Instructional Considerations For Virtual Reality In Engineering Training And Education: Preliminary Research Results

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INSTRUCTIONAL CONSIDERATIONS FOR VIRTUAL REALITY IN ENGINEERING TRAINING AND EDUCATION: PRELIMINARY RESEARCH RESULTS

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ABSTRACT

Digital reality has been gradually introduced into all parts of human society, and the field of education is no exception due to the potential of technology and related tools to enhance the teaching and learning process. However, there is still a paucity of research in this area within an Irish higher education context.
The research explores how to best employ virtual reality (VR), using the Oculus Quest 2 system, to improve and develop the level of contemporary training, as well as to enhance the educational experience. Both the technical and educational perspectives will be considered.
The researched sample consists of 25 undergraduate students representing different profiles from within engineering education. The data collection included two stages, namely written questionnaires, and short semi-structured interviews relating to training sessions with Oculus Quest 2, in which participants were exposed to life on board the International Space Station (ISS), including the experiments and missions performed on the station.
The results of the short interviews and questionnaires extracted in this work reflected that all the participants were very excited to work and interact with the experiences of virtual reality in engineering education. In addition, they rated the usability of virtual

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reality glasses overall as being very satisfactory, despite some students expressing the presence of minor challenges or problems.
Most of the participants' reactions were positive regarding the possibility of including virtual reality devices and associated technologies in future training and support, as they indicated that these training sessions increased their motivation and passion for learning, whilst at the same time, supported the development of their digital reality skills.. In general, the outputs of the research show that the inclusion and empowerment of digital reality within higher education programmes can have significant value and benefit, leading to the recommendation that it would be used more extensively in the future.

1 INTRODUCTION

Digital tools based on virtual reality (VR) technologies have witnessed a remarkable expansion in recent times, especially with the increase in features and characteristics available and their relative ease of use. The popularity of these technologies has increased rapidly in the field of games platforms, in addition to gaining traction within the fields of education and health care training (W. Werner et al. 2007 and R. Jaziar et al. 