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WIP: Virtual Reality as a Tool for Reinforcing Real-World Robot Programming Skills

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This work-in-progress continues to build upon previous work that aims to explore the effectiveness of teaching and learning fundamental industrial robotics skills using industrial robotics software with consumer-grade virtual reality (VR) equipment. The initial goal of the project was to create an innovative curriculum designed to provide students with an immersive robotics education experience. In this curriculum, students program and create simulated robotic work cell digital twins using VR. Previous findings indicated that students found programming robots in VR to be simpler than programming on a real controller, despite most participants being new to VR. All participants agreed that using VR helped them better understand how to program a robot as well. Students first completed a jogging exercise using a physical robot, then performed a similar jogging task in VR. Then, students' feedback was collected from a survey that sought to understand whether students perceive a robotics task differently in VR compared to the real-world version in terms of difficulty, engagement, and learning effectiveness. Implementation of curriculum improvements, anticipated steps for collecting and analyzing new feedback, and possibilities for future research are also discussed.

Keywords: Curriculum, Immersive Learning, Robotics Education, Virtual Reality

Introduction

The potential of VR as a cost-effective tool for applied robotics education has been increasingly recognized [1], [2]. While the cost of robotics technology has significantly decreased in recent years [3], the expenses associated with industrial robots, including maintenance, supplementary control systems, and considerable space requirements continue to present challenges for educational institutions, particularly those with limited resources. VR offers a promising alternative, as it demands minimal financial investment, maintenance, and physical space.

As a form of digital twin technology, VR is evolving to the point where it can replicate many aspects of physical interaction and system interface [4]. This advancement opens the possibility for students to achieve comparable educational outcomes without the need to directly interact with physical robots. For educational environments where access to real robots is constrained, VR could provide an effective solution for teaching applied robotics. As noted by [5], both the United States and the global market are expected to experience a substantial increase in robot installations in the coming years. Thus, it is imperative that students receive the necessary training to meet this demand, and that educators are equipped with the tools to deliver such training effectively.

Methods

This study was modelled around Situated Learning Theory (SLT), which emphasizes that learning is most effective when it occurs in authentic contexts that mirror real-world environments [6]. As described by [6], genuine engagement in practical tasks is essential for building expertise. Consequently, this study was designed to compare learning through physical and virtual mediums. The activity was chosen to replicate a realistic robotics operation that students might encounter in a real industrial setting. In the first phase, students completed a physical robotics task where they operated an industrial robot using a teach pendant. The same students then undertook the same task in a VR environment designed to replicate many aspects of the physical lab. Following both tasks, students completed a structured survey to compare their experiences in terms of perceived difficulty, engagement, and learning effectiveness. Additionally, open-ended responses were collected to gain deeper insights into how the degree of contextual authenticity influenced their learning. By analyzing the results through the lens of SLT, the authors aimed to understand how variations in environmental authenticity affected the acquisition and transfer of robotics skills. The conceptual model of the framework is outlined in Figure 1.

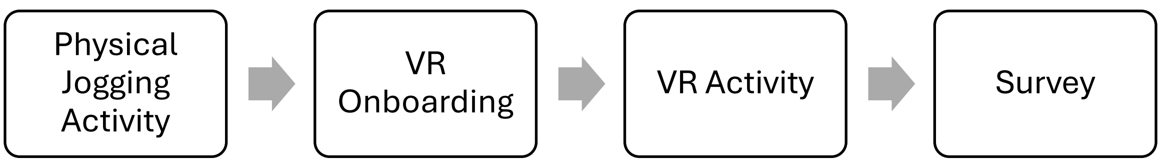

Figure 1. Model of the Framework

Implementation

The participants in this study were undergraduate students pursuing a bachelor's degree in an applied robotics course at a midwestern R2 university. The majority of participants were in their freshman or sophomore year within an Engineering Technology degree program and were a reflection of the program's historical demographic trends, although specific demographic data was not collected for this study. As part of their regular coursework, these students participated in a hands-on activity that involved controlling a physical robot to navigate along a predefined “path” marked on a sheet of paper placed on a table. This exercise aimed to reinforce the students’ understanding of coordinate systems, axis configurations, and jogging controls. Students typically worked in pairs to operate the robots and complete the task. The paths utilized in this activity are illustrated in Figure 2.

