pay close attention to for the entire duration."

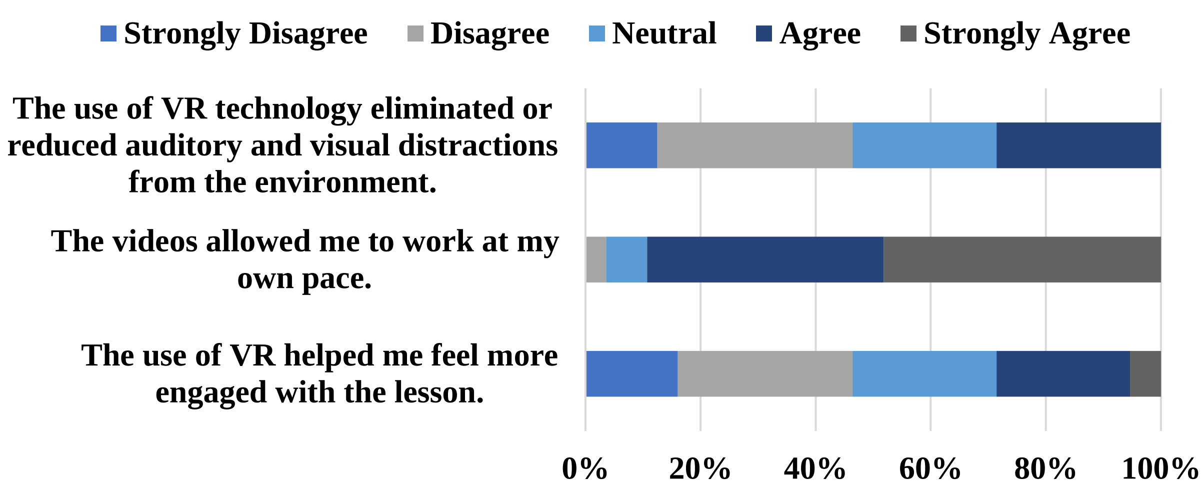

Figure 1. Response distribution to the survey Likert questions regarding student engagement with the material.

3.2 Video Content

Four Likert questions, shown in Figure 2, and one open response question regarding the content of the videos were asked.

A majority of students responded that they agree or strongly agreed, 46% and 13% respectively, that the videos met their expectations for the remote lab course. 7% of participants strongly disagreed, 13% disagreed, and 21% responded neutral. A great majority of students, 61%, agreed that the videos provided enough information to understand the tasks shown in the videos, with an additional 13% strongly agreeing with the statement. 21% of students responded neutral, and only 5% disagreed with the statement. The statement "The VR videos increased my retention of the course material" received a response distribution of 2% strongly agreeing, 14% agreeing, 36% responding neutral, 30% disagreeing, and 18% strongly disagreeing. The student responses to the statement, "The use of VR technology helped me understand the material," received responses of 14% strongly disagree, 39% disagree, 38% neutral, and 9% agree.

The open response question, "Did you watch any of the videos multiple times?" was asked. 68% of participants responded that they had watched the whole videos or parts of the videos multiple times, many noting they reviewed in order to study for lab quizzes. A student commented, "Yes. I typically watched every video more than once to prepare for the lab quizzes."

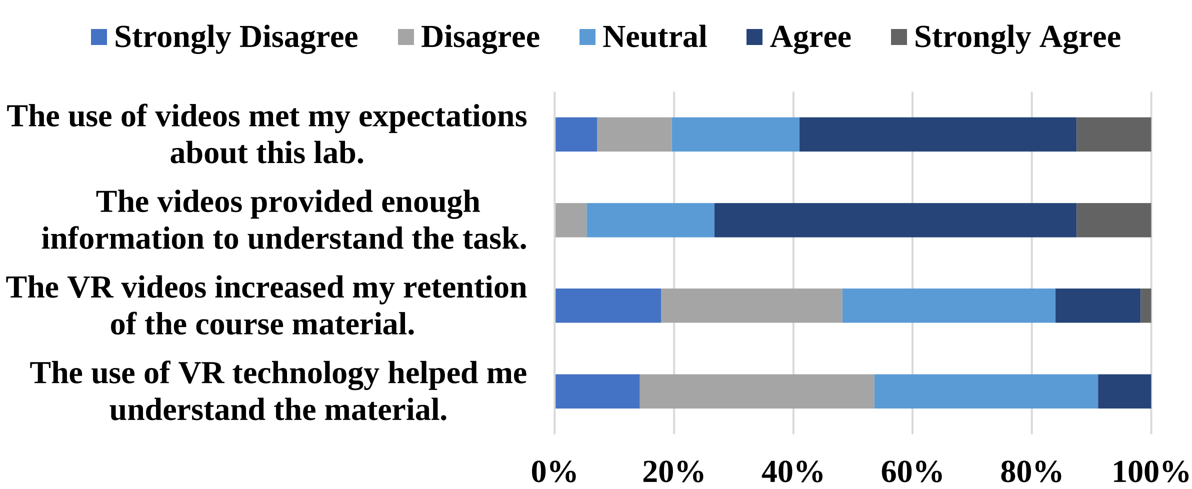

Figure 2. Distribution of responses for the survey questions regarding the video content.

