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Virtual Reality: A Learning Tool for Promoting Learners' Engagement in Engineering Technology

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Peter Soudah

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Abstract

Engineering education aims to create a learning environment capable of developing vital engineering skill sets, preparing students to enter the workforce and succeed as future leaders. With all the rapid technological advancements, new engineering challenges continuously emerge, impeding the development of engineering skills. This insufficiency in developing the required skills resulted in high regression rates in students' grade point averages (GPAs), resulting in industries reporting graduates' unsatisfactory performance. From a pedagogical perspective, this problem is highly correlated with traditional learning methods that are inadequate for engaging students and improving their learning experience when adopted alone. Accordingly, educators have incorporated new learning methodologies to address the pre-defined problem and enhance the students' learning experience. However, many of the currently adopted teaching methods still lack the potential to expose students to practical examples, and they are inefficient among engineering students, who tend to be active learners and prefer to use a variety of senses. To address this, our research team proposes integrating the technology of virtual reality (VR) into the laboratory work of engineering technology courses to improve the students' learning experience and engagement. VR technology, an immersive high-tech media, was adopted to develop an interactive teaching module on hydraulic gripper designs in a VR construction-like environment. The module aims to expose engineering technology students to real-life applications by providing a more visceral experience than screen-based media through the generation of fully computer-simulated environments in which everything is digitized. This work presents the development and implementation of the VR construction lab module and the corresponding gripper designs. The virtual gripper models are developed using Oculus Virtual Reality (OVR) Metrics Tool for Unity, a Steam VR Overlay utility created to make visualizing the desktop in a VR setting simple and intuitive. The execution of the module comprises building the VR environment, designing and importing the gripper models, and creating a user-interface VR environment to visualize and interact with the model (gripper assembly/mechanism testing). Besides the visualization, manipulation, and interaction, the developed VR system allows for additional features like displaying technical information, guiding students throughout the assembly process, and other specialized options. Thus, the developed interactive VR module will serve as a perpetual mutable platform that can be readily adjusted to allow future add-ons to address future educational opportunities.

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Introduction

Engineering education is an essential discipline that endeavors to create a learning environment capable of developing engineering skill sets, like problem-solving, logical thinking, etc., [1]. It enables the development of students' engineering skills providing real-world applicability to theoretical engineering concepts. Despite the significant role of engineering in preparing students for their future careers, educators have faced multiple challenges because of technological advancements and societal developments [2]. Such challenges are related to being out-paced by new advances of new technologies being created and added to our everyday lives despite the ongoing mere theoretical and abstract exposure of these advancements to students [3]. Such technological advances can add more expenses to educational institutions that strive to integrate job market applications in a pedagogical setting to expose students to real-world applications.

Many educational institutions have been developing new styles and instruction tools that could be readily integrated into undergraduate engineering laboratories [4]. The role of the laboratory in engineering is to teach students how to extract data for a specific design, analyze a new device, and discover a new piece of information to their knowledge of the world [5]. Capstone projects are one of the well-known methodologies utilized in laboratories for overcoming some of the mentioned challenges in engineering education [6]. It aims to expose students to hands-on experience, increasing their level of expertise required by the job market [7]. Besides adopting capstone project learning, using simulation software as an educational tool through courses and examinations has also been a step toward bridging the gap between education and job market requirements. It will likely expose students to software optimization tools like Matlab and coding platforms like Python, which are commonly utilized in the study and instruction of statics and dynamics of mechanics of machines [8].

Despite their proximity to the real world, project and simulation learning tools utilized in engineering education laboratories still have limitations. The hands-on teaching process's limits are receiving a lot of attention from research institutions on how to be minimized it. Real devices are challenging to model accurately since simulations' optimal instruction efficiency can be as good as the model used [9]. Therefore, the model must be detailed and accurate. However, most simulations are simplified using fewer variables and constraints of the model for financial purposes.

