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Integration of extended reality demonstration to a junior mechanical engineering design course

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Integration of extended reality demonstration to a junior-level mechanical engineering design course

Abstract:

The integration of extended reality (XR) technologies in engineering education, particularly in engineering design courses, has gained traction recently. The XR prototype demonstration was integrated into a junior undergraduate Mechanical Engineering design course.

ME386W is a junior design course that explores engineering design methods, including project planning and management, effective multi-disciplinary team skills, professional and effective technical writing, oral communication skills, professional ethics, and extended. This course is the last design course before the full-year capstone graduation project and does not involve making a physical prototype. The educational content, assessment plan, and rubric for integrating the XR demonstration are provided. Students' opinions were collected using a survey approved by the university ethics review board. 47 out of 72 students participated voluntarily in the study, which was completely blind to the instructor. Three example projects are explained, and outcomes are presented.

XR educational content development: Documents, videos, and training sessions were prepared to teach students how to translate their final designs from SolidWorks to other platforms that can be used for virtual reality (VR), augmented reality (AR), and mixed reality (MR). XR demonstration and rubric: The XR demonstration was designed as a team assignment in which students were required to demonstrate the function(s) of their final design concept using an XR-developed prototype/environment.

An extended reality demonstration was successfully performed for all projects. Three examples of these projects and their outcomes were analyzed and presented: 1 - A geodesic dome for Mars habitation; 2- Dynamic Dolly; 3- Exofit Biomedical Device.

Students evaluated the course design, including the XR prototype demonstration, was more engaging. The evaluation of projects was less subjective, and the course design was more inclusive than lecture-based courses. However, 54.4% expressed that this course required more workload than the traditional lecture-based courses.

Keywords: Extended Reality, Virtual Reality, Augmented Reality, Engineering Education, Mechanical Engineering, Design, Biomedical Engineering.

Body of the Paper

Introduction:

Extended reality has been used as an umbrella term that includes various technologies that provide an immersive experience of a product or process through using a digital space developed based on a virtual environment (virtual reality, VR), or augmented environment in real-world space (augmented reality, AR), or a combination of both (mixed reality, MR) [1].

XR has gained significant attention in education [2] because it can provide multiple complementary additions to traditional education [3] such as providing interactive and immersive training [4], improved visualization and demonstration [5], collaborative and remote learning [6], and improved accessibility and inclusion for students with disability [7] or students in rural areas [8]. Therefore, extended reality has been used in many areas of education such as engineering education design [9], health care[10], entertainment [11], travel [12], etc. This paper is focused on the integration of extended reality demonstration into an engineering design undergraduate course at the junior level in mechanical engineering.

The integration of XR in engineering design courses has shown a more active and engaging learning experience for students [13]. Also, XR allows for an immersive experience of the engineering product or process and enhances the problem-solving skills of students [14]. There is also evidence that using XR platforms in engineering design courses improves the project management and communication skills of students [15] and allows for a better demonstration of engineering concepts [16] particularly when making a physical prototype is not feasible due to a lack of time and resources [17]. The improved demonstration using XR allows for tackling multidisciplinary projects in engineering design courses, particularly in junior and sophomore years when making a physical prototype could be challenging considering time, cost, and safety challenges. [18]. In our curriculum, ME386W is the 3^{rd}-year junior design course and the last design course before capstone projects. ME386W does not require a physical prototype to be made, considering the limited departmental resources and limited time of the semester. Therefore, ME386W could potentially benefit significantly from the use of XR technology [19]. However, there is limited information about integrating XR technology into mechanical engineering design courses [20]. Particularly, we did not find a publication about integrating XR technology into a mechanical engineering design course at the junior level.

This study hypothesized that XR technology could be successfully integrated into a 3^{rd}-year mechanical engineering undergraduate program, indicated as ME386W. XR demonstration (AR/VR/MR) was successfully used to demonstrate the final prototype design and function. Also, the educational content, the assessment plan, and the rubric for the XR demonstration are explained. Finally, some students' feedback and some examples of the XR prototype were presented. It is aimed that this paper provides some useful information about the potential learning benefits and procedures for integrating XR technology into a junior Mechanical Engineering design course.

