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Implementing Virtual Reality Project Activities for Enhancing Student Learning Experience in Robotics and Automation

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Implementing Virtual Reality Project Activities for Enhancing Student Learning Experience in Robotics and Automation

Abstract

This paper describes the experience of implementing virtual reality (VR) project activities for teaching robotics and automation for students in engineering and engineering technology. This work provides an innovative solution for optimizing learning effectiveness and improving educational outcomes through the development of virtual reality models that can be used and integrated into the existing robotics laboratory. The project activities provide students with opportunities to work with industrial robots. Students complete structured laboratory activities that introduce them to different aspects of applied robotics, including the design of end-effector tooling and fixtures for different tasks. The goal is to apply these VR simulators to train undergraduate engineering, engineering technology students, and professionals in robotics and automation education; and to offer experiential learning opportunities in 3D modeling, simulation, and visualization for robotics and automation. The students were given multiple robotics projects in these courses on robotics and mechatronics. The final projects were assigned to the students with the topics on virtual reality robotics applications related to manufacturing, renewable energy, environment, or other engineering topics. In addition to providing useful lessons in teamwork and project management, the projects provide a working demonstration of an automated system integrated with robotics. The interactive project-based learning gives students an incentive to seek creative solutions to accomplishing project goals.

1. Introduction

This paper presents the project learning result of a laboratory course on robotics and automation integrated with virtual reality (VR) in the Department of Engineering, Leadership, and Society at Drexel University. This course provides a requisite understanding of Internet-based robotics/automation/machine vision for students to progress to the advanced level in the curriculum. The course also serves as a means for students to gain exposure to advanced industrial automation concepts before partaking in their required senior design project. The course has an applied learning focus, offering flexibility to the students through an open laboratory philosophy. Since the concepts of Internet-based robotics and mechatronics are best conveyed through application-based learning, the course is divided into two components: a classroom lecture component and an associative laboratory component. The laboratory component is central to the course and is available to the students outside of normal class time. This allows the students the freedom to explore the concepts of each lesson without time constraints inhibiting learning. In order to provide an enhanced laboratory experience, the students work with real world industrial components [1-4].

Virtual reality industry is getting more recognition due to its application in various fields other than gaming such as education, manufacturing, medical, entertainment, military, fashion, healthcare, business, media, film, construction, sport, etc. The most crucial advantage of using VR as a teaching aid is that it boosts student learning performance through visual representation of complex concepts which they might have found hard to grasp otherwise. Apart from these, its other advantages include assisting in research, increasing outreach to a wider audience remotely, and making the learning environment safer by eliminating risks. In consideration of the many advantages of using VR as a teaching aid, a comprehensive standalone VR based teaching toolset is created to advance education in the automotive, manufacturing, and aerospace engineering fields. The material consists of a wide array of content ranging from e-books and lecture videos to fully immersive virtual environments of laboratories and workshops [5-11].

In preparing students for their future career, virtual reality experiences and hands-on training is an important part of their education. VR research projects and laboratories are excellent teaching aids for providing students with opportunities to implement the theory they learn in class. Educating the younger generations about sustainable and clean energy sources is vital to living in a clean and bright environment in the future [12-14]. Design tasks were performed by teams of students in the engineering and engineering technology programs after completing the same prerequisites. Each team was asked to select wind or solar energy generation technology based on their interest and experience. Students began their projects by identifying the main components of a given system and building CAD models. Based on the loading type and the nature of the structure, they analyzed force and stress and determined the size of the structure. Students were asked to design with VR technology based on renewable energy type, operating environment, etc. and verify by simulation [15-16]. For grading, a rubric was provided with an expected design content and steps to be followed. The evidence of learning included a final project report with description, analysis, experimental results, and power point presentation.

This paper presents the project-based learning result of robotics and automation integrated with VR in the Department. This work provides an innovative solution for optimizing learning effectiveness and improving educational outcomes through the development of virtual models that can be used and integrated into the existing robotics laboratory. The goal is to apply these prototypical simulators to train undergraduate engineering students and professionals in robotics education; and to offer experiential learning opportunities in 3D modeling, simulation, and visualization. The final project was assigned to the students with the topics on virtual reality modeling related to green manufacturing or other engineering topics. These projects have become a good example of student-centric STEM program as well as providing valuable virtual reality experience to the students. In addition to providing useful lessons in teamwork and project management, the projects provide a working demonstration of robotic systems. The interactive project-based learning gives students an incentive to seek creative solutions to accomplishing project goals.

2. Robotic Design Learning via Virtual Reality

2.1. Robotic Design Flow Diagram

Robotics design for manufacturing automation has its own challenges. Along with design improvements, it is necessary to enhance robotic performance, weatherability and resistance to environmental elements. Therefore, it is very important to come up with robot designs following same or more cost-effective methods of production and the most optimized path design giving increased efficiency. The overall goal for the project is to develop an innovative VR framework for project-based learning with implementation of virtual reality for robotics education.