Given these existing challenges, this work proposes using Virtual Reality (VR) technology as a pedagogical tool for instruction and concept delivery by incorporating interactive VR teaching modules into the laboratories of engineering technology. The rest of this paper is organized as follows. Section (**Background)** expands on the introduction, where it reviews a series of methods and techniques adopted by various educators to overcome some of the mentioned challenges and improve students' learning. Also, it highlights the new additional challenges that these methods can add. Section (**Virtual Reality: An Effective Learning Tool)** introduces the proposed methodology (the use of VR as a teaching tool), presents its features, and discusses its applicability to overcome some of the existing challenges to improve students' learning experience and engagement. Section (**VR construction lab and Module Development)** expands on the previous section, exhibiting the adopted VR technique (development of an interactive VR construction lab

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module). It presents the stages of developing the VR laboratory module to be incorporated into future engineering and engineering technology labs. Finally, Section **(Conclusions and Future Work)** reveals the work outcomes and proposes future work.

Background

Given the research problem defined in Section 1, developing more realistic and formative teaching methodologies is recommended to be adopted in incoordination with traditional-based techniques [10] [11]. Some educators have been adopting project-based learning (PBL) and competition-based learning (CBL) as essential tools throughout the teaching process [12] [13] [14]. PBL and CBL are student-centered pedagogical paradigms that offer educators alternative solutions to surpass many of the student's deficiencies associated with losing engagement, self-esteem, motivation, etc. [15], [16]. PBL focuses on the theory and practice of real-world applications in timed projects, which influence individual and group learning [17] [18]. Besides PBL, CBL aims to apply theoretical knowledge acquired in classes by conducting student competitions and rewarding the winners after completing the task [19]. It is a contest between individuals or groups to achieve a particular goal [20]. PBL and CBL approaches have proven to motivate and promote students who would lose focus throughout a long lecture. Courses incorporating hands-on learning can stimulate students' minds and help them connect what they learned to real-world applications, resulting in more exciting material [21] [22].

In addition to PBL and CBL techniques, educators utilized modular educational demonstrators as interactive tools to reinforce students' learning [13]. Many educators have designed educational demonstrators to be incorporated into classes and laboratories to allow the delivery of course topics/concepts in a more fun and exciting way [23]–[26]. For instance, in [23], the researchers developed a portable mechanically controlled hydraulic demonstrator, shown in Figure 1, to incorporate in undergraduate fluid power courses. The hydraulic demonstrator was an excavator arm created using a unique multi-layered Lexan and mechanically controlled using pneumatic actuators and valves. The developed demonstrator served as a pedagogical simulator for teaching basic fluid power concepts.

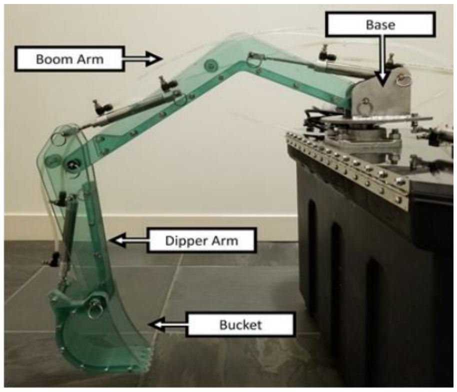

Figure 1. Hydraulic demonstrator developed for teaching basic fluid power concepts [23]

Another hydraulic demonstrator, shown in Figure 2, was designed and built in [25] to be utilized as an interactive tool to allow students to apply their theoretical knowledge learned in classes to

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real-world applications. Unlike the demonstrator in Figure 1, this demonstrator is remotely controlled using a Bluetooth module on an Android tablet and thus could be utilized in a wide range of engineering courses.

Figure 2. Electrically Actuated Hydraulic Arm: An Interactive Tool for improving student's learning [25]

Besides the excavator arm demonstrators, a modular remote-controlled hydraulic vehicle was developed in [26] to be utilized as an educational tool to incorporate hands-on learning activities in STEM Education. This hydraulic vehicle adds some advantages over the excavator arms, where it has a modularity feature and thus offers flexibility in the design and operation. It was designed to achieve various configurations by allowing students to change between three different wheel sizes, hydraulic pumps, and motors. Such modularity allows engineering students to control the speed and torque of the demonstrator.

Despite the significance of the previously adopted learning methods in improving the students' learning in engineering courses, these techniques still lack the potential to expose students to industry-like situations [27]. Furthermore, adopting these learning styles adds additional educational challenges. It requires designing hands-on kits and demonstrators (mechanical/hydraulic parts), which can be time-consuming, hard to manufacture, and thus unavailable to some educational institutions, as shown in the example of the modular hydraulic vehicle in Figure 3 [26].