Methodology:

1. Course Description:

ME386W explores engineering design methods, including project planning and management, effective multi-disciplinary team skills, professional and effective technical writing, oral communication skills, professional ethics, and extended. At the beginning of the semester, students decide on a project that is interesting for them and build their team. A major focus of the course is to translate core engineering knowledge from other courses to design and to learn and apply principles of effective technical writing to produce clear, concise, well-organized, well-written documents, presentations, and demonstrations of XR prototypes. This course is the last design course before the full-year capstone graduation project and does not involve making a physical prototype. Students will use XR to demonstrate the function(s) of their designed project.

2. XR educational content:
Some educational content in the form of documents, videos, and training sessions was prepared to teach students how to translate their final designs from SolidWorks to other platforms that can be used for VR, AR, and MR. Namely, educational contents were developed to use the Unity platform [21], Blender software [22], and the eDrawings viewer [23]. Training sessions and interactions with software engineers, who were experts in these packages, enhanced the learning curve for students.

3. XR demonstration and rubric:
The XR demonstration was designed as a team assignment in which students were required to demonstrate the function(s) of their final design concept using an XR-developed prototype/environment. The purpose of this assignment is to help students practice the following skills using extended reality technology:

- Identify, formulate, and solve complex engineering problems
- Apply engineering design to produce solutions
- Communicate effectively with a range of audiences
- Function effectively on a team

The rubric for the XR demonstration, which was used to assess the performance, is provided in Table 1. The rubric is flexible and can be applied to various projects, often multidisciplinary projects, such as projects in the fields of construction, energy, water, automotive, aerospace, and biomedical industries.

Table 1- Grading rubric for the XR demonstration assignment

	Novice	**Competent**	**Proficient**	**Grade out of 100**
Project description	No project description mentioned (0-5)	Description of the project exists but is not complete (5-10)	A complete description of the project (10-15)	15
Design description	No description of the design concept (0-5)	A description of the design concept exists but is not complete (5-10)	A complete description of the design concept (10-15)	15

Use XR to identify, solve, and communicate the solution to a range of audiences	XR is not used to identify, solve, and communicate the solution to a range of audiences (0-15)	XR is somewhat used to identify, solve, and communicate the solution to a range of audiences (15-30)	XR is completely used to identify, solve, and communicate the solution to a range of audiences (30-45)	45
Quality of functioning as a team	No and low level of teamwork (0-10)	Some level of teamwork (10-15)	High level of teamwork (15-25)	25

Results and Discussion:

1. Explanation of the projects

An extended reality demonstration was performed successfully for all projects. Some examples of these projects and their outcomes were analyzed and presented. Below, brief explanations of projects followed by the potential project goal(s) are provided. Also, an image is provided to show the XR demonstration.

In general, XR demonstrations (AR/VR/MR) helped students to have a clear understanding of the engineering concepts that they had in mind. Also, students used this demonstration to receive specific feedback from subject matter experts about their team projects. Finally, XR demonstrations were used for the final presentation of the project to the instructor, classmates, and industrial guests.

1-1. A geodesic dome for Mars habitation: The project was focused on determining how to create a habitable geodesic dome on the surface of Mars to advance the exploration and understanding of the planet. Adequately designing a habitat suitable for life on Mars would allow for prolonged manned missions and further research. This can be beneficial to the future survival of humanity, as Earth's natural resources are being depleted and a future need to outsource the acquisition of these materials or relocate the population may arise. Goal statements for this project are 1) Develop a geodesic dome that can withstand the atmosphere of Mars. 2) Research and modify previous dome designs to fit better the requirements introduced by this problem. 3) Design a dome that meets all client needs and given customer requirements.

Figure 1 – A sample project on a geodesic dome for Mars habitation.