3.3 Potential for future use

Three Likert questions were included in the survey regarding the potential for future use of VR videos in lab courses, as shown in Figure 3.

The statement, “I would like to use this kind of video in future labs,” received the response of 18% of participants strongly disagreeing, 27% disagreeing, 23% neutral, 25% agreeing, and 7% strongly agreeing. Regarding the students' confidence in using the skills presented in the videos, 14% strongly disagreed and 23% disagreed that they would feel confident using the techniques. 23% of students agreed and 7% strongly agreed they would feel confident. 32% responded neutral. The statement, “The videos provided an acceptable alternative to in-person labs,” received a fairly even split between agreement and disagreement with 16% strongly disagreeing, 25% disagreeing, 16% responding neutral, 25% agreeing, and 18% strongly agreeing.

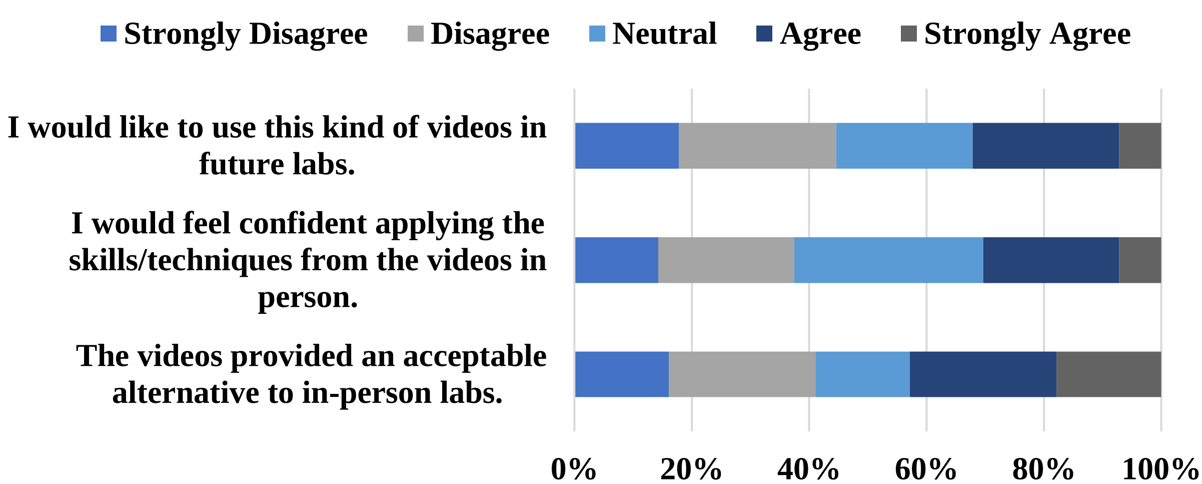

Figure 3. The response distribution for the survey Likert questions regarding the potential for future use of VR video in lab courses.

3.4 Functionality

One Likert question and two open response questions were included in the survey regarding the functionality of the VR equipment. The response distribution for the Likert question is depicted in Figure 4.

A majority of students experienced discomfort with the VR videos with 36% agreeing and 29% strongly agreeing with the statement, “I experienced some kind of discomfort (e.g. claustrophobia, nausea, dizziness) while using the VR technology.” 9% of participants responded neutral, 16% disagreed, and 11% strongly disagreed.

In response to the question, “Did you experience any problems using/viewing the videos for the lab?” 62% of students reported no problems while 38% reported experiencing problems. Of the students that did have problems viewing the videos, some noted discomfort with the headset itself, text not appearing correctly, video or audio quality, or experiencing nausea. A student noted, “The quality of the lens[es] were too low and as a result the video was too blurry to actually see any fine detail.”

When asked, “Did you use the headset while watching the VR videos?” 54% of participants reported they did not use the headsets to view every video, citing discomfort with the headsets or nausea. Student comments included, “Sometimes. Though they did seem to keep me more engaged in the labs, they did hurt my head/eyes after a while,” and, “I did for 2 of the labs. Out of convenience I would watch on a laptop. I did not find the headset to be beneficial to my understanding of the material.”

