The Future of Engineering Education
2024 Annual Conference & Exposition
Oregon Convention Center
Portland, OR . June 23 - 26, 2024
Paper ID #42358

WIP: Designing an Immersive Robotics Curriculum with Virtual Reality

Jordan Osborne, Illinois State University

Jordan Osborne is a Lecturer in the Department of Technology at Illinois State University, where he teaches courses in Engineering Technology and Computer Systems Technology. Before joining the university faculty, Jordan manufactured and designed switchgear power distribution systems. He has also worked in the electronics manufacturing industry to develop circuitry for high-resolution media broadcast. His research interests include interdisciplinary STEM education and applied educational technology.

Jeritt Williams, Illinois State University

Jeritt Williams is an assistant professor of Engineering Technology at Illinois State University, where he teaches applied industrial automation and robotics.

Dr. Yi-hsiang Isaac Chang, Illinois State University

Dr. Yi-hsiang Chang is an associate professor in the Department of Technology at Illinois State University. He received an MSME degree from Carnegie Mellon University, an MSIE degree, and a PhD in Technology from Purdue University. Dr. Chang's research interest includes Kaizen thinking, human spatial cognition, and eXtended Reality applications for teaching and learning.

Designing an Immersive Robotics Curriculum with Virtual Reality

Virtual Reality (VR) has emerged as a transformative educational tool, especially after the shift to distance-learning, offering immersive and interactive learning experiences in many fields. In the field of robotics education, VR presents a promising avenue for enhancing pedagogy, providing students with a unique opportunity to program, simulate, and interact with robotic systems in virtual environments [1]. As the demand for robotics skills continues to grow in industries ranging from manufacturing to healthcare, the integration of VR into robotics education becomes increasingly pertinent.

This work-in-progress aims to address this need by presenting the development of a curriculum module designed to teach students how to effectively utilize ABB robots in VR environments using ABB's RobotStudio software. This research seeks to bridge the gap between theory and practice, offering a practical curriculum informed by the latest educational research and technological advancements. To this end, this project provides an initial investigation into the following questions: 1) To what extent does VR support acquiring the procedural knowledge and motor skills expected in robotics programming? 2) To what extent does this curriculum contribute to students' mastery of robotics programming principles and ability to apply these skills in complex tasks? 3) To what extent does this curriculum influence students' interests toward a future career in a related field? Preliminary results from an initial pilot test are discussed. Opportunities for future teaching and research are presented.

Literature Review

For decades, the integration of VR technology into educational settings has gained significant attention. One particular area of interest is its application in robotics education. VR offers the potential for highly immersive and interactive learning experiences that can enhance learning outcomes by providing simulated training and learning environments. This allows students to learn the core concepts of programming a robot without laying a hand on a real robot controller. Several studies, such as those compiled in [2], have highlighted the effectiveness of VR in enhancing education. [3] shows how two groups of students, one of which received training for robot-assisted surgery in VR, performed equally well on an identical post-test. [4] concludes that, "students' motivation had increased after the VR intervention or was higher than other pedagogical conditions", but also warns that the so-called "novelty effect" of VR must also be considered with this claim.

Despite its potential benefits, the use of VR in robotics education presents certain challenges. Technical issues, such as the prohibitive cost of VR equipment and the need for specialized software, pose barriers to widespread implementation in educational settings [5]. Additionally, creating realistic and accurate VR simulations that mimic real-world robotics scenarios remains a significant challenge for developers. Concerns regarding the lack of physical interaction with tangible robots in VR environments have been raised. While VR simulations offer a safe learning space, some argue that physical interaction with actual robots is crucial for comprehensive skill development [6].

Curriculum Development

The preliminary curriculum structure comprised three sequential hands-on activities, each designed to progressively enhance students' proficiency in a VR setting. The sequential nature ensured a gradual growth in both skills and difficulty as students advanced through the activities.

The initial activity served as an introductory phase where students familiarized themselves with the VR environment. Emphasizing the basics of the camera controls, this phase was meant to serve as an introduction for students unfamiliar with VR devices, allowing them ample time to navigate and explore the space at their own pace. Students may be entirely new to VR at this stage, so proper training and hardware adjustment is crucial for them to succeed.

