Exploring Diversity, Equity, and Inclusion in Remote Laboratories

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Animesh was born in Tripura, India, and raised in a liberal modern ”brown” military upbringing. He prefers the pronouns ”He/They” and considers himself a creative, sanguine, and outgoing individual. He graduated with a bachelor’s degree in Technology focusing on Electronics and Electrical Engineering from KIIT University. He is now a part of the Engineering Education Transformation Institute as a Ph.D. student under the advisement of Dr. Racheida Lewis. His research is in Engineering Education, focusing on equity, inclusion in the classroom, and easing student transition to the workforce catering to STEM graduates.

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Marcos Inonan is a PhD student and research assistant in the Remote Hub Lab (RHLab) of the department of Electrical and Computer Engineering at the University of Washington in Seattle. His research is centered on developing remote laboratories with a lens of equitable access to engineering education, and driven by his commitment to promote diversity, equity and inclusion in STEM education. In addition to his research on remote laboratories, Marcos has expertise in digital communication theory, signal processing, radar technology, and firmware engineering. Additionally, he has extensive experience in teaching embedded systems and senior design courses.

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Dr. Rania Hussein is an Associate Teaching Professor in the Electrical and Computer Engineering department at the University of Washington, where she also serves as the founder, principal investigator, and director of the Remote Hub Lab (RHLab). With her research focus on embedded systems, medical image analysis, digital twinning, and remote engineering, Dr. Hussein is committed to developing innovative solutions that enhance equity and access in engineering education and telehealth practices. Her work in promoting diversity, equity, and inclusion in higher education led to the successful building and passing of the religious accommodation law in the State of Washington, which provides alternative exam testing accommodations for students due to religious observances. Dr. Hussein is the recipient of the 2021 Innovative Program Award from the Electrical and Computer Engineering Department Head Association (ECEDHA), for founding the RHLab, as well as the 2022 IEEE Region 6 Outstanding Engineering Educator, Mentor, and Facilitator in the Area of STEM Award, recognizing her contributions to advancing students’ success, mentorship, empowering under-represented communities, and promoting equitable access to engineering education.

Dr. Dominik May, University of Georgia

Dr. May is a Professor at the University of Wuppertal. He researches online and intercultural engineering education. His primary research focuses on the development, introduction, practical use, and educational value of online laboratories (remote, virtual, and cross-reality) and online experimentation in engineering and technical education. In his work, he focuses on developing broader educational strategies for designing and using online engineering equipment, putting these into practice, and providing the evidence base for further development efforts. Moreover, Dr. May is developing instructional concepts to bring students into international study contexts to experience intercultural collaboration and develop respective competencies.

Dr. May is President of the International Association of Online Engineering (IAOE), which is an international nonprofit organization to encourage the wider development, distribution, and application of Online Engineering (OE) technologies and their influence on society. Furthermore, he serves as Editor-in-Chief for the International Journal of Emerging Technologies in Learning (iJET) intending to promote the interdisciplinary discussion of engineers, educators, and engineering education researchers around technology, instruction, and research. Dr. May has organized several international conferences in the Engineering Education Research field.

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Abstract

Over the past two decades, Remote Labs (RLs) - physical laboratory equipment that can be accessed remotely - have undergone significant advancements and have been integrated into undergraduate laboratory instruction, providing flexibility in terms of location, timing, and learning opportunities. The global pandemic further highlighted the importance of RLs, as they allowed institutes to incorporate laboratory work in engineering courses despite social distancing requirements and other restrictions. In this ongoing study, we investigate learners' perceptions of RLs as a platform that could promote diversity, equity, and inclusion (DEI). We utilized a mixed-method approach to analyze the perception of DEI among sophomore students enrolled in a digital theory course at a public university. Participants completed a survey and participated in semi-structured interviews, with the results from the survey reported in this paper, while data from interviews will be reported in future publications.