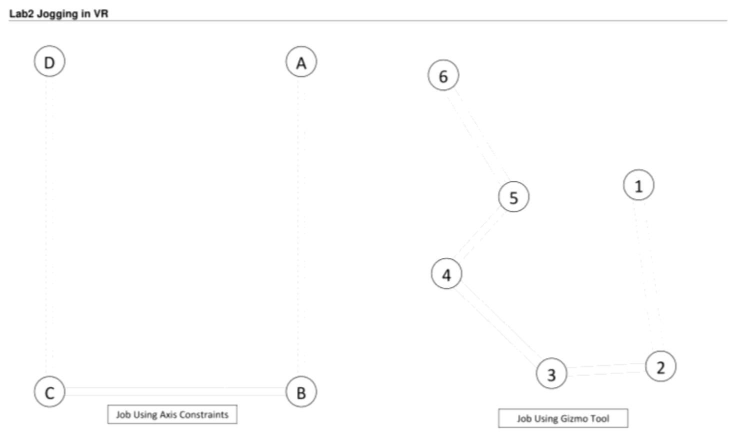

Figure 2. Jogging Activity Sheet Given to Students for Physical and VR Activity

Several weeks after the initial activity, the same group of students were invited to participate in a virtual iteration of the assignment. RobotStudio was chosen for the VR adaptation because it is the software which students are already familiar with for modeling and programming robots in the lab, and it provides an integrated, feature-rich VR environment mode that aligns with the task requirements. Examples of the VR environment are given in Figure 3. In this virtual iteration, each student worked independently, with the instructor available to assist in setting up the VR hardware and offering support throughout the activity. This structure allowed students to progress through the virtual jogging task at their own pace, fostering a more individualized learning experience.

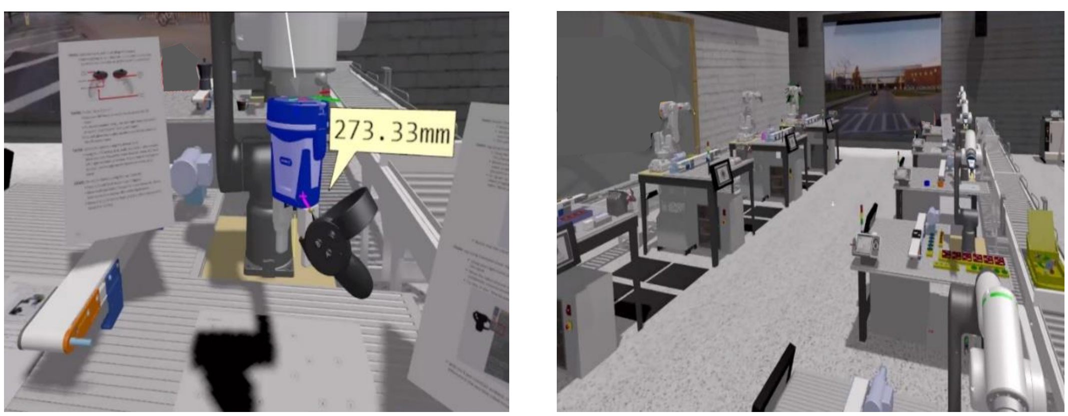

Figure 3. Views Inside the Simulated Lab Environment

Participation in the VR activity was voluntary but incentivized with extra credit toward the course grade. A total of 12 students chose to participate and successfully completed the activity. The VR exercise was conducted using a Meta Quest 3 headset within the same laboratory space as the traditional robotics class, with a designated open area that allowed students to move freely while engaging with the virtual environment. Upon completing the virtual lab activity, students were invited to participate in a brief, confidential survey to provide feedback. All 12 participants completed the survey. The survey was designed to assess and compare key aspects of the physical and virtual jogging tasks.