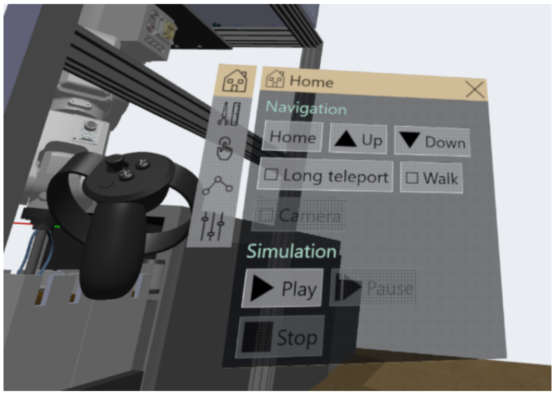

Fig. 1. Working With the Application Menu in Lab 1

The focus of the second activity shifted towards robot manipulation. Here, students were tasked with reorienting the robot across all of its six movement axes. By the activity's conclusion, students are expected to become familiar with the software's movement constraints system for precise robot maneuvering. These acquired skills set the stage for the culminating activity of the curriculum.

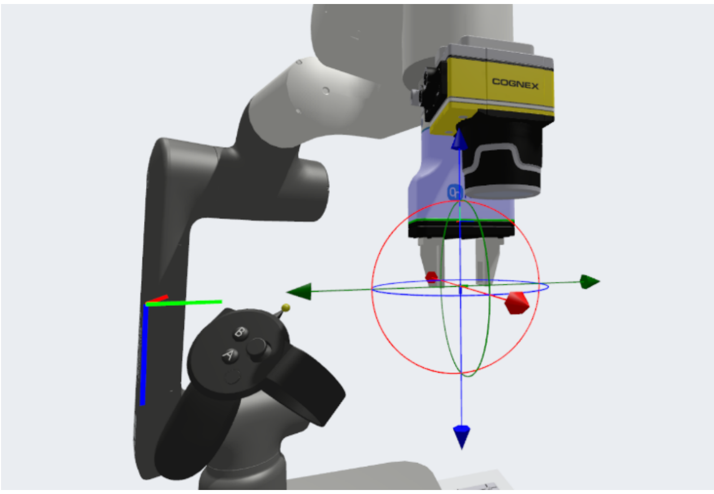

Fig. 2. Jogging the Robot Using Axis Constraints in Lab 2

The third activity was a synthesis of the preceding two, introducing students to programming motion instructions. Their task involved accurately maneuvering the robot around geometric constructs within the VR environment and creating motion instructions for the robot to follow. This phase essentially initiated students into the realm of programming robots within a virtual space.

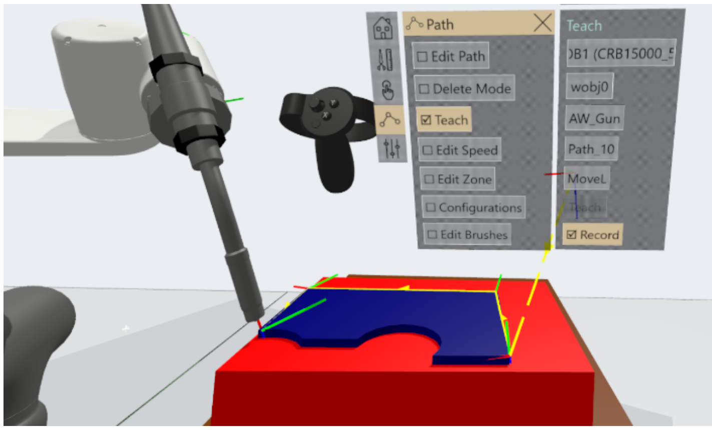

Fig. 3. Teaching Move Instructions in Lab 3

The rationale for this specific curriculum layout was to gradually develop students' VR-related competencies. The sequential progression aimed to ensure a step-by-step acquisition of skills, enabling students to acclimate gradually to working within a VR environment. The intention being that at the end of the curriculum, students felt just as comfortable programming in VR as they would in the real world.