SolidWorks is a computer aided design and engineering software used to create and simulate 3D models. Students were instructed to design a small-scale wind turbine in SolidWorks consisting of five different parts in a robot. After parts of the robot are created individually, they are then assembled in SolidWorks as well. The parts can be changed within the assembly then fitted together accordingly. The Mate controller tool in SolidWorks is used to “link” the components and give them a point of reference in space by restricting their movement. If every part is mated, they can no longer move freely. For the function of the turbine, some students chose to not mate the axil for rotation. Instead, their model is brought into SolidWorks’ motion study and added with motor properties to simulate movement.

The virtual reality learning experience for an undergraduate student engineering and technology class is shown in Figure 1. The basic workflow of the project goes as given in the Figure. Students needs to go through literature review and come up with their idea. As shown in the block diagram, the SolidWorks 3D model of the setup is obtained by designing the model by considering the real-world applications. The Mate controller in specific is modeled by monitoring how a robot moves the end effector in real-world to perform the applications. The simulation helps students in validating the model before designing the VR applications. The SolidWorks 3D parts are saved as .stl files and these files are imported to Blender where the origin is set to geometry, a process which aligns every part corresponding to its origin instead of scaling it and placing it at a random point in the 3D space. This file is later exported as .obj file from the Blender. The .obj file is imported as an asset to the UNITY 3D game engine to begin the VR application design [17-19].

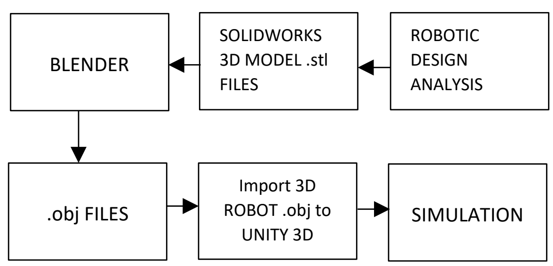


Figure 1. The VR robotic design flow diagram

Once the motion studies and simulations are completed, their models are exported as an STL file and imported into Blender or any CAD exchanger software to create the OBJ files. Blender is an animation tool used for different 3D modeling applications and assembling multiple models where the origin is set to geometry, a process which aligns every part corresponding to its origin instead of scaling it and placing it at a random point in the 3D space. Lastly, these OBJ models are be imported into Unity to be used in a VR application.

Unity is a VR environment where projects can be imported into rather accurate simulations of the real world. C# scripts can be added as a component to each part of a model and animate movement in Unity. Students were given a script to spin the turbine blades at a specific speed after setting a wind parameter to the environment. To write such script in C# in Unity 3D, a Unity 3D command is used and parent child hierarchy is used. Another option of simulating movement was to record a video of the animation in SolidWorks and import it into Unity to be animated in a 3D environment.

Through this process, students were able to familiarize themselves with the Unity software and learn about its features such as its specific import file compatibility and orienting the plane to film the VR scene. If they were given more time to dive in deeper with all of Unity's capabilities and write their own code, they might be able to simulate more realistic wind flow and real-life applications of their turbine designs. Once their animations were completed, they can be exported as a virtual reality project which can be viewed with the help of VR headset so the environment could be used by others.

3. Final Project Description

3.1. Project Overview

The student were asked to have their final team project as required in the course. The project report essentially follows the format with final report and project presentation. The required section includes the following: Cover sheet, project title, name, course number, submission date, introduction, description of project, significance and objectives of the project, data collection methods, literature review, analysis, conclusion, references, and appendices. The students chose their topics on robotic design within the field of green manufacturing, renewable energy systems, 3-D printing technology, etc. The time for presentation allotted to each team was 15 minutes followed by a five-minute question and answer session.

Since this course provides technical introduction to Industrial automation of robots, final project topics include flow line production, material handling, group technology, and flexible mechatronics-integrated manufacturing. This course involves a lecture class for two different batches on Mondays and Tuesdays, and a lab class for both the sections on Wednesdays and Fridays. During lab classes, students are taught the basics of Industrial automation and as a part of lab session, students are also allowed to work in groups to understand the use of Robot Pendants, practice to teach the robot with coordinate points, write efficient assembly codes, save, compile, and execute to see the Robots response to the corresponding code. To understand the use of Virtual Reality in applications developed specifically for Environmental energy. Below provided are the project titles that the students from both the sections worked on for the final VR project. Students were given a project of coming up with an idea of how the Industrial robotics find application in the scope of Environmental Energy and present their project in the form of simulating the 3D models that can be used in Virtual Reality.

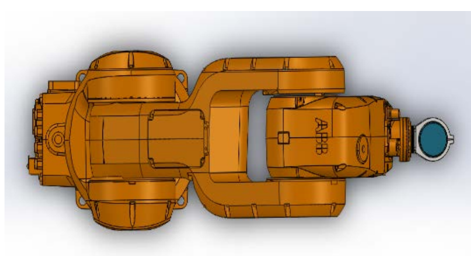
3.2. Final Projects in Virtual Reality Robotics

Several examples of final projects are presented in the following subsection of this paper. Each team demonstrates the finished project to the entire class and then a written report summarizing the project is handed in as part of the senior project design course.