1-2. Dynamic Dolly: The project's goal was to design an electric four-wheeled autonomous wheelbarrow that can navigate a construction site efficiently and make a construction project more productive by freeing up a man on the site. Since workers on a construction site are strained by many tasks, giving the task of lifting heavy materials to a machine reduces the strain on the workers. This leads to the workers being more valuable to their employers since they are more productive with the time, they are given to complete a job. Implementing the autonomous wheelbarrow into the job site requires less travel throughout the job site and makes it safer for the workers.

Figure 2- A sample project on Dynamic Dolly

1-3. Exofit Biomedical Device: The ExoFit is an exoskeleton built for recreational use to assist professional athletes in exercise, providing a more effective workout. The ExoFit is fitted with two sensors placed on the hip to track the users' gait cycle which signals to actuators located on the hip to provide torque during the swing phase of the gait cycle. This allows for both assistance and resistance in human motion. The ExoFit is a reliable and inexpensive option compared to other similar exercise exoskeletons on the market. The ExoFit aims to be the most cost-effective, efficient, and lightweight recreational assistive belt for athletes.

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Figure 3 - A sample project on Exofit Biomedical Device

2. Students' opinions about the course design

The opinions of students about the design of the course and the potential impact due to the integration of XR into the course were collected using a voluntary and blinded questionnaire. 47 out of 72 students participated in the survey. The questions and the statistics of responses are as follows:

Question 1) Assessments of ME386W are based on more tangible outcomes (e.g., quality of the final project and XR demonstration). Do you agree that such assessment formats are less subjective than those of traditional lecture-based courses because they are linked to student performance throughout the semester (e.g., weekly submissions and final project XR demonstration)?
The distribution of results is shown in Figure 4. The results showed that 65.9% (31/47) of students either agreed or strongly agreed with the question statements.

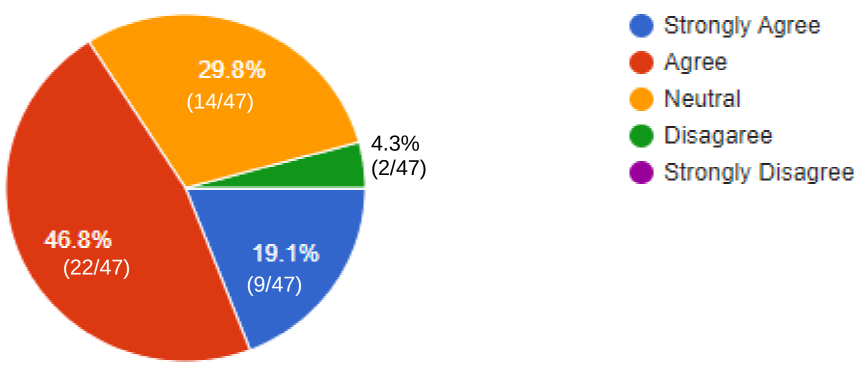

Figure 4 – Survey results for question 1.

Question 2) Increased participation of underrepresented groups within the engineering workforce helps the engineering profession better understand, and therefore protect and contribute to the public interest. Students from underrepresented groups, however, may find conventional formats of course assessment challenging (e.g., due to language barrier). Assessments of ME386W are believed to be more inclusive and equitable as the majority of them are based on hands-on experiences and XR demonstrations.
The distribution of results is shown in Figure 5. The results showed that 76.5% (36/47) of students either agreed or strongly agreed with the question statements.

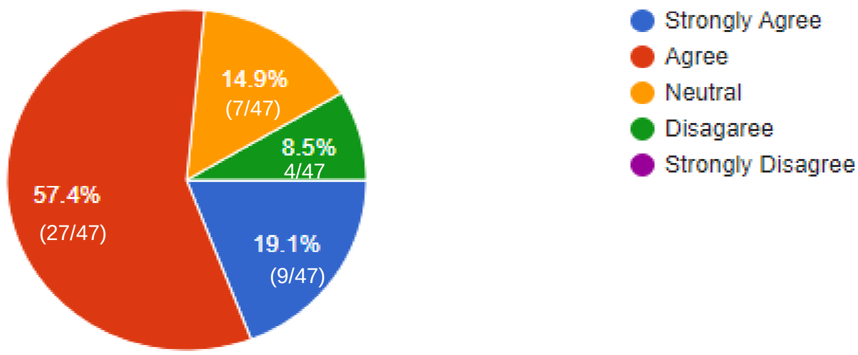

Figure 5 – Survey results for question 2.