Figure 3. A modular miniature car kit was developed and incorporated into MET classes [26]

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Figure 3 shows a modular hydraulic kit developed for studnets in MET courses. This educational kit was developed in multiple stages. It required designing and manufacturing mechanical components, buying hydraulic parts (pump, motor, valve, etc.), and selecting electronic parts [26]

Overcoming some of the mentioned educational challenges requires adopting more optimized educational strategies that have the potential to improve the students' learning and engagement, exposing them to real-life career situations in better efficient ways. Therefore, this work proposes incorporating interactive VR lab modules into engineering courses to enable the delivery of course topics more practically and realistically. It presents the development of an interactive VR teaching module lab for a hydraulically actuated gripper to be incorporated in the laboratories of fluid power engineering technology courses. This VR lab improves students' pedagogical performance and conceptual understanding of a specific range of tasks.

Virtual Reality: An Effective Learning Tool

Digitized-based technology, also known as digitization, uses high-tech visualization media to introduce the digital representation of physical assets, processes, or systems, exposing students to more factual real-life situations [28] [29]. Amidst many digitized technologies, virtual reality (VR) technology has been widely utilized as an educational tool that enables the delivery of course topics more practically and realistically [30]. VR technology can be defined as immersive multimedia that integrates hardware and software systems to offer users an immersive artificial experience by creating a sense of immersion and presence [31]. It provides a far more visceral experience than screen-based media through the generation of a fully computer-simulated environment, known as the VR environment, in which everything is digitized [32]. This VR environment is a computerized setting comprising virtual displayed elements and sensorimotor channels linked to the user's body movements and responses through a technical interface [32]. VR utilizes smart-wear techs like tech togs, headsets, skin electronics, and many other wearable technologies to immerse users in this computer-generated world. These smart-wear techs allow for achieving a sense of presence and immersion by creating a realistic, visceral experience that tricks the user's senses into thinking of being immersed there and surrounded by that environment [33] [34].

With all these features, VR technology can be a promising pedagogical tool for addressing the problem of students' learning, motivation, and engagement in multiple engineering fields (see Figure 4). Incorporating VR into education can improve learning outcomes by providing a richer context and allowing for more realistic situations that students can experience in a classroom setting [35]. This technology enables a more authentic and realistic course delivery by exposing students to real-life career settings through VR's immersive artificial experience. All this can assist students in acquiring sought-after concepts by applying the theoretical knowledge gained in class to real-life situations. Besides improving the learning outcomes, this technology can promote the students' spatial-visual abilities, addressing spatial visualization problems using the precept of virtual-real object interaction [37]. VR technology can help develop these spatial skills by permitting students to interact virtually with 3D digital objects in an extended environment. Students can merge their substantial environment with the predesigned virtual world through a smooth human-computer interface [40][41].

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Figure 4. Virtual Reality: An educational Tool for Improving Engineering Education

Therefore, throughout this work, a VR construction lab module is developed to be adopted in coordination with classical-based laboratories to improve the teaching curricula of engineering technology courses. The following section discusses the development of the VR construction lab module.

VR Construction Lab and Module Development

An interactive VR module on hydraulically actuated grippers is developed for undergraduate-level mechanical engineering technology (MET) students. Hydraulically actuated grippers are highly-coupled complex systems comprising hydraulic and mechanical units like pumps, motors, hydraulic actuators, valves, etc. The complexity of the utilized units and their corresponding mechanisms makes it difficult to understand the grippers' operation. For such reasons, 3D digital representations of different hydraulic actuated gripper models are designed and created in a spatial interactive VR construction lab. The VR module is developed in three main stages: (Phase 1: VR Environment Design, Phase 2: VR Development, and Phase 3: VR Demonstration and Testing) (see Figure 5). The following subsections discuss each of the three stages of VR module development.