Implementation

All students in an undergraduate applied industrial robotics course were offered to take part in this curriculum outside of class time, near the end of the semester. Their participation was rewarded with extra credit applied to their course grade. Four students from the course signed up and completed the curriculum. The curriculum was delivered with a Meta Quest 3 VR headset, in the same lab space as the traditional robotics class. The lab space featured a section of open space for students to walk around freely. Each student took the curriculum individually with the instructor present to set up the VR hardware and assist them, if necessary, with lab completion. Each activity was completed in order, starting with the first lab, and ending with the final lab. Students moved through the curriculum at their own pace, but were instructed to remove their headset to allow a chance for their eyes to adjust and relax.

Upon successful completion of the labs, students provided feedback via a 10-question survey. The survey asked students to provide short-answer style responses to various aspects of their experience. The results of this survey will be discussed in the following sections.

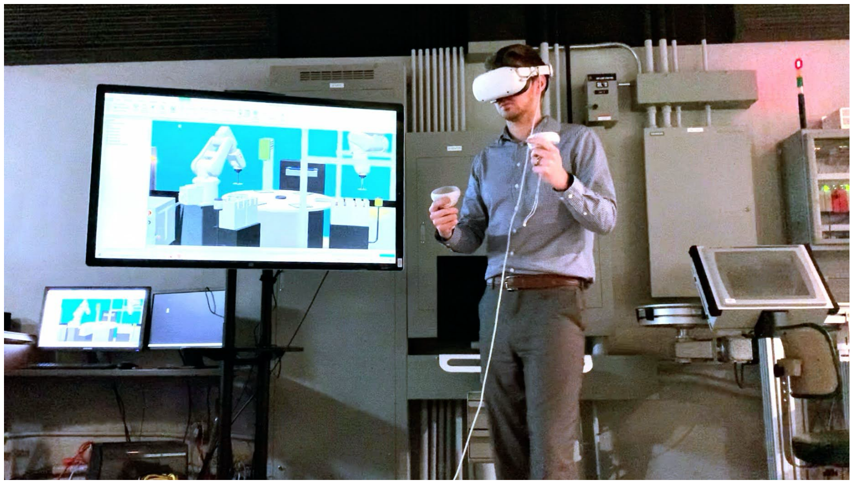

Fig. 4. Completing the Lab Activities

As this curriculum is done primarily in the VR environment, finding a way to communicate instructions to the students was a challenge at first. In the traditional classroom, students work with printed paper handouts that contain the instructions for them to complete the day's lab activity. The intent of this curriculum was to create an experience that felt similar to what students have come to expect during their class time. However, having students don and doff the VR headset just to read instructions on a sheet of paper would be too cumbersome, so a method to incorporate their lab sheets in the VR environment was devised. By importing a PDF version of the lab sheets and attaching it to a CAD model of a sheet of paper in the simulated environment, students were able to fully interact with their lab sheets as if they were real pieces of paper. All lab sheets were presented to students in this way. Students could pick up the "paper" in the VR environment and read from them to get the instructions for the task they were completing. This also allowed students the ability to organize their sheets in such a way that they were readily accessible throughout the lab activity.

Fig. 5. Students Have Access to Lab Sheets in VR

Preliminary Findings

After their lab activities were completed, students were prompted to participate in a brief survey to gather feedback. While the survey was designed to elicit open-ended responses, a substantial portion of the students' feedback was condensed into straightforward "yes" or "no" categories. The student responses obtained from the survey have been categorized as such for analysis and are shown in the figure below. The responses to the remaining questions were not easily categorizable into a similar system and are thus presented and discussed in the following section.