Findings

Responses from the 12 student surveys were categorized for analysis, with the results summarized in the figures below. In addition to the categorical data, open-ended responses were collected to provide context and rationale behind the answers, and these were analyzed alongside the quantitative data to offer a more comprehensive understanding of the students' experiences. Figures 4 through 8 present the results of the survey.

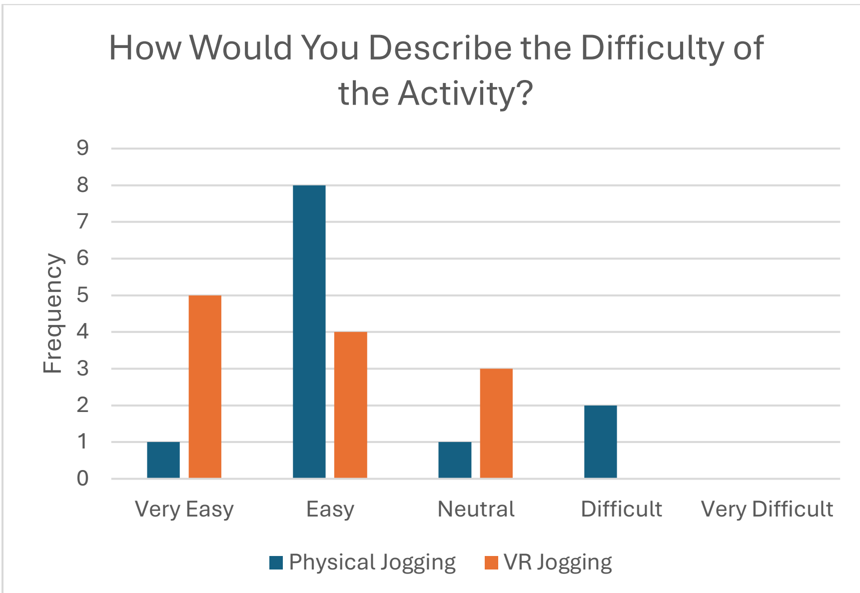