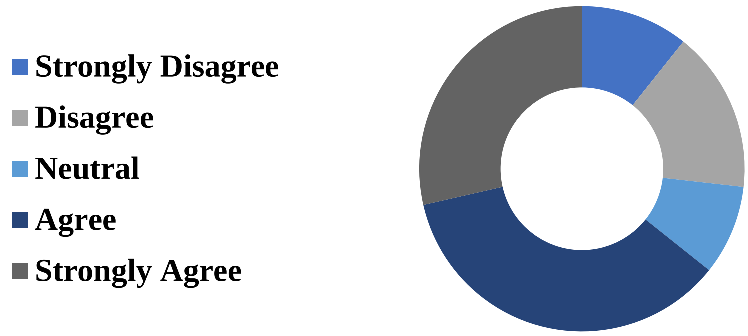

Figure 4. The response distribution of the survey question “I experienced some kind of discomfort (e.g. claustrophobia, nausea, dizziness) while using the VR technology.”

3.5 Other Comments

General “commonly occurring” representative comments from students included:

- “The visual[s] were useful to convey the procedures. I am a visual learner so it was easier to comprehend the material better by watching someone rather than reading a protocol sheet.”
- “I liked being able to pause/rewind/rewatch to make sure I understood the material. I also like being able to move around the VR video with my mouse in the window. It's helpful to have explanations of the material beyond just demonstrating steps (explaining the importance of each task).”
- “Lens quality MUST improve and perhaps break up any videos longer than 10 minutes into 2 videos to help with attention.”
- “It was just overall difficult to feel comfortable and confident in the material through video since it should have been skills we were learning hands-on.”
- “When viewing through the headset, the video was blurry and the headset was uncomfortable. Also, the text would often not display correctly on the videos.

4. Discussion

Students were divided when asked about engagement, however, a majority of students agreed that the videos provided the opportunity to work at their own pace. This allows students to stop or rewatch parts of the video/lab they did not understand. This keeps students engaged with the material because they can stay focused and get all the needed information without the lesson going too fast or too slow. The headsets did not prove effective in removing distractions from the environment. This could be partly due to the Google Cardboard headsets not having audio capabilities and relying on the speakers in the smartphone unless headphones were used. The ability to hear the outside environment while watching the VR videos would have affected the immersion students felt in the VR video environment, possibly taking away from the students' engagement with the VR videos. Additionally, videos should be kept between 10 to 20 minutes, or broken up into segments for longer videos, in length to help students keep their focus and attention on the lesson.

A majority of students did not feel as though the VR aspect of the videos helped their understanding or the retention of the course material, however, they agreed that the videos contained the needed information to understand the procedures of the labs. As many students reported watching parts of the video multiple times in order to study for lab quizzes or reports, the videos were effective in conveying the course material.

The students were close to an even split in agreement or disagreement when asked if the videos provided an adequate alternative to in-person labs. In addition, student comments pointed to students preferring in-person labs when possible and would not want VR videos to fully replace an in-person experience. Students were also split in their confidence in the learned skills with the most responses being neutral. Overall, students would prefer in-person labs, as the main function of a laboratory component of a class is to get hands-on experience with the theory learned in a course. VR videos in this current form would best be used as a supplement to an in-person lab course, if available, rather than replacing in-person lab time. Student responses show that they felt the videos were helpful and contained enough information, but would not want the VR videos to be the only option for learning lab skills.

A majority of students experienced discomfort from viewing the VR videos. This could be caused by multiple aspects. Students reported that the headset itself was uncomfortable. This is due to the design of the Google Cardboard headset, as the folded cardboard box cannot comfortably conform to the planes of the face and the weight of the phone caused the headsets to not sit properly on the face. The VR effect of the videos also caused feelings of nausea and affected some students greater than others. Nausea due to VR experiences could have been exacerbated by the fact that the smartphone was used as the viewing screen. The google cardboard headsets do not contain gyroscope capabilities to accurately depict the movement of the user's head, instead, relying on the gyroscope capabilities of the phone, most of which can only estimate based on phone location. This can cause a disconnect between the user's actual movement and the movement of the VR environment, resulting in a greater feeling of nausea than inclusive headsets might cause.

A continuation of this project is currently being implemented. A higher-quality camera was obtained allowing recording of 3D 360° videos with higher quality images. Oculus headsets were also obtained. These sets are more comfortable and self-contained, not requiring the students' phones to be used. The lab videos were recorded in a similar manner, containing the teaching assistants performing the lab experiments. As lab spaces were available, these VR videos were used as supplementary pre-lab videos before students performed the lab procedures in person. This study is ongoing, but some preliminary student feedback has been obtained.