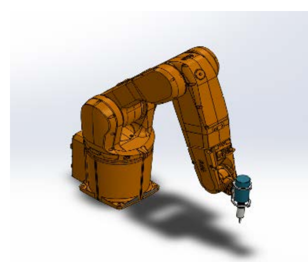
3.2.1. Ultrasonic Welding Robotic Design

The 3D CAD model for the ABB robot equipped with its ultrasonic probe as its end effector was created in SolidWorks. As shown in Figure 6, the robot arm is complete with its base, linkages, revolving and twisting joints and end effector. The ultrasonic probe assembly is also exploded with its mounting bracket and horn included. The 3D CAD model is an accurate representation of the robot being used for ultrasonic welding. As can be seen in Figure 2, the model does not include the IR camera, workpiece, US generator or worktable. Furthermore, since no VR simulation was done, the model is not interactive. However, all the moving and most important parts of the robot are present and fit together as intended for the scope of displaying the configuration of the ABB IRB robot outfitted for ultrasonic welding.

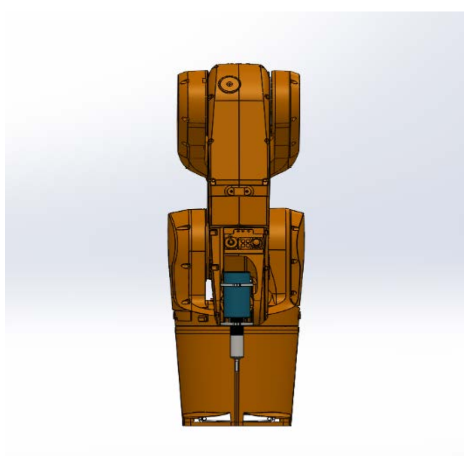
This project uses a 3D CAD modeling software to design a robot for industrial application and simulate it with VR software. Students have selected ABB IRB robot that was used in a previous study from Drexel's Engineering Technology Program for this project. Simulating this robot using available software such as 3D Virtual Reality gives experience that normally is unattainable. This gives the students an opportunity to use a soon-to-be-implemented industrial ultrasonic welding robot and also get an experience in troubleshooting issues in industrial automation. 3D Virtual Reality allows the students to become familiar with the dynamics and control of the robot as well as its application in ultrasonic welding. This project established the advantages of using virtual reality to demonstrate how robotics can be used to offer an environmentally friendly solution to industrial systems. This particular project was based around ultrasonic welding. The program CAD 3D was used to design an ABB IRB robot with an ultrasonic probe for welding purposes.



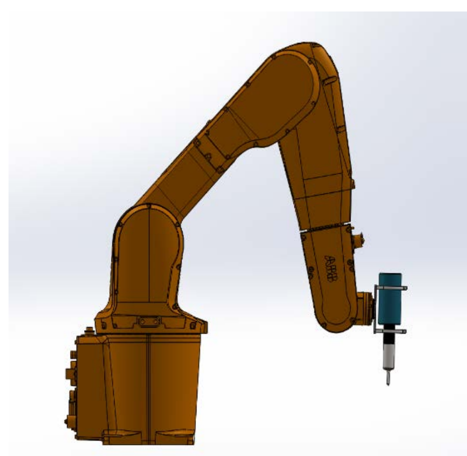
(a) Top View



(b) Iso View



(c) Front View



(d) Side View

Figure 2: Views (a), (b), (c), and (d) of the Ultrasonic Welding ABB Robot

3.2.2. Robotic Solar Panel Cleaner

The project goal is to design a robot to clean the solar arrays of a solar farm autonomously. This was completed through the use of CAD, animation, and VR software. Different data collection methods were adopted from online sources to clean the designed solar arrays. The design process began with brainstorming ideas for creating a robot for green energy application. A basic design was sketched out and approved, 3D design began in fusion 360. After the model was completed, the various parts were exported as .stl files to be converted to .obj files via the program MeshLab to be used in Unity, a video game design software. Once imported into Unity, the models were assembled and scripts written to allow the models to move as they would in reality, as seen in Figures 3 and 4. A script was also written to allow the camera to change position for different views. Once completed, the Unity program was built to allow a standalone demonstration of the robot's functionality as seen in Figures 5 and 6. Concurrently, the .obj files were loaded into VR Robotics Simulator. Once in the simulator, the robot could be viewed through a VR system for purposes of understanding scale and appearance, as seen in figure 8. Both the Unity program and VR Robotics Simulator implementation provided different methods by which the robot could be demonstrated and/or previewed.