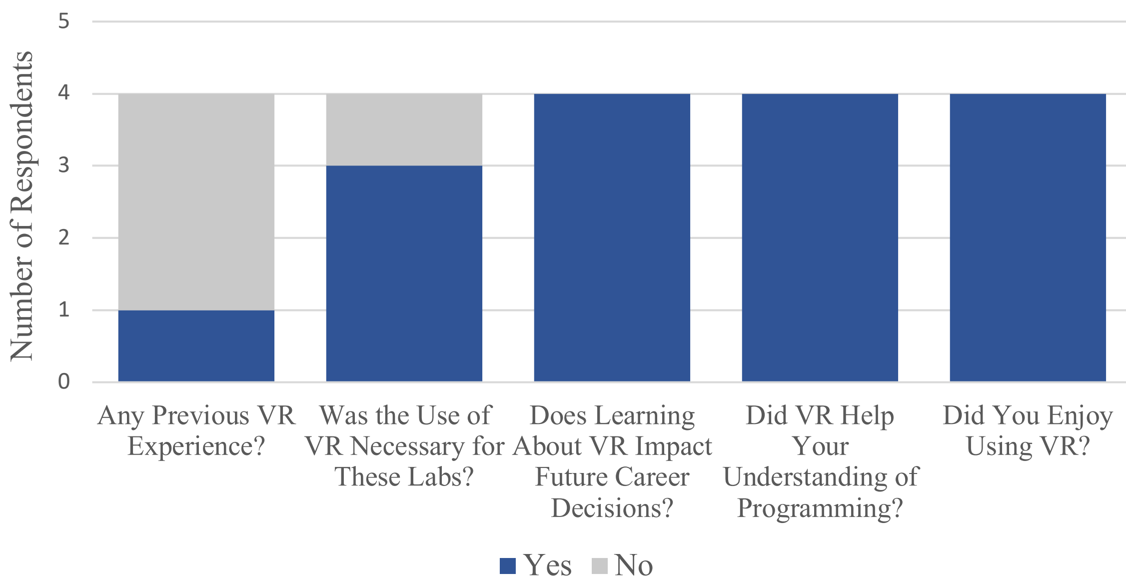

Fig. 6. Generalized Student Feedback on Selected Questions from Survey

Discussion

Although VR has been available in the commercial space for quite some time, few students today have had the opportunity to experience it for themselves. This was the case with our students, as evidenced by Fig. 6. Three of the students had no prior experience with VR at all, and the one student that did have experience noted it was very minimal and limited to a single video game. The need for VR curriculum to be accessible was extremely apparent in our trial. The first lab exercise took the longest for students to complete, as for many of them, it was their very first time experiencing VR. It takes time to adjust to the virtual environment and to learn the methods of controlling the camera view.

When asked if the usage of VR was easier to use than traditional programming methods, all four students agreed that VR was easier to use. This was surprising, as most of the students were experiencing VR for the first time with this curriculum. The students also became familiar with the usage of traditional programming methods over the 16-week class. All four students remarked that using VR helped them better understand the programming of a real robot. This result helped answer the second research question. One student mentioned how the VR space was a “simpler” approach to programming, with many of the more complicated features of a traditional controller not available in VR. The fact that students had such an easy transition between real robots and using VR seems to answer the first research question.

Students were asked to provide areas where they struggled, or to describe challenging aspects of the curriculum. Two of the students mentioned having a challenging time using the VR headset controls. It is worth noting that these students also indicated they had no prior experience with VR. The other two students had difficulty understanding the instructions. This feedback will be incorporated in further revisions of this curriculum.

There were a few key points that students made that really stood out. One student mentioned that, even though one curriculum session lasted 30 minutes, it gave them what they referred to as “eye fog” or eye strain. It became obvious after this statement that some time spent teaching students the proper ways to adjust their headset to conform to their level of comfort was necessary before the first lab. Another student mentioned how this curriculum would be beneficial for students who are “stuck at home,” due to illness or for students who have learning impairments. A separate student wrote that this “training can be done from home,” adding to the conclusions of the previous student. This method of using VR, while limited, still allows students the ability to create a program that can be ran on a real robot from the comfort of home, which has the potential to change the way we teach about and work with robots in the future.

Conclusion

The intent of using VR in a traditional undergraduate applied robotics classroom was to study its effectiveness as a pedagogical tool. VR can be beneficial to many different educational areas, as evidenced by the student participants' responses in Fig. 6. Yet, the efficacy of VR still remains linked to the capabilities of software. In the context of ABB's RobotStudio, the current iteration lacks comprehensive software support beyond fundamental workflows. Although feedback indicates that students indeed acquired procedural knowledge and a grasp of programming fundamentals, the present version of RobotStudio’s VR environment lacks the necessary software tools and functionality to fully substitute for its desktop counterpart. While the curricula acquainted students with robotics programming basics in VR, the software lacks substantial follow-up content, limiting the students’ educational journey post-completion of these initial labs.