Introduction

Diversity, Equity, and Inclusion (DEI) are crucial measures because it helps institutions understand and track their progress toward creating a more diverse, equitable, and inclusive classroom culture, ensuring all students feel valued and respected. Those data can also inform decision-making and allocation of resources to address systemic issues and drive cultural change. The earliest remote laboratories were designed to permit flexibility of equipment access. Incorporating such laboratories in engineering education, however, also allows inclusivity, democratization, and participation [1, 2]. Information technology's affordance and fairness become crucial when accessing laboratory equipment. While there is much research on how remote labs contribute to the overall learning experience, there is little or no investigation into whether and how remote labs promote inclusion and equity in conjunction with instructional laboratory experiences. In addition to that, ABET (Accreditation Board for Engineering and Technology) proposed modifications to the general criteria for accrediting engineering programs, which states that the curriculum should also include a professional education component consistent with the institution's mission and the program's educational objectives and promotes diversity, equity, and inclusion awareness for career success [3]. "The need to feel belongingness and linked with others" is how relatedness is defined (Baumeister and Leary [8]). According to studies, learning environments that provide a sense of connectedness to peers, parents, and instructors can enhance motivation and improve academic results (Ryan, et al. [9]). Self-efficacy, engagement, interest in school, higher grades, and retention have all been connected to feelings of relatedness, which are measured in terms of "school environment" and instructor-student connections (Inkelas, et al. [10]). Research on student motivation in hybrid and remote engineering lab modes was presented in the publication "Understanding Remote Student Motivation in Hybrid and Remote Engineering Lab Modes" by Li and Bringardner. The study intends to show how remote learning affects engineering students' motivation and engagement in a laboratory environment [7]. The utilization of virtual labs in engineering education and the difficulties and advancements reported in the paper Introduction to Engineering Virtual Labs: Challenges and Improvements. Here, most students expressed that they prefer in-personal laboratories, especially those who learn by doing [11]. While there is research on how remote

labs contribute to student success and learning outcomes, there needs to be more research that brings light to remote labs being equitable and inclusive to all student groups. Academic achievement has increased across all grade levels and subjects when there is a positive classroom climate [12]. A faculty member may also be required to "show understanding and abilities relevant to establishing an equitable and inclusive environment for its students, as well as knowledge of appropriate institutional policies on diversity, equity, and inclusion" [13].

This research serves as a follow-up to the research presented in Atienza and Hussein's [5] of the Remote Hub Lab group [6], that investigated students' perspective on equitable access using remotely accessible laboratories. The authors surveyed a small number of students and the results showed evidence that remote labs could be a viable solution for equitable access in engineering education. This study leverages the survey used in [5] with a focus on DEI and surveying a larger number of students. Additionally, we conducted another study [14] that focused on investigating digital inequalities and equitable access in remote laboratories (RLs) in engineering education. The outcomes of these studies shall shed light on the role of remotely accessible laboratories in improving the accessibility and fairness of hands-on labs for all learners.

Methodology

The research adopts a mixed-method approach as it allows us to take advantage of both qualitative and quantitative methods to produce a comprehensive and nuanced answer for the following research question.

Research Question: How does remote laboratories contribute to diversity, equity, and inclusion (DEI)?

The study surveyed students in a sophomore level course on digital theory who are using the remote laboratories for the first time. Demographic questions gather information on the background and characteristics of learners, such as their age, gender, ethnicity, socio-economic status, etc. That information provides a baseline understanding of the learners using the remote lab environment. The demographic information is further utilized to create a targeted focus group. Climate questions focus on fairness in remote lab environments and are meant to assess the inclusiveness of the remote lab environment. These questions evaluate the RL's contribution towards equal access and inclusion in a classroom setting. The answers to these questions are utilized to provide valuable insights on how to improve the remote lab experience and ensure that technology is not a barrier to success in the remote learning environment. The qualitative focus group interviews were organized to delve more in-depth into equitable access and fairness of RLs, focusing on the challenges faced and further recommendations to enhance the technology.

