2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering
Education for 130 Years
ASEE
Paper ID #38478

# Board 17: Work in progress: Immersive Virtual Reality-Based Learning in Biomedical Engineering Labs: Lessons Learned and Recommendations for Efficient Integration

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Dr. Mostafa Elsaadany is an Assistant Professor in the Department of Biomedical Engineering at the University of Arkansas. He received his Ph.D. in Biomedical Engineering from the University of Toledo. Dr. Elsaadany teaches Introduction to Biomedical Engineering, Biomechanical Engineering, Biomolecular Engineering, Senior Design, and Entrepreneurial Bioengineering. He is active in Engineering Education Research, where he studies different mentoring strategies to ensure the academic and professional success of underrepresented groups. Further, he studies strategies for instilling the entrepreneurial mindset in engineering students as well as innovative approaches to teaching such as using virtual reality.

# Work-in-Progress: Immersive Virtual Reality-Based Learning in Biomedical Engineering Labs: Lessons Learned and Recommendations for Efficient Integration

**Dr. Ishita Tandon, University of Arkansas**

Ishita Tandon is an SEC Emerging Scholars Postdoctoral Fellow in the Department of Biomedical Engineering. Her research involves developing multiscale *in vitro* and *in vivo* models of heart valves aimed at studying the early detection and monitoring of calcific aortic valve disease. She has received the American Heart Association Predoctoral Fellowship and the University of Arkansas Doctoral Academy Fellowship along with multiple other honors and travel grants. She has also published 13 peer-reviewed articles, a book chapter, and given over 20 conference presentations including an invited talk. Ishita served as the finance chair of the Graduate Society of Women Engineers (SWE) and was the co-founder and president of the Biomedical Engineering Department Graduate Students' Organization. Her career objective is to pursue translational biomedical research in academia. Her leadership goal is to inspire and uplift women who lack opportunities for education, self-development, growth, and leadership.

**Mr. Vitali Maldonado, University of Arkansas**

Vitali is a recent graduate of the University of Arkansas with a B.S. in Biomedical Engineering.

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Megan is a recent graduate of the University of Arkansas with a B.S. in Biomedical Engineering.

**Ms. Amanda Walls, University of Arkansas**

Amanda Walls is a doctoral student, funded by an NSF Graduate Research Fellowship, in the Department of Biomedical Engineering at the University of Arkansas. She received her B.S. in Biomedical Engineering from Harding University, where she was first introduced to engineering education research examining students' perceived identities in a first-year engineering course. While her current dissertation work is focused on developing organ-on-chip technology to study the human airways, Amanda also has a strong interest in teaching and education research. She has devoted a semester to teaching as an adjunct instructor for Fundamentals of Chemistry at John Brown University, completed a micro-certificate in the professoriate, and led several educational experiences for underrepresented high school students. Amanda plans to pursue a higher education teaching career and research strategies to promote active learning and improve self-efficacy amongst engineering students.

**Dr. Raj R. Rao, University of Arkansas**

Dr. Raj R. Rao is a Professor of Biomedical Engineering, University of Arkansas, Fayetteville. He currently serves as the Editor-in-Chief of the Journal of Biological Engineering, as an ABET Program Evaluator; and is a member of the Biomedical Engineering Society (BMES) Education Committee. His research interests are in the broad area of cellular engineering that utilize interdisciplinary approaches toward a better understanding of stem cell fate in the context of regenerative biomedical therapies. He is committed to the integration of research and education and has developed courses and programs that relate to entrepreneurship, service learning, and community engagement. He is an elected Fellow of the American Institute of Medical and Biological Engineering (AIMBE), an elected Fellow of BMES, and Past-President of the Institute

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**Dr. Mostafa Elsaadany*, University of Arkansas**

Dr. Mostafa Elsaadany is a Teaching Assistant Professor in the Department of Biomedical Engineering at the University of Arkansas. Dr. Elsaadany teaches Introduction to Biomedical Engineering, Biomechanical Engineering, Biomolecular Engineering, Senior Design, and Entrepreneurial Bioengineering. He is active in Engineering Education Research where he studies different mentoring strategies to ensure the academic and professional success of historically marginalized minorities. Further, he studies strategies for instilling the entrepreneurial mindset in engineering students as well as innovative approaches to teaching such as using virtual reality.