The absence of fundamental programming or path planning tools in the current release raises questions regarding the substantive benefits of VR beyond serving as an immersive simulation viewer. For instance, the inability to accurately position the robot’s tool in VR to align with the simulation's geometry poses a significant barrier for further content essential for authentic robot-oriented tasks. Although it is possible to maneuver the robot in VR and record points without utilizing the "object snaps" available in the desktop version of RobotStudio, such positional inaccuracies would prove wildly inadequate for any real-world operation. This confines the current state of the VR environment to essentially viewing pre-defined programs in a virtual space.

Despite these limitations, the VR environment notably succeeded in sparking students’ interest in the curriculum, robotics, and related disciplines, which answered the third question proposed by this article. Surveyed students unanimously highlighted how VR influenced their future career considerations. Notably, one student stressed the significance of VR in the future, stating that it "will be a big part of the future," emphasizing the importance of learning about VR and emerging technologies. This underscores a pivotal takeaway from this article: while the present software iteration of RobotStudio might not directly replace traditional teaching methods, it potentially could do so in the lifetimes of these students. Projections suggesting the growth of VR technology, from $54.24 billion in 2023 to an estimated $163.82 billion by 2028, underscore the need to introduce students to its core concepts. Embracing and highlighting technologies such as VR not only familiarizes students with evolving technologies but also serves to ignite their interest and passion in the field, which will always be a worthwhile venture.

Plans for Future Study

As research continues in this area, future work will include understanding the feedback from students and addressing their concerns with the curriculum. In future semesters, new student groups will be participating in the revised curriculum. Their involvement will add to the analysis provided, adding more perspectives on the curriculum. To evaluate how effective the curriculum is, a quantitative analysis could be conducted, specifically examining task completion rates. This analysis could compare the use of VR to traditional robotic programming methods and provide valuable insights into the curriculum's ability to teach essential concepts. Future student surveys could be written to quantify student understanding between the two pedagogies, further showcasing any potential differences. As the software evolves with subsequent releases, more opportunities for curriculum development could emerge. In the future, the curriculum will need to incorporate these changes, ensuring it stays aligned with the software's expanding features.

References

[1] Y. Chang and K. Devine, "A Tale of the Robot: Will Virtual Reality Enhance Student Learning of Industrial Robotics?" *2018 ASEE Annual Conference & Exposition Proceedings*, 2018. doi:10.18260/1-2—30118

[2] Z. Yu, "A Meta-analysis of the Effect of Virtual Reality Technology Use in Education," Interactive Learning Environments, vol. 31, no. 8, pp. 4956–4976, Oct. 2021. doi:10.1080/10494820.2021.1989466

[3] F. H. Halvorsen et al., "Virtual Reality Simulator Training Equals Mechanical Robotic Training in Improving Robot-assisted Basic Suturing Skills," Surgical Endoscopy, vol. 20, no. 10, pp. 1565–1569, Aug. 2006. doi:10.1007/s00464-004-9270-6

[4] J. Jiang and L. K. Fryer, "The Effect of Virtual Reality Learning on Students & Motivation: A Scoping Review," AERA 2023, pp. 1–14, Oct. 2023. doi:10.3102/ip.23.2005486

[5] C. Graeske and S. A. Sjöberg, "VR-Technology in Teaching: Opportunities and Challenges," International Education Studies, vol. 14, no. 8, p. 76, 2021. doi:10.5539/ies.v14n8p76

[6] S. Grassini, K. Laumann, and M. Rasmussen Skogstad, “The Use of Virtual Reality Alone Does Not Promote Training Performance (But Sense of Presence Does),” Frontiers in Psychology, vol. 11, Jul. 2020. doi:10.3389/fpsyg.2020.01743

[7] Mordor Intelligence, “VR Market - Virtual Reality - Size, Share & Growth,” VR Market - Virtual Reality - Size, Share & Growth, https://www.mordorintelligence.com/industry-reports/virtual-reality-market (accessed Dec. 20, 2023).