Some students thought the videos were helpful and liked the VR aspect. Others felt that viewing the videos at the start of their scheduled lab session immediately before performing the lab in-person may have been unnecessary as the TA could answer any questions while the students performed the lab. Further data will be collected and analyzed using pre-and post-surveys and quiz grades

5. Conclusion

Student feedback has provided evidence that VR videos created with course-specific content were capable of conveying the procedures of a laboratory course, but students would prefer in-person labs when available. VR videos would best be utilized in combination with regular lab courses. The VR viewing experience could be greatly improved by better equipment, both in the camera used when creating the videos and the headsets used to view VR videos. In the future, if VR videos are to be utilized, they should be in combination with in-person labs if possible. They provided an adequate substitute but cannot fully replace in-person labs in their current form. More studies should be conducted with better equipment to further determine their potential as an education tool.

6. Acknowledgements

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Appendix I: Informed Consent

Incorporating immersive learning into Biomolecular Engineering Laboratories using Virtual Reality

Consent to Participate in a Research Study

Principal Investigator: Mostafa Elsaadany

INVITATION TO PARTICIPATE

You are invited to participate in a research study about the use of virtual reality (VR) in a laboratory at the University of Arkansas Biomedical Engineering Department. You are being asked to participate in this study because you are a Biomedical Engineering student who is currently enrolled in the University of Arkansas Biomedical Engineering Department.

WHAT YOU SHOULD KNOW ABOUT THE RESEARCH STUDY

Who is the Principal Investigator?

Dr. Mostafa Elsaadany
Email: mselsaad@uark.edu

Who are the principal Researchers?

Megan Wilkerson
Email: mrwilker@uark.edu

Vitali Maldonado
Email: vvm001@uark.edu

What is the purpose of this research study?

The students enrolled in the Biomolecular Engineering course in the Biomedical Engineering Department will participate in a remote laboratory corresponding to the course with virtual reality (VR) labs implemented to study the effectiveness of VR to teach biomedical engineering material.

Who will participate in this study?

Approximately 70 students who are enrolled in the Biomolecular Engineering course at the University of Arkansas.

What am I being asked to do?

You will attend the lab component of the course remotely as a course requirement. You will watch the lab procedure (whether VR or regular video recorded labs). If you agree to participate in this study, at the end of the semester, you will complete a survey. Your lab quizzes' grades will be collected and analyzed.

What are the possible risks or discomforts?

Students using the VR equipment may experience simulator sickness for a short time. Also, the risks are leakage of participants' grades or their demographic information.

VR videos can be converted to a 2D video. The students who are not comfortable with using the VR equipment will be excluded from the study and provided links to the 2D videos. The duration and content of both video formats are identical.

What are the possible benefits of this study?

All the course students will be provided with VR equipment. They will learn how to use VR technology and will receive a more realistic experience of the biomolecular engineering lab. Also, the research aims to improve the learning experience and engagement in the lab of the students using VR.

How long will the study last?

The course is offered in the Spring 2021 semester. Closer to the end of the semester, the students who consent will be asked to complete a survey. The study survey/questionnaire will take about 10-15 minutes to complete.

Will I receive compensation for my time and inconvenience if I choose to participate in this study?

No.

Will I have to pay for anything?

No, participation in this study will **not** cost you any payment.

What are the options if I do not want to be in the study?

If you do not want to be in this study, you may refuse to participate. Also, you may refuse to participate at any time during the study. Your grades and academic standing in the classes will not be affected in any way if you refuse to participate. If you decide not to participate in this study, regular 2D videos will be used for the labs and your data (surveys and quiz grades) will not be included in the study.

How will my confidentiality be protected?

All information will be kept confidential to the extent allowed by applicable State and Federal law. All the data collected will be kept in a secure domain. The participants' names will **not** be included in any reported or published data. Collected data will not be deleted at the end of the semester. However, data will continue to be secured as above.

Please note that grades and class assignments will be included in the research data. Confidentiality will be protected as above.

Will I know the results of the study?

At the conclusion of the study, you will have the right to request feedback about the results. You may contact Dr. Mostafa Elsaadany (mselsaad@uark.edu). You will receive a copy of this form for your files.

What do I do if I have questions about the research study?

You have the right to contact the Principal investigator as listed above for any concerns that you may have.

You may also contact the University of Arkansas Research Compliance office listed below if you have questions about your rights as a participant, or to discuss any concerns about, or problems with the research.

Ro Windwalker, CIP
Institutional Review Board Coordinator Research Compliance
University of Arkansas 109 MLKG Building
Fayetteville, AR 72701-1201
479-575-2208
irb@uark.edu

I have read the above statement and have been able to ask questions and express concerns, which have been satisfactorily responded to by the investigator. I understand the purpose of the study as well as the potential benefits and risks that are involved. I understand that participation is voluntary. I understand that significant new findings developed during this research will be shared with the participant. I understand that no rights have been waived by signing the consent form. I have been given a copy of the consent form.