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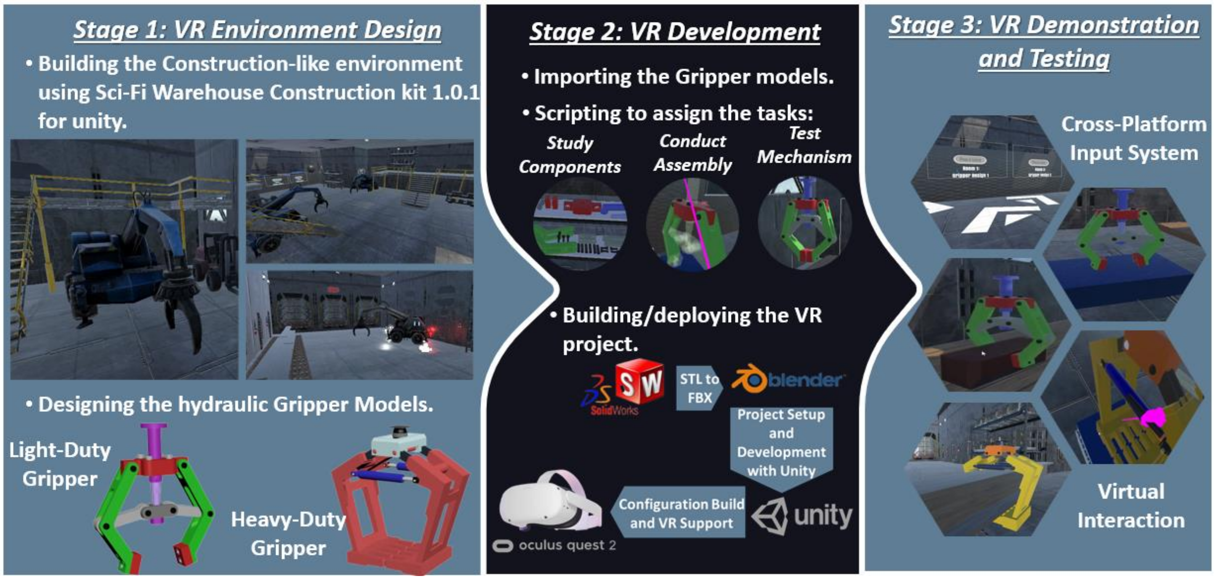

Figure 5. Diagram illustrating the stages of developing the VR construction Lab

1. VR Environment Design

Stage 1 focuses on building a VR like-environment that offers MET students an immersive digital experience of an industry-like situation. It serves as a computerized setting created using the *Warehouse Construction kit 1.0.1 for Unity*, a fully modular and detailed warehouse construction kit with over 50 individual realistic assets with prefab counterparts [42]. The VR environment includes digital representations of heavy-duty machines, like tractor grippers and material handling equipment, merchandise, and other industrial warehouse items, all of which allow creating the sensation of being entirely transported into this digitally constructed three-dimensional world. Besides building the environment, this stage involves designing the 3D gripper models used for conducting the lab activity (tasks). Two gripper models are designed to be imported as unity assets into the VR environment; the first is a conceptual 3D design for a light-duty gripper, whereas the second is a conceptual design for a heavy-duty gripper. Both designs comprise two subsystems: mechanical and hydraulic. The mechanical subsystem involves the structural model of the gripper, e.g., gear train, shafts, joints, flexible brackets, sliders, etc. The hydraulic subsystem consists of the corresponding hydraulic circuit encompassing the hydraulic units and components, like the pump, motor, hydraulic actuators, valves, etc.

2. VR Development

Stage 2 is pivoted on building and deploying the developed VR models of the gripper CAD designs using (OVR) Metrics Tool for Unity to visualize the designs in a VR environment. During this stage, the CAD files generated in SOLIDWORKS are converted into FBX file format supported by Unity using Blender Software. Then, the FBX data files involving the 3D components of the grippers are imported into Unity to set up the project. The imported assets (gripper's 3D components/ animations) are positioned and organized in the required scene as unity game objects to create and design the sought-after environment.

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The main goal is to create an interactive VR module with visual and audio interactive instructions that allow students to apply their conceptual understanding to real-life engineering tasks (assembling grippers and testing their mechanism). The students should complete the module without the instructor's help or instructions. For this reason, Oculus Integration package is downloaded from Unity Asset Store and imported as unity assets [43]. It allows for advanced rendering, social, audio, and avatar interactions support for Oculus VR devices. Thus, the VR module is developed with many Oculus Integrations, like the audio manager, avatars, VR, interaction SDK, etc. After setting up the Oculus VR project, the OVR scripts (OVRGrabber), (OVR Grabbable), etc., are utilized and edited for grabbing and manipulating the gripper components and conducting the virtual assembly. Also, additional unity scripts are built and compiled using `(UnityEngine)`, `(UnityEngine.Events)`, `(System.Collections)`, `(System.Collections.Generic)`, `(HoloToolKit.Unity.Buttons)`, etc., to allow for various types of interactions, spatial awareness, hand tracking, and user-interface (UI) controls, as shown in Figure 6. Figure 6 shows the user-interface VR environment involving two gripper stations (one for the light-duty and one for the heavy-duty gripper). This user-interface VR environment enables students to learn about the gripper components, conduct the virtual assembly, and test the grippers' mechanisms.