Figure 4. Comparing the Perceived Difficulty of Jogging

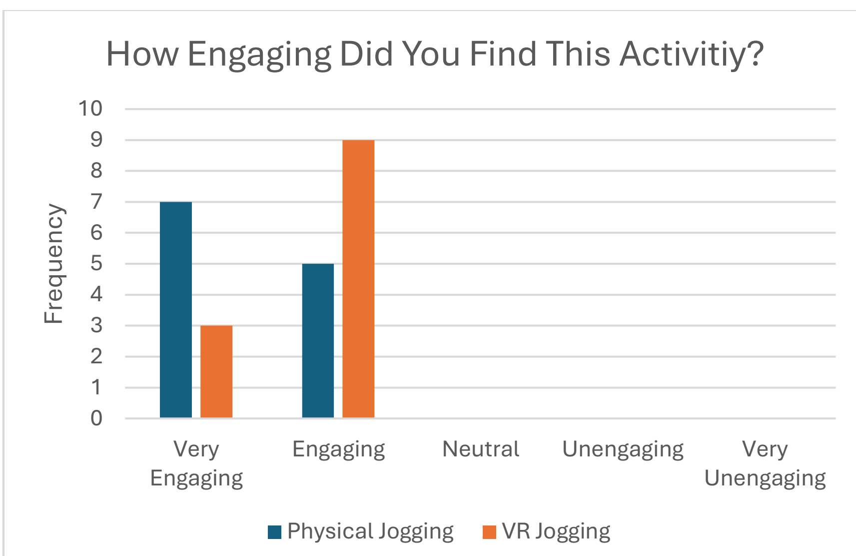

Figure 5. Comparing Level of Engagement with Activity

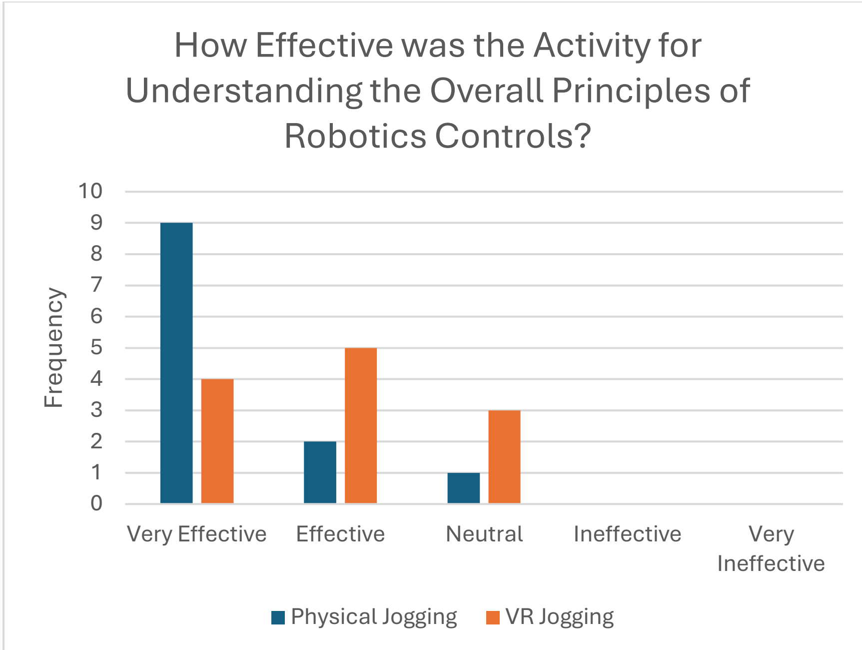

Figure 6. Comparing the Modalities' Effectiveness in Conveying Larger Principles of Robotic Controls

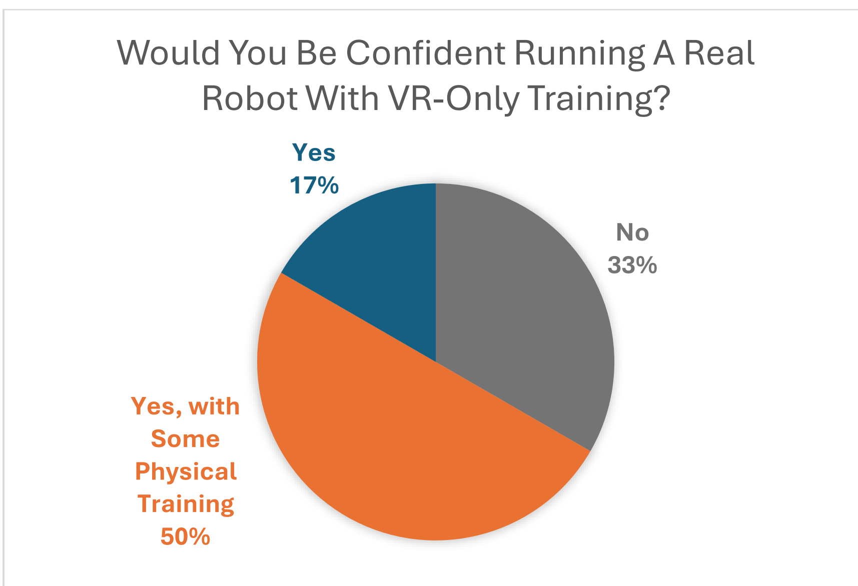

Figure 7. Self-Reported Confidence Level in Operating a Hypothetical, Physical Robot, Given VR only Training