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## Introduction

Immersive virtual reality (VR) based laboratory demonstrations have been gaining traction in STEM education. VR may serve as a valuable tool not just for remote learning but also to broaden outreach, reduce waste, enhance safety, generate increased interest, and modernize education. VR holds great potential to complement existing education strategies [1, 2]. However, to ensure better utilization of VR-based education, it is pivotal to perform optimizations of VR implementation, in-depth analyses of advantages and trade-offs of the technology, and assessment of receptivity of modern techniques in STEM education [1, 3, 4].

There have been several studies that tested the effectiveness of VR in the educational field. A study utilized VR technology to simulate a radiotherapy treatment machine for radiotherapy students. The results showed an improvement in their understanding of technical skills and their confidence in applying them [5]. Another study used VR technology to teach students chemistry concepts and was successful in improving the performance of students having poor spatial ability [6]. In a previously published study [7], we developed VR-based demonstrations for a biomedical engineering laboratory and assessed their effectiveness using surveys containing free responses and 5-point Likert scale-based questions. In a cohort of 56 students, more than 70% reported VR videos allowed them more flexibility of pace and understanding of the task while 65% of students reported experiencing some form of discomfort. Overall, students performed significantly better in lab quizzes after VR-based demonstrations. The Insta360 EVO VR camera in 180° 3D mode was utilized to record 20-50 minute-long labs incorporating a brief overview and experiment and visualized via Google Cardboard headsets [7].

The current study aimed to overcome the limitations of video length and equipment quality and integrate VR as a complementary mode of lab instruction. State-or-the-art VR equipment, i.e., Insta 360 Pro2 camera and Meta Quest 2 headsets were used in combination with an in-person lab. The goals of the study were to assess the students' perception and experience with VR in terms of engagement, content, functionality, and potential for future use. Insights from this study help in optimizing the implementation of immersive VR to effectively supplement in-person learning experiences and overcome the potential challenges and pitfalls of integrating VR with traditional modes of learning.

## Materials and Methods

To assess the utility of VR technology and its potential as an effective complement to in-person labs, VR videos were introduced to a junior-level biomolecular engineering lab consisting of 53 students, in the Department of Biomedical Engineering. A total of 8 labs focused on topics related to bacterial growth, transformation, protein isolation and assessment, and mammalian cell culture. Each lab included a pre-lab quiz that was submitted before the students came to the lab. During the lab, the students were given a brief overview of the lab concepts and background information along with a detailed procedure for performing the experiments via traditional Powerpoint slides. The first four in-person labs did not utilize VR videos and were designated as pre-VR labs. The VR-based videos were incorporated in lab number 5 and forward and were designated as post-VR labs. The 3-20 minute long VR videos were presented during their respective lab time. Four lab instructors were trained to film and edit the videos. Insta360 Pro II was used to film the VR videos. All the students were able to watch the video at the same time on a personal Oculus Quest 2 VR headset. Students were asked to watch the videos at the beginning of each lab utilizing the VR headsets and use the information presented in those videos to execute the lab procedures. The video content was created by the lab instructors and contained step by step procedure of the experiment to be performed during the respective lab. The lab instructors were present throughout the lab to assist the students in watching the videos, navigating the VR technology, and performing the lab experiments.

Students were divided into groups of 2-4 to be able to work together to perform the experiments. After the end of each lab session, students were asked to submit a post-lab quiz which was due a few days later. After every 2 labs, the students were asked to submit a lab report detailing the background, methods, results, conclusion, and discussion. Assessment of quiz scores and lab report scores were used for the assessment of the utility of VR along with the two surveys. Each survey contained both open-response questions and 5-point scale Likert questions with the options of “Strongly Disagree”, “Disagree”, “Neutral”, “Agree”, and “Strongly Agree”. The first survey was intended to measure the student’s expectations about the use of VR technology and was distributed after the students completed the first four labs (Appendix). The second survey (Appendix) was distributed at the end of the semester and intended to measure the experience and opinion of the students about VR technology as supplemental academic material after they experienced the videos. All the participants of this study gave consent to participate in it. This research was approved by the university [] Institutional Review Board (IRB protocol #: 2012306663).