Figure 3. Robot Transfer Cart Model

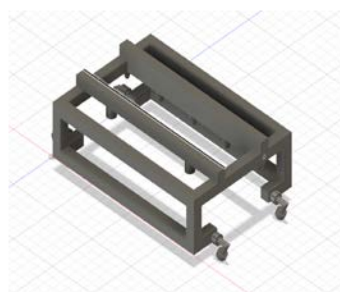


Figure 4. Solar Panel Cleaner Robot Base

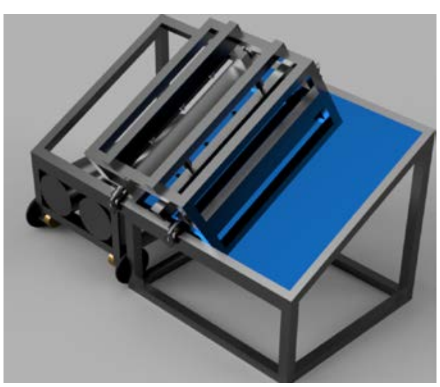


Figure 5. Robot, Cart, and Solar Panel Assembly

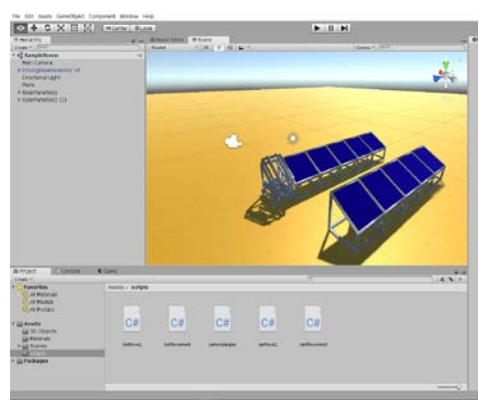


Figure 6. Assembly Unity Model with Solar

3.2.3. Robotic Solar Panel Assembly

This project specifically focuses on the framing portion of the solar panel production cycle which is simulated using VR. Solar panel 3D models were created to be used in an end stage production environment through VR. Solar panel production was focused on because the overall process is simple in theory and that if a portion was selected out of the total it would be within the group's capabilities to perform. The first part of the project was to select the appropriate portion of the assembly process. The overall assembly process generally goes glass loading and treatment, Ethylene-Vinyl Acetate (EVA) Lay-up to meld the glass plates together, weaving of the Photovoltaic Materials via stringing; which means that lines of photon receiving material are laid in parallel on the vertical then in the horizontal to create patches of diodes, then more EVA on top of the stringed materials, then further lamination and heat treating, then trimming, then framing, and finally testing and packing the completed panels for shipment. The group chose to do the framing portion because it was with the machines and the software the group had access to. The framing process generally goes the solar panel is moved to a container or to metal containing walls which are then pressed to the dimensions of the panel and then spot welded together. There should be an opening for an electrical terminal for power to be drawn from the panel cut into the case before the assembly process.

The first step in the creation of the assembly line in VR was to select the appropriate CAD software and then model out the panels. There are many choices for this software such as PTC Creo, Solidworks, and Fusion 360. Fusion was chosen because of its versatility, its innate ability to export its files as .stl which allow us to then convert those into .obj files which means they can then have a physics engine applied to then to simulate physical space with realistic causes and effects.

To make 3D models in Fusion 360 the first step is to sketch out a shape and then extrude that shape to the proper dimensions and other criteria. For the group the students needed the case for the solar panel glass pane, the glass panel with the diodes on it, then finally the stages of the case being folded just in case the program that either converts the 3D model into a 'physical' object or the simulator cannot manipulate the unfolded case. The electrical terminal was not modeled because that is post this part in the assembly line. The cases were basic rectangles with small folding edges and flaps modeled in to give then a more realistic feel, and then one of the cases had the flaps moved at a 60-degree angle to represent the folding process. The actual glass panel was just a rectangle with a .jpeg pasted on top that was rendered to give it a realistic sheen as shown in Figures 7 and 8.

Once the models were fabricated, they were saved natively as Fusion 360 files then as .stl files and exported to a converting program. On the market there are many programs that can do this. They range from Blender, Autodesk Maya, Unreal Engine, Unity Engine, MeshLab, etc. The great majority of these programs are for the videogame and graphical design industry, but for our purposes they are used to make files that are essentially a graphical shell (.stl files) and convert them to 'real' objects (.obj file format). The program chosen was Blender because it is free and required the least set-up. Essentially all that is done is the .stl is imported into the software and there appears to be a small cube in the place where the object appears. If this cube is not selected and deleted the program sets the origin wrong and make the center of the imported the median position of both the cube and the object. The reason this occurs is due to the fact both objects appear ‘clipped’ or melded into each other and in order to give an object its ‘real’ physics the origin must be set to the object and not some universal origin (Figure 9).

After successfully performing the origin setting operation for all the uploaded files they are then saved natively then exported in .obj format. These are then uploaded to the program VR Robotics Simulator where they are then used as props to perform certain tasks. In the program the user with a VR headset and controls can select from a menu multiple robots and end effectors to simulate certain assembly line configurations. Ours specifically has the form of two conveyor belts; one with the panel complete and one with the case cut out and stamped. Then an ABB 120 series six axis robot would use its suction cup array end effector to move the panel from its belt to the case and place it inside. From there angle plates or compressors would use plungers to fold and press the case together to create a friction fit around the panel. From there a second ABB robot would spot weld the case together and then finally the conveyor belt would move the completed panel onwards.