We conducted this research to hear from students using remote labs for day-to-day laboratory activities for Electrical/Computing courses. The course involved in this study is developed to equip learners with a comprehensive understanding of digital computer systems. It covers fundamental concepts such as digital logic, Boolean algebra, combinational and

sequential circuits, and programmable logic devices. Additionally, the course emphasizes using the Verilog hardware description language, which is widely used in the industry to design and implement complex digital systems. The participants of this study are from Electrical and Computing Engineering at a reputed R1 institute in the western United States of America. 95% of the survey participants constitute senior and Junior students enrolled full-time in their program, and 88% of the class population have never used remote hardware prior to registering for this course. Out of the entire student population, almost 97% of the class participated in this study. 47% of the survey respondents expressed their interest in being further contacted about their remote lab experience, of which 26% were recruited for focus group interviews.

The findings of this paper were based on data analyzed from the survey, which helped to comprehend the research inquiry. However, we will explore the focus group interview transcripts and establish a correlation between students' backgrounds and any potential feelings of exclusion and inequality. By thoroughly examining and analyzing the transcripts, we aim to provide deeper insights in our upcoming research to enhance the remote lab experience. The focus group results will be published in another study in the future.

Demographic Data

The classroom involved in this study consisted of a diverse group of students, with 35% being first-generation college students. Additionally, 44% of students identify as people of gender, and 12% identify as part of the LGBT population (figures 1, and 2). Furthermore, 13% of students identify as having a disability (figure 3).

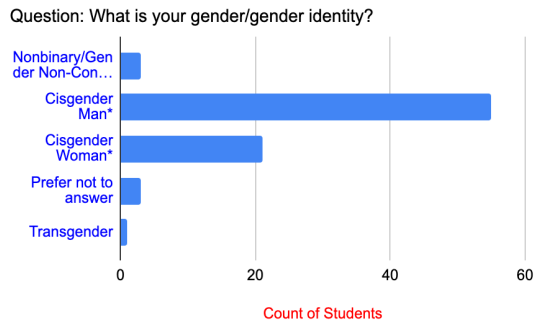

Figure 1: Class Representation as per gender identity

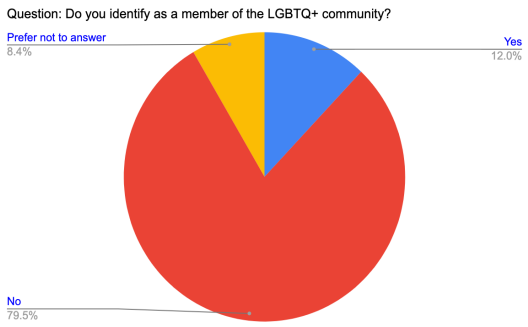

Figure 2: Representation of students with LGBTQ+ identity

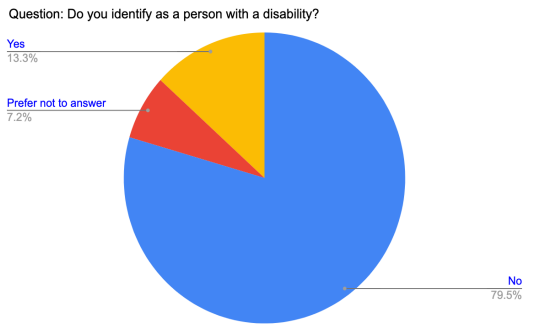

Figure 3: Class Representation of students with disability

Respondents were allowed to check all racial or ethnic groups they identify with when asked, "Please indicate the racial or ethnic groups with which you identify." The results indicate that the largest group of respondents identified as Asian American/Asian constituting 42.2 percent of the class, followed by White 27.7 percent, Hispanic/Latinx 6 percent, African American/Black 4.8%, Middle Eastern/North African 3.6 % and Native American/Alaskan Native and White 2.4%. Some respondents identified with multiple racial/ethnic groups, resulting in various combinations (figure 4). Data also showed that 25% of students come from a low-income background (figure 5).