**Results and Discussion**

**Few students had a positive/hopeful perception of VR-based labs**

Pre-VR Survey revealed that 62.26% of students admitted to having some form of previous experience with VR equipment; however, 39.4% of those students said to have experienced some kind of discomfort (e.g., claustrophobia, nausea, dizziness) while using VR technology previously (Figure 1A). However, 58.48% of students agreed or strongly agreed that the novelty of VR videos would make the course material more interesting (Figure 1B).

**Video content and the VR equipment quality influenced the student experience with VR**

Students in the current study comprised cohort 2 (C2) for whom Insta 360 Pro2 camera and Meta Quest 2 headsets, were used in combination with an in-person lab. The experience of cohort 2 students was compared to students from a previous semester designated as cohort 1 (C1) that utilized the Insta360 EVO VR camera in 180° 3D mode to record 20-50-minute-long labs incorporating a brief overview and experiment and visualized those videos via Google Cardboard headsets [9]. In response to the question that the videos provided enough information to understand the task, compared to cohort 1 a fewer number of students agreed or strongly agreed in cohort 2 (Figure 1C). Additionally, a greater number of students in Cohort 2 agreed or strongly agreed that the use of VR technology helped them understand the material as compared to Cohort 1 (Figure 1D). These responses may suggest that the quality of content created by the lab instructors influenced the VR experience of students. However, the use of advanced VR equipment positively impacted the delivery of the content to the students. As expected, the advanced VR equipment was found to significantly reduce the discomfort associated with the use of VR among cohort 2 students as compared to cohort 1 students ($p = 0.0007$) (Figure 1E).

**The use of VR aided in the understanding of lab procedures and tasks but not the lab concepts and background**

Between cohorts 1 [7] and 2, post-lab quiz scores for the VR-based labs were not significantly different suggesting that the equipment quality may not have impacted the material reception and retention of the lab concepts and background information (Figure 1F). Students in cohort 2 scored significantly higher in lab reports for the VR-based labs as compared to non-VR labs and compared to cohort 1 VR-based labs (Figure 1G). This may suggest that VR videos may have provided a better understanding of the lab procedures and tasks leading to a better-written lab report.