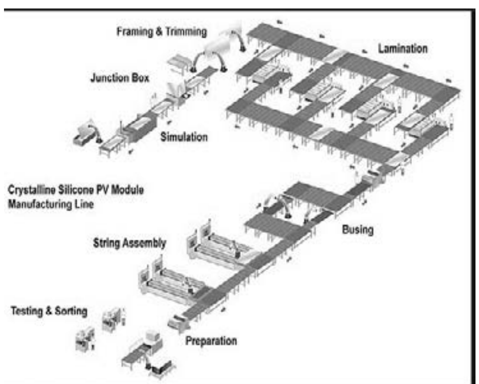


Figure 7. Solar Panel Production line

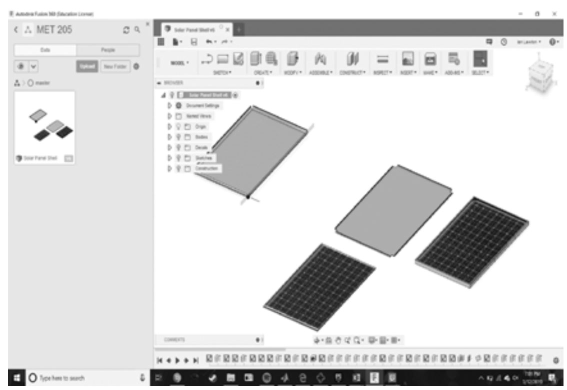
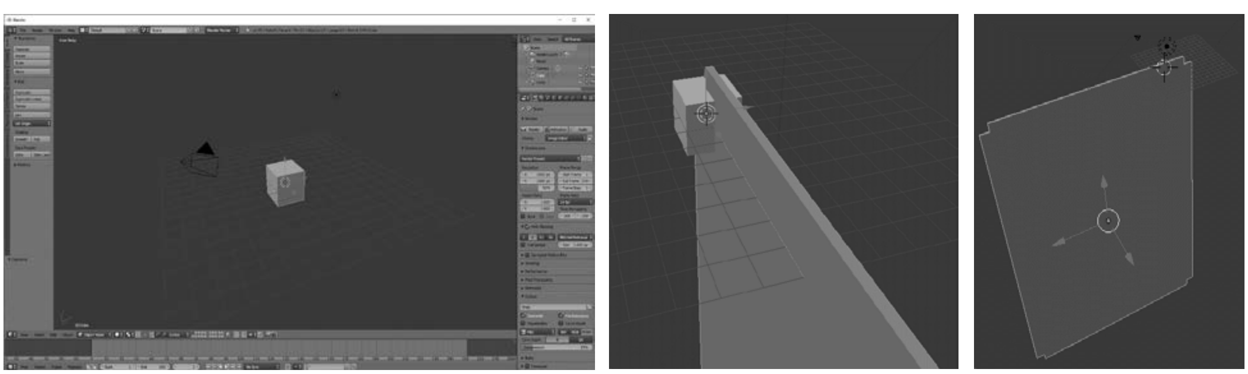


Figure 8. Solar panel parts



(a) (b)

Figure 9. Blender application model upload stages: (a) and (b)

4. Student Learning Outcomes and Analysis

The final project idea for the course was with virtual reality was given to students in groups so that they could play around their knowledge in robotics and understand and applications in the area. A total of 2 sections among 24 students followed given procedures and wrote concluding reports on their final projects. They were instructed to design a small-scale robot using a 3D CAD modeling software, to simulate it with VR, and to compare the simulated data with calculated data from the course labs. Overall, the feedback received at the end of the term from the participating students was largely positive with regards to the experiments involving renewable energy systems. Many students appreciated the ease with which the robot can be designed and simulated in an attempt to deal with issues as they arise. Without a doubt all the students were exposed to the product topic surrounding materials, fabrication, testing, and measurements. Students are required to analyze, design, and simulate a completely functional system by the end-of-term project.

Difficulties in Design: Most of the difficulties present in our design stage would be Unity's specific import file compatibility as well as the compatible files still not being able to be imported properly because of windows video file decoder. This led to a couple hours of the project being dedicated solely to getting the video file into unity and functioning properly. Another design aspect that had to be considered was the orientation of the plane as well as the main camera that is filming the "scene" of VR. This was mostly due to the unfamiliarity with Unity software.

STUDENT SURVEY RESULTS:

The final assessment of how this idea fared is done by providing the students with surveys in Tables 1 and 2 based on seven criteria listed below:

1 Rate your understanding of meaning and nature of the robotics lab course.
2 How will you rate your understanding of Virtual Reality (VR)?
3 How will you rate VR enhances your understanding of robotics?
4 Rate your understanding on the project IDEA.
5 How well do you know SOLIDWORKS and 3D modeling?
6 How well do you know BLENDER and Unity 3D?
7 How well do you rate your 3D modeling experience for VR?

The students rate these questions a score out of 5 based on their understanding before and after taking this course. We later used this survey data to analyze how 3D modelling and VR helps student understand more about the Industrial Robotics application.

Student Understanding Score: Sum of all the ratings given by an individual student for the survey. This is a measure of how well each student knows about all the topics.