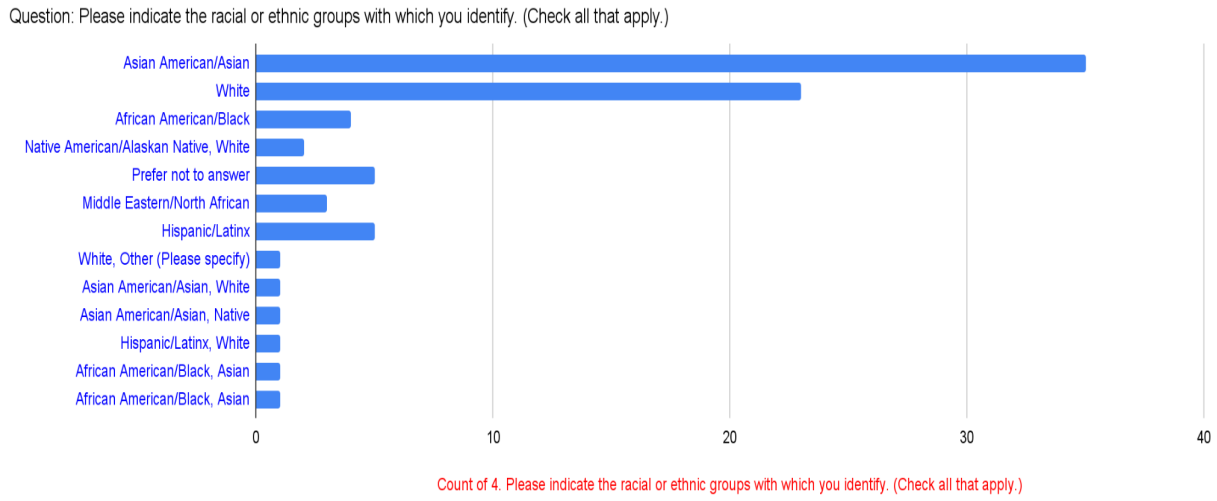

Figure 4: Count of students indicating racial and ethnic identity

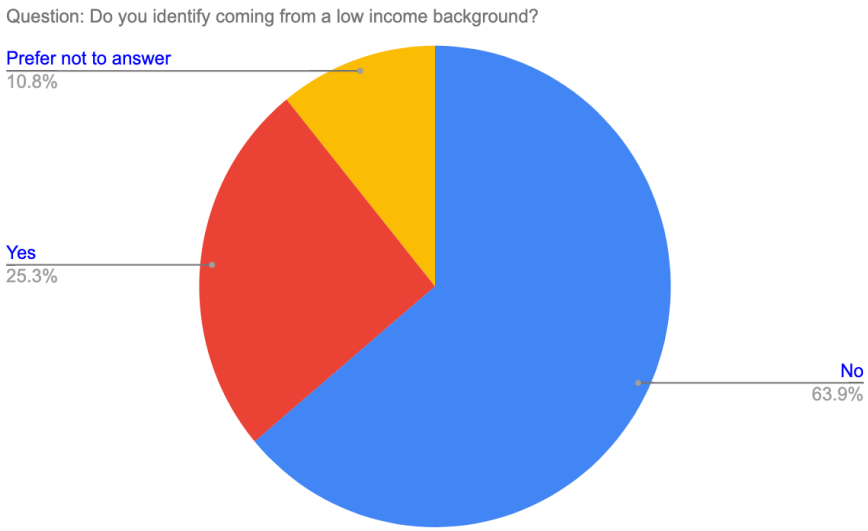

Figure 5: Percentage of students of low income

Findings

In this section, we present analytical findings about students' responses to remote laboratories which were analyzed and gathered from survey responses that include both qualitative and

quantitative perspectives. When asked about other helpful or challenging aspects of the remote lab, no responses related explicitly to DEI issues, which indicated that none of the students faced any challenges related to DEI. In addition to figure 6 & 7 the survey results showed that most class respondents found remote labs accessible, constituting approximately 95% of the class population. However, 42% of the class responded neutrally to the importance of building and implementing remote lab experiences considering diverse individual learners (figure 5). Additionally, close to 11% of the class respondents felt excluded from the course activities while using the remote lab (figure 6).