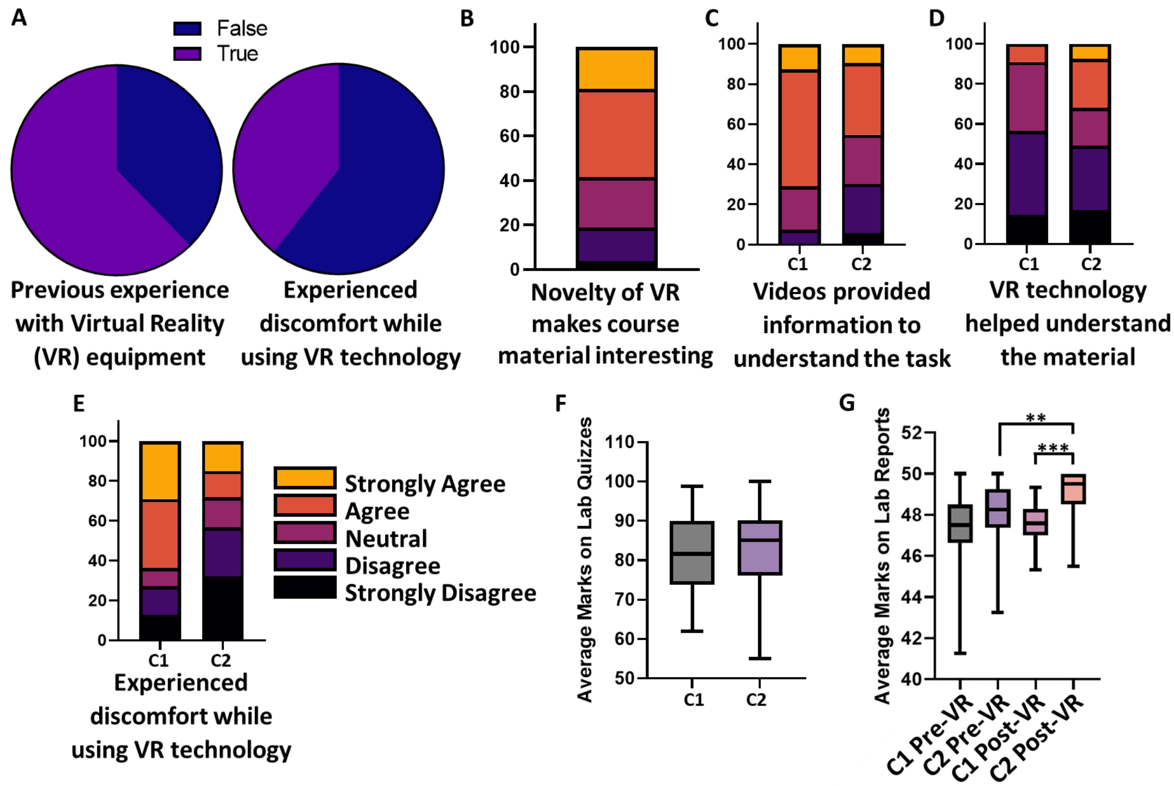


**Figure 1:** (A) Student perception and (B) Experience with VR from Pre VR and Post VR survey from Cohort 2. (C-E) Comparison of VR experience of Cohort 1 and Cohort 2. (F-G) Comparison of Lab quizzes and Lab reports scores.

**Conclusions and Future Directions**

Overall, this study aims to assess the student perception of incorporating VR technology as a complementary mode of teaching in biomedical engineering labs. It also aims to assess the utility of VR-based labs in terms of student engagement, potential for future use, understanding and retention of material and tasks, and usability. Thus far, student scores on quizzes and lab reports suggested that VR might be helpful in visual demonstration, understanding, and retention of the lab procedures while the traditional teaching methods may be more suitable for explaining lab concepts. A comparison of the two cohorts suggests that the advanced equipment reduces the discomfort associated with watching VR videos. Apart from equipment quality, content quality, and teaching styles may also impact the experience of students with VR. Future quantitative and qualitative (coded) evaluations of survey questions are required to understand student experience with VR. Completion of this study will help in furthering our understanding of how to successfully integrate VR videos in traditional biomedical engineering labs.

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Appendix1

Table A: Questions present in the survey pre-VR

| **5-point-scale Likert question** | |
|---|---|
| Perception about VR | I think the Virtual Reality (VR) videos will help me feel more engaged with the lesson. |
| | I think the VR videos will help my retention of the course material. |
| | I believe the VR videos will be helpful in learning the course material. |
| | I think the skills/techniques in the VR videos will be transferable to real life. |
| | The novelty of VR videos would make course material more interesting. |
| Experience with Traditional Labs | In the previous labs, I found the traditional lab introduction helpful in understanding the purpose of the lab. |
| | In the previous labs, I found the traditional lab introduction helpful in understanding the procedures of the lab. |
| Familiarity with VR | I feel comfortable/familiar with VR equipment. |
| **True/False questions** | |
| Previous Experience with VR | I have previous experience with Virtual Reality (VR) equipment before. |
| | I have experienced some kind of discomfort (e.g. claustrophobia, nausea, dizziness) while using VR technology. |
| **Open Response questions** | |
| What are your expectations for the VR videos? | |
| What about the traditional pre-lab introduction is helpful or not helpful? | |
| Suggestions or Comments? | |

Table B: Questions present in the survey post-VR

| 5 point-scale Likert questions | |
|---|---|
| Engagement | The use of VR helped me feel more engaged with the lesson. |
| | The use of VR technology eliminated or reduced auditory and visual distractions from the environment. |
| | The length of the videos was appropriate for the material covered. |
| Content | The VR videos increased my retention of the course material. |
| | The videos provided enough information to understand the task. |
| | The use of VR technology helped me understand the material. |
| Potential for Future Use | I felt confident applying the skills/techniques from the videos in the lab. |
| | I would like to use this kind of video in future labs. |
| | The use of videos met my expectations about this lab. |
| Functionality | I experienced some kind of discomfort (e.g. claustrophobia, nausea, dizziness) while using the VR technology. |
| **Open response questions** | |
| Did you experience any problems using/viewing the videos for the lab? If so, which ones? | |
| Please comment on the video length. | |
| What aspects of the VR lessons were helpful and/or effective? | |
| What aspects of the VR lessons were not helpful or effective? | |
| Suggestions or comments? | |