Class Understanding Score: Sum of all the ratings given by all the students to a particular criterion. This is a measure of how well the class knows about a topic.

Table 1. MW SECTION

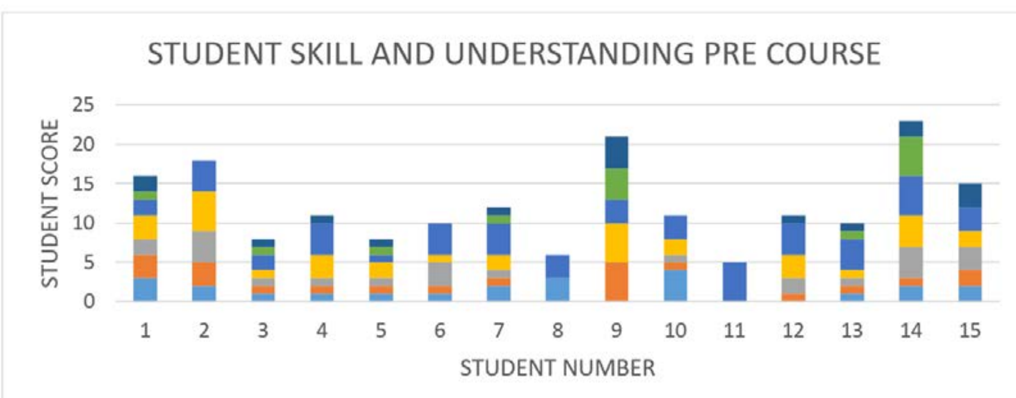
PRE-COURSE RATING		Student 1	Student 2	Student 3	Student 4	Student 5	Student 6	Student 7	Student 8	Student 9	Student 10	Student 11	Student 12	Student 13	Student 14	Student 15	CLASS UNDERSTANDING SCORE
S No.	Survey Questions	Pre Course RATING (Out of 5)	Pre Course RATING (Out of 5)	Pre Course RATING (Out of 5)	Pre Course RATING (Out of 5)	Pre Course RATING (Out of 5)	Pre Course RATING (Out of 5)	Pre Course RATING (Out of 5)	Pre Course RATING (Out of 5)	Pre Course RATING (Out of 5)	Pre Course RATING (Out of 5)	Pre Course RATING (Out of 5)	Pre Course RATING (Out of 5)	Pre Course RATING (Out of 5)	Pre Course RATING (Out of 5)	Pre Course RATING (Out of 5)	
1	Rate your understanding of meaning and nature of the robotics lab course	3	2	1	1	1	1	2	3	0	4	0	0	1	2	2	23
2	How will you rate your understanding of Virtual Reality (VR)?	3	3	1	1	1	1	1	0	5	1	0	1	1	1	2	22
3	How will you rate VR enhances your understanding of robotics?	2	4	1	1	1	3	1	0	0	1	0	2	1	4	3	24
4	Rate your understanding on the project IDEA.	3	5	1	3	2	1	2	0	5	2	0	3	1	4	2	34
5	How well do you know SOLIDWORKS and 3D modeling?	2	4	2	4	1	4	4	3	3	3	5	4	4	5	3	51
6	How well do you know BLENDER and Unity 3D?	1	0	1	0	1	0	1	0	4	0	0	0	1	5	0	14
7	How well do you rate your 3D modeling experience for VR?	2	0	1	1	1	0	1	0	4	0	0	1	1	2	3	17
	STUDENT UNDERSTANDING SCORE PRE-COURSE	16	18	8	11	8	10	12	6	21	11	5	11	10	23	15	185

POST-COURSE RATING		Student 1	Student 2	Student 3	Student 4	Student 5	Student 6	Student 7	Student 8	Student 9	Student 10	Student 11	Student 12	Student 13	Student 14	Student 15	CLASS UNDERSTANDING SCORE
S No.	Survey Questions	Post Course RATING (Out of 5)	Post Course RATING (Out of 5)	Post Course RATING (Out of 5)	Post Course RATING (Out of 5)	Post Course RATING (Out of 5)	Post Course RATING (Out of 5)	Post Course RATING (Out of 5)	Post Course RATING (Out of 5)	Post Course RATING (Out of 5)	Post Course RATING (Out of 5)	Post Course RATING (Out of 5)	Post Course RATING (Out of 5)	Post Course RATING (Out of 5)	Post Course RATING (Out of 5)	Post Course RATING (Out of 5)	
1	Rate your understanding of meaning and nature of the robotics lab course	5	5	3	5	4	4	5	5	3.8	5	5	4	4	5	3	65.8
2	How will you rate your understanding of Virtual Reality (VR)?	3	4	2	3	2	3	3	0	5	2	3	3	3	3	3	42
3	How will you rate VR enhances your understanding of robotics?	2	5	1	4	3	3	4	0	4	2	3	4	1	4	3	43
4	Rate your understanding on the project IDEA.	3	5	1	4	4	4	5	3	5	4	5	4	5	5	4	61
5	How well do you know SOLIDWORKS and 3D modeling?	2	4	2	4	3	4	5	4	4	3	5	4	4	5	3	56
6	How well do you know BLENDER and Unity 3D?	2	3	1	1	1	3.5	3	2	4	0	0	3	2	5	2	32.5
7	How well do you rate your 3D modeling experience for VR?	2	1	3	3	2	3.5	2	0	4	1	1	3	1	3	3	32.5
	STUDENT UNDERSTANDING SCORE POST-COURSE	19	27	13	24	19	25	27	14	29.8	17	22	25	20	30	21	332.8