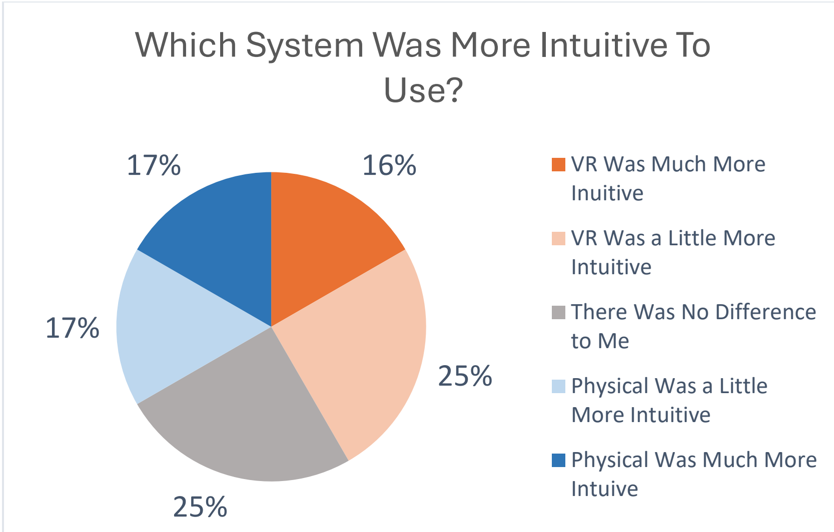

Figure 8. Comparing Perceived Intuitiveness of Activity

The findings from the current survey are consistent with the results of the authors' prior study [7], which indicated that students unanimously acknowledged the benefits of VR in enhancing their comprehension of robotic programming concepts, even among those with no previous experience with VR. In the earlier study, participants consistently characterized VR as user-friendly and beneficial in advancing their understanding of real-world robotic programming [7]. Similarly, the majority of participants in the present study found VR to be simpler and more intuitive than working with physical robots. However, the current study also revealed that students rated VR as significantly less engaging compared to physical robots. This difference warrants attention, as student engagement and motivation are fundamental factors in facilitating effective learning. If students are initially motivated by the prospect of working with physical robots, their enthusiasm for learning may be diminished if they are subsequently informed that the entire class will be conducted virtually. While students expressed excitement about using VR, it remains uncertain whether this enthusiasm would endure over multiple training sessions, or if the novelty of VR may diminish over time.

Discussion

The comparison between physical and virtual jogging tasks revealed several insights. Among the 12 students who participated in the VR activity, eight reported having prior experience with VR, primarily through video games, and some indicated ownership of VR hardware like that used in the activity. When asked to rate the relative difficulty of each task, more students found the VR jogging activity easier than the physical counterpart. This result aligns with expectations, as the VR environment is a simplified abstraction of real-world robot jogging. In VR, students only needed to "pull" on the robot to move it, bypassing the need to navigate multiple settings screens or precisely control a joystick as required in physical robot jogging. In open-ended responses, students identified their primary challenge with using the physical robots as precisely positioning the robot. This difficulty reportedly stemmed from managing various settings, such as speed and jogging methods. One student highlighted their anxiety of potentially crashing the physical robot as a major concern. For the VR activity, the main difficulty reported was mastering the navigation controls, settings menu, and gestures necessary for effective interaction. While most participants were familiar with VR, the specific controls in this context required a brief adjustment period.

Although the VR environment was generally regarded as easier to use, interestingly, students reported that they found the physical robots more engaging. This preference likely reflects the hands-on nature of robotics education and the students' predisposition to enjoy said nature of tasks. Despite 84% of participants acknowledging that the VR environment was a reasonable recreation of their lab space, students noted the inherent differences between controlling a virtual and a real robot. One student stated, “Being there in person and not in VR made you feel more accomplished when you finished a task.” Similarly, another student wrote, “Jogging the physical robot is more engaging because you have actual consequences with the physical robot. In VR, I was engaged because I have little experience in VR.” While many students expressed an enthusiasm for working with VR, the physical experience was ultimately preferred for its tangible nature and real-world implications.