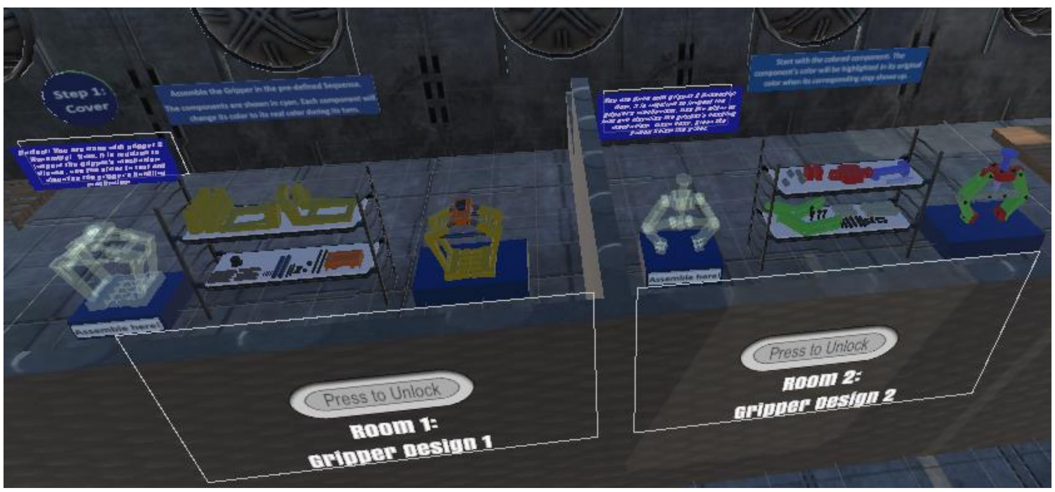

Figure 6. The hydraulic grippers in the developed user-interface VR construction-like environment

Furthermore, since this module will be utilized for education, i.e., conducted among students, safety is crucial. Thus, the Fundamentals of Oculus Best Practices are adopted while developing the module [44] [45]. They allow for ensuring that the content conforms to safety/comfort and industry standards to avoid any simulator sickness in the students when experiencing the VR modules. Then, the project is finally deployed and installed on Oculus Quest 2 to test the visualization and the assembly of the gripper designs in the VR construction-like environment.

3. VR Demonstration and Testing

After building and deploying the VR module, testing its effectiveness from the technical and safety aspects is further required before incorporating it into MET laboratories. As mentioned before,

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ensuring safety is an inevitable factor, given that this VR module will be conducted for education (among students). Thus, besides having the potential to achieve the required learning outcomes, the VR module must be safe for the students to conduct, i.e., it should not cause motion sickness, dizziness, or headaches. For this reason, the module is tested among a small group of students (volunteers with no VR experience) to ensure that the VR module does not cause motion sickness to students, especially those who have never experienced VR before. After inspecting the entire module, the VR module is ready to be incorporated into the teaching curricula of MET courses.

Conclusions and Future Work

This work presents the development of an interactive VR module on hydraulic actuated grippers to be incorporated into future MET courses to improve the students' learning experience and engagement. The module is pivoted on exposing students to hydraulic gripper designs and operation by allowing them to study different gripper designs, visualize their internal structure, conduct their assembly, and test their mechanisms in a VR construction-like environment. It enables exposing students to real-life situations that mimic engineering tasks in an industry-like setting, thus preparing them for their future careers. Students can interact with the lab's 3D digital assets, like mechanical/hydraulic components, through this virtual industry-like environment. The module was developed on multiple stages using Oculus Virtual Reality (OVR) Metrics Tool for Unity, a Steam VR Overlay utility. It involves visual and auditory instructions to guide students throughout the module without the instructor's interference. The developed interactive VR module will serve as a perpetual mutable platform that can be readily adjusted to allow for future add-ons to address future educational opportunities. This module will be incorporated into MET courses, where a research study will be conducted to collect data regarding the students' learning to test the module's effectiveness in improving students' learning.

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