Table 2. TTR SECTION

PRE-COURSE RATING		Student 1	Student 2	Student 3	Student 4	Student 5	Student 6	Student 7	Student 8	Student 9	Student 10	Student 11	Student 12	CLASS UNDERSTANDING SCORE
S No.	Survey Questions	Pre Course RATING (Out of 5)	Pre Course RATING (Out of 5)	Pre Course RATING (Out of 5)	Pre Course RATING (Out of 5)	Pre Course RATING (Out of 5)	Pre Course RATING (Out of 5)	Pre Course RATING (Out of 5)	Pre Course RATING (Out of 5)	Pre Course RATING (Out of 5)	Pre Course RATING (Out of 5)	Pre Course RATING (Out of 5)	Pre Course RATING (Out of 5)	
1	Rate your understanding of meaning and nature of the robotics lab course	1	0	1	1	0	1	1	1	4	4	3	2	19
2	How will you rate your understanding of Virtual Reality (VR)?	3	0	3	0	0	1	1	1	4	3	3	3	22
3	How will you rate VR enhances your understanding of robotics?	2	0	0	2	3	1	1	1	3	0	3	3	19
4	Rate your understanding on the project IDEA.	0	0	0	0	0	1	1	3	4	0	0	2	11
5	How well do you know SOLIDWORKS and 3D modeling?	3	5	5	0	4	5	1	1	5	5	3	5	42
6	How well do you know BLENDER and Unity 3D?	0	0	0	0	0	0	1	2	1	0	1	1	6
7	How well do you rate your 3D modeling experience for VR?	5	0	0	0	0	5	1	2	3	0	1	1	18
	STUDENT UNDERSTANDING SCORE PRE-COURSE	14	5	9	3	7	14	7	11	24	12	14	17	137

POST-COURSE RATING		Student 1	Student 2	Student 3	Student 4	Student 5	Student 6	Student 7	Student 8	Student 9	Student 10	Student 11	Student 12	CLASS UNDERSTANDING SCORE
S No.	Survey Questions	Post Course RATING (Out of 5)	Post Course RATING (Out of 5)	Post Course RATING (Out of 5)	Post Course RATING (Out of 5)	Post Course RATING (Out of 5)	Post Course RATING (Out of 5)	Post Course RATING (Out of 5)	Post Course RATING (Out of 5)	Post Course RATING (Out of 5)	Post Course RATING (Out of 5)	Post Course RATING (Out of 5)	Post Course RATING (Out of 5)	
1	Rate your understanding of meaning and nature of the robotics lab course	5	4.5	4	5	3	5	2	4	5	5	4	4	50.5
2	How will you rate your understanding of Virtual Reality (VR)?	5	2	3	2	0	2	2	2	4	4	3	3	32
3	How will you rate VR enhances your understanding of robotics?	4	3	2	4	3	2	2	4	4	3	4	4	39
4	Rate your understanding on the project IDEA.	5	4	1	3	2	2	2	4	4	3	1	2	33
5	How well do you know SOLIDWORKS and 3D modeling?	4	5	5	4	4	5	2	3	5	5	3	5	50
6	How well do you know BLENDER and Unity 3D?	5	2	2	3	2	0	2	2	2	2	3	2	27
7	How well do you rate your 3D modeling experience for VR?	5	2	3	2	1	5	2	2	4	3	3	3	35
	STUDENT UNDERSTANDING SCORE POST-COURSE	33	22.5	20	23	15	21	14	21	28	25	21	23	266.5