Question 3) XR demonstrations in ME386W improve the motivation of students to reach the end of the project.
The distribution of results is shown in Figure 6. The results showed that 65.9% (31/47) of students either agreed or strongly agreed with the question statements.

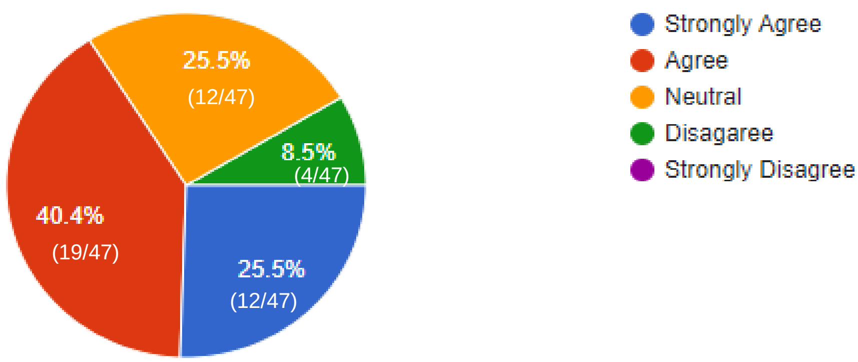

Figure 6 – Survey results for question 3.

Question 4) ME386W results in a higher workload for students than traditionally taught courses.
The distribution of results is shown in Figure 7. The results showed that 57.4% (27/47) of students either agreed or strongly agreed with the question statements.

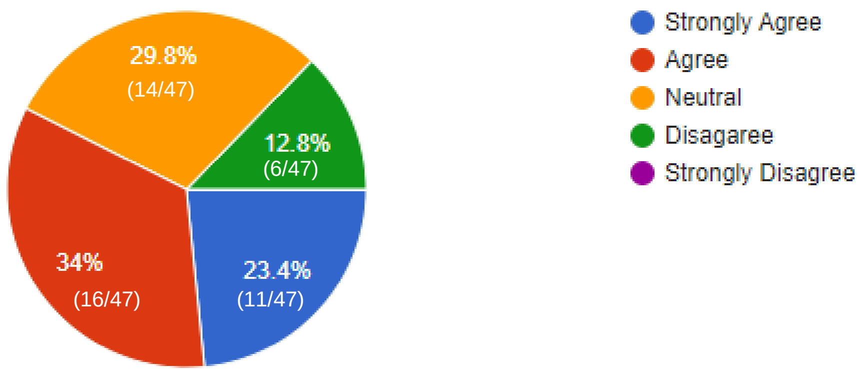

Figure 7 – Survey results for question 4.

Overall, based on questions 1 to 4, students provided positive feedback about the integration of XR technology to the ME386W, which is consistent with limited previous experiences in the field of Mechanical Engineering [24] and with the observation of the course instructor. This was also reflected in the official and independent general course evaluation that was performed by the institution from students. The XR demonstration allowed students to present their ideas and designs to subject matter experts and stakeholders more clearly and succinctly and receive more specific feedback during and at the end of the semester.

This study is subject to limitations. The findings are based on one semester. Continuous observations in multiple semesters are needed to ensure the educational value of XR demonstration to students and the course. Also, the student survey should be improved using standard survey methods to improve the phrasing of questions and expand the potential evaluation areas. With limitations in mind, this study provided a first step toward integrating the XR technology in a junior-level mechanical engineering design course for the first time in our institution which can be potentially improved in the future.

Conclusion:

XR technology was successfully integrated into ME386W, a junior mechanical engineering design course. Some practical insights about the process, such as the needed educational content, the assessment plan, and the rubric for the XR demonstration, are explained. Finally, some examples of the XR prototype and students' feedback were presented.

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