Finally, students were asked to rate how effective they thought each modality was for understanding the overall principles of robotics control. More students thought that the physical robot was a better choice for understanding the overall principles. This is most likely because physical robots have many more options for jogging methods. In the simulation, students are only given two basic methods of control. It is also likely that students see a clearer transfer of skills to the real world from working on a physical robot. Despite the comparisons above, students are almost equally mixed on the intuitiveness of each system. The reason for this divisiveness is unclear, but it is worth mentioning that this question was asked after 16 weeks of formal instruction using real robots. Students only had one 10-minute session in the virtual environment, so this could be contributing to how students perceive each system.

Despite favoring the physical mode of instruction, Figure 7 shows that 67% of students reported that they would feel comfortable operating a real robot in a real scenario after only receiving VR training. One student commented, “VR would be good to see how a robot executes certain moves in a virtual environment to avoid causing real-life damage.” Another noted, “It was very similar to the real world and allows you to experiment and try things without major consequences.” In the context of robotics training, VR could potentially be a low-risk training tool, enabling students to explore system limits without fear of damaging equipment. The apprehension some students feel about using physical robots, which some described as a “fear of failure,” may hinder their learning. By mitigating this fear, VR could serve as an effective complement to physical training. If VR systems were further refined to closely mimic real-world conditions, down to the physical controller functionality, they could help students build confidence and reduce anxiety during physical tasks.

Conclusion

This study investigated the effectiveness of using VR to reinforce applied robotics programming skills. To achieve this, students in an applied robotics course performed a jogging task both physically and virtually. The VR environment, developed using ABB’s RobotStudio, was designed to replicate a physical task and lab space as realistically as possible given the available tools of the software. After completing the VR activity, students were invited to participate in a confidential survey to share their experiences.

Survey results revealed differences in student perceptions of the robotics activity. Overall, students found the VR-based activity easier to complete than its physical counterpart, likely due to the simplified control methods. However, despite its accessibility, VR was perceived as less engaging than working with physical robots, as students valued the hands-on, tangible experience and the sense of accomplishment that comes with operating real equipment. While VR proved effective in teaching robotic programming concepts, some students found it too abstract, which may have limited their ability to see a clear transfer of skills to real-world applications. In the VR environment, the lack of physical interaction may have made it more challenging for students to bridge the gap between virtual experiences and real-world tasks. Nonetheless, VR demonstrated its potential to capture students' interest and motivate further participation in the robotics curriculum, aligning with the idea that engagement and motivation are critical to effective learning. Although VR may not fully replace the benefits of hands-on, physical training, it potentially represents a viable alternative and an effective supplementary tool for teaching applied robotics, particularly when integrated with real-world tasks for a more comprehensive learning experience.

Plans for Future Study

As this is a work-in-progress, there are some limitations that should be addressed in future work. This includes increasing the number of participants, as well as refinement of the feedback survey itself. More tasks should be added to better reflect the holistic nature of the SLT approach. While student feedback indicated that the simplicity of the VR interface was appreciated, some indicated that it was at times too dissimilar to the real-world experience. Specifically, students noted that the absence of interaction with a proper teach pendant reduced the authenticity of the training. In essence, students felt like they were learning how to use the VR software, and not the real teach pendant software. To address this, future iterations of the VR simulation could incorporate a virtualized teach pendant that is modeled after its physical counterpart. This virtualized teach pendant would have the same functionality, navigation, and controls available as its real-world counterpart. This enhancement could provide a more accurate replication of the lab environment, reducing the abstraction introduced by the VR interface and jogging methods.

While many students expressed confidence in their ability to operate a physical robot after VR-only training, it is important to contextualize this feedback. These responses were gathered at the conclusion of a semester-long robotics course, during which students gained significant exposure to physical robot operation. Further research is needed to evaluate whether VR training alone is sufficient to prepare a novice operator for real-world tasks without any additional physical training. A possible follow-up study could involve four distinct groups: one receiving only physical training, one receiving only VR training, one receiving an equal mix of virtual and physical training, and one with no background training whatsoever. These groups could then be assessed on their performance in a standardized robotics task (like the one used in this study) to compare the effectiveness of each instructional method. The results could possibly contribute to the body of research in this area and be of potential significance to industries that rely on remote or virtualized training programs.

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