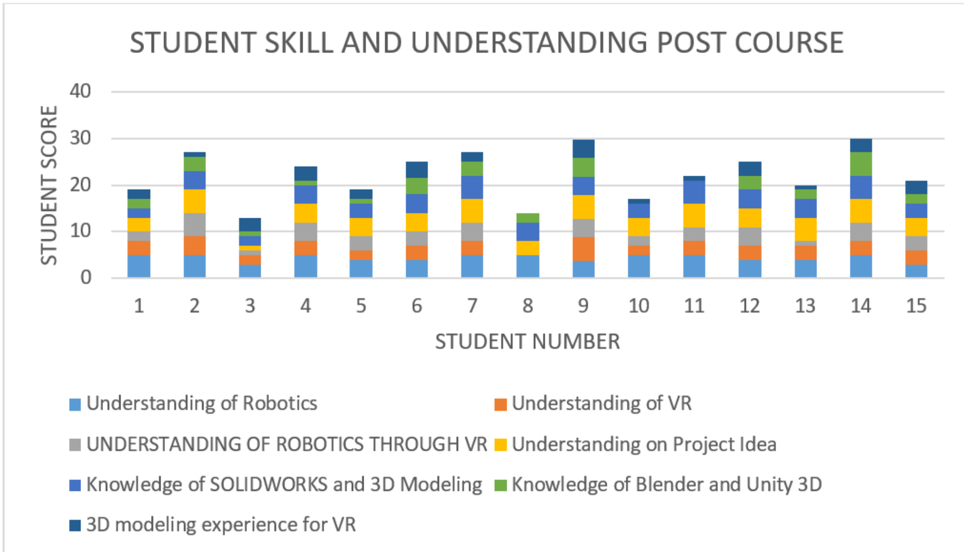


Figure 10. Results pertaining to MW Section

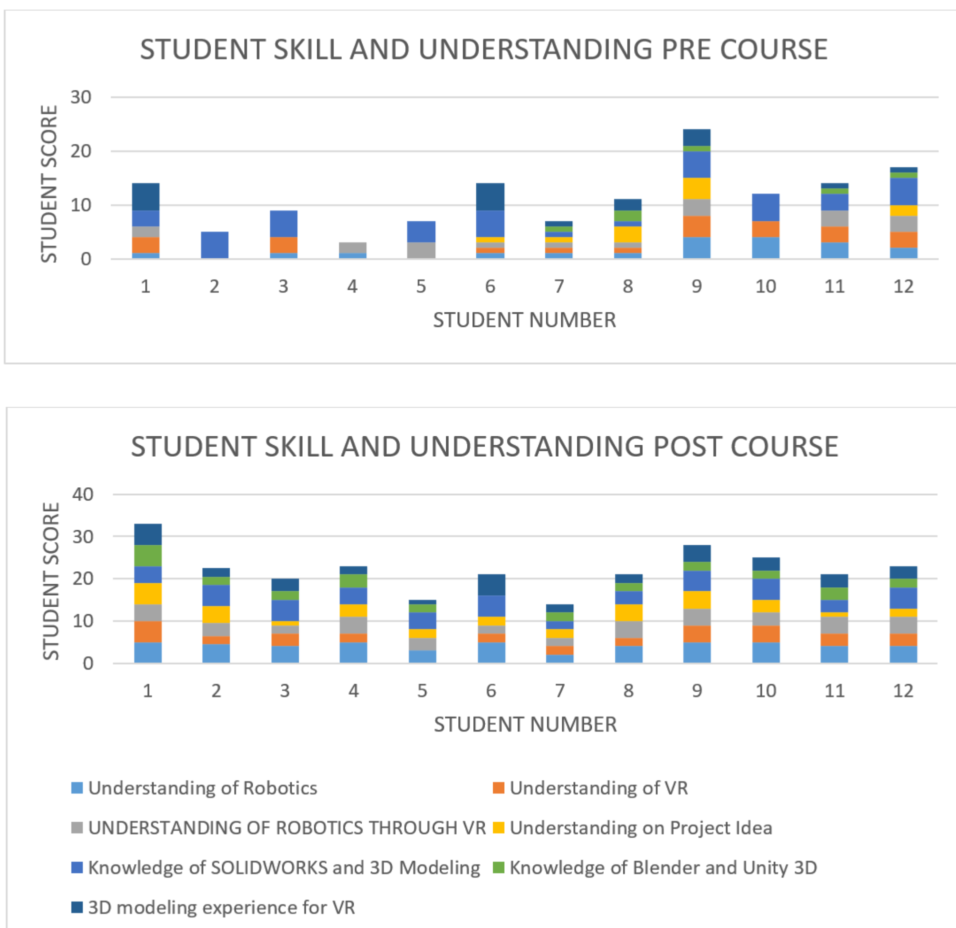


Figure 11. Results pertaining to TTR Section

Analysis of the data: As per the data and graph presented in above Figures 10 and 11, it is clear that we are able to see a good increase in student's understanding by using 3D modelling, simulation and VR in industrial automation. We found the mean class understanding of the topics before the course during the MW section was 12.33 and the class understanding after the class is 22.187, which is a fair increase of 79.89 %. Similarly, based on the individual student score, students found that it was easy to understand and learn from the course related to the concepts of industrial robotics, 3D modelling for VR and environmental energy, after the final project.

5. Conclusion

Having had a previous experience in a quarter conducting the 3D modelling design for Virtual Reality, we made major changes in providing the students with a proper hands-on step, clear idea about the projects and received the student feedback about the project. All this project was effective in demonstrating the advantages of using VR software as well as how to implement student projects into a VR environment. The design process was a challenge, but the final goal was met in that students were able to realize the 3D design in a VR environment. This project was a good demonstration of the whole robotic design process, from the 3D design all the way to VR analysis. By incorporating VR into robotics Education, this interactive method of learning brings about benefits to both engineering and technology students. The ability to model and simulate presents the tools and incentive for students to come up with creative and innovative solutions. This style of teaching can be appealing for the younger generation and motivating for slow learners, thus optimizing its effectiveness and improving the overall educational outcome.

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