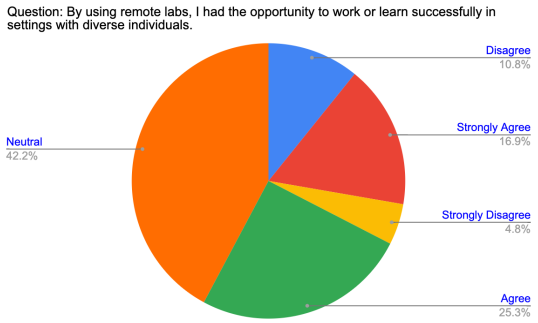

Figure 6: Showing percentage of students expressing RL's opinion on promoting diversity

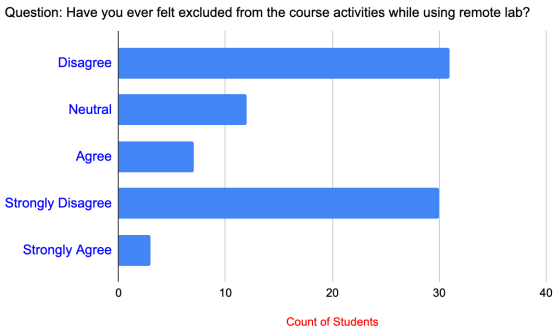

Figure 7: Showing count of students who felt excluded using RLs.

While it's true that some students may be interested in purchasing physical technology for various purposes, regardless of their socioeconomic status, the expensive DE1-SoC hardware may not be affordable for everyone. When asked about their willingness to purchase a lab kit or share one either for classwork or for personal projects or interview preparation, the responses showed a tendency to acquire one (figure 8.1 & 8.2). This is where remote labs can provide an accessible solution, enabling all students to gain access to industry-grade, expensive hardware at an affordable cost.

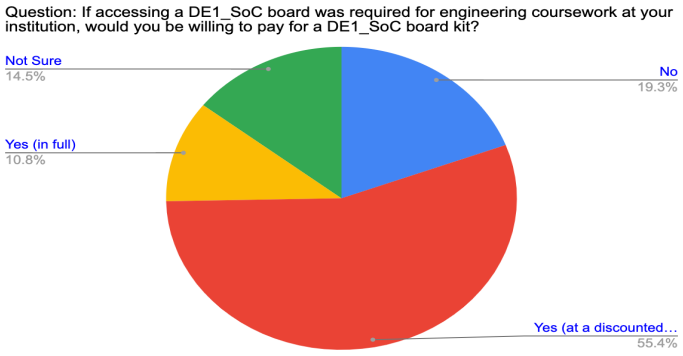

Figure 8.1: Percentage of students' willingness to acquire a lab kit as a part of course coursework Requirement

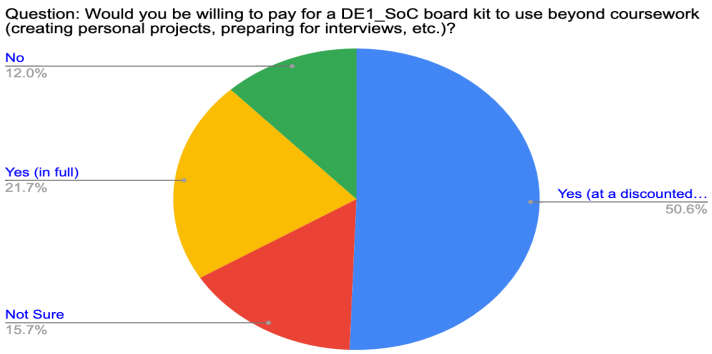

Figure 8.2: Pie chart showing percentage of students' willingness to acquire a lab kit beyond coursework requirement

Unfortunately, we could not operationalize "low" and "high" income definitions while designing the survey due to limited information in the literature. In addition, the demographic question of figure 5 was limited in its ability to gather information. It relied on self-reported data without specifying whether the responses were based on individual or family income. The following are analytical findings that were described in detail based on the responses gathered from the survey:

The Convenience and Effectiveness of Remote Labs - When asked about the number "Please explain the factors (if any) that you felt were distracting while using Remote Labs. (if none write "N/A")," 66 percent of the students responded with N/A which indicates that they perceived remote labs as convenient to use and constituted no distraction during use. However, approximately 33 percent of the students found certain aspects of remote labs distracting, such as timed sessions, connectivity, interface, or being online. The results establish that students appreciate the convenience and accessibility of remote labs and the opportunity to experiment and practice with real-world scenarios in a safe and controlled environment. According to the student's responses, the absence of physical hardware and wiring in remote labs makes the labs less stressful and more accessible for students, which is a significant advantage over traditional lab setups. Furthermore, the availability of a smooth and faster web interface with features such as live editing and auto-complete functionality has further enhanced the convenience and effectiveness of remote labs. However, 7 percent of students mentioned that being online is distracting, and dealing with a slower internet connection and a computer with less computing power made their experience distracting. Additionally, 8 percent of students experienced difficulty with the interface, making it challenging to navigate the platform and access the necessary features. While data has revealed that 33 percent students have mentioned experiencing distractions while learning using remote labs; there is limited evidence on how these distractions impact equity in the classroom.

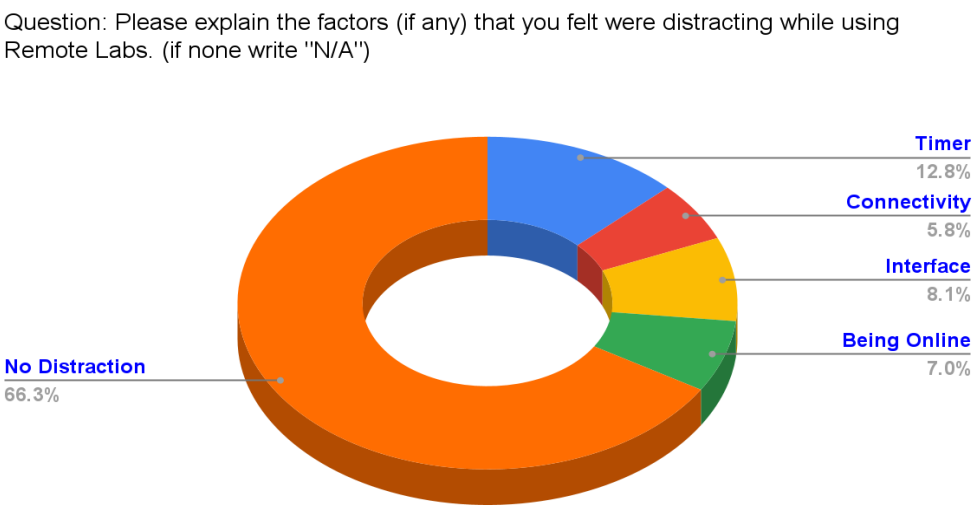

Figure 9: Percentage of students' feeling distracted.

It is essential to explore whether these distractions affect certain student groups more than others and whether they contribute to inequalities in academic performance. To gain a deeper understanding of this issue, we plan to design a new survey that focuses explicitly on distractions' impact on classroom equity. This survey will inform by data collected from focus groups, which will provide valuable insights into the specifics of distractions that students are experiencing and how they are affecting their learning experiences.

Conclusion and Future Work

This study represents a work in progress investigation into the potential of remote laboratories as a viable and effective platform for promoting diversity, equity, and inclusion (DEI) in engineering education. The paper has provided insights into student perceptions of remote labs and the role of DEI in this context. However, to gain a comprehensive understanding of the remote lab experience with a lens on DEI, we plan to further analyze the transcripts of focus group interviews in our forthcoming research. While our survey findings only provided information on the accessibility and convenience of remote labs for students who used them for the first time, we acknowledge that we were not able to capture a more in-depth understanding of students' perspectives on DEI through the survey data alone. Nevertheless, we are actively working on analyzing the focus group interview transcripts, and we plan to publish the results in future studies to provide more nuanced insights into the role of DEI in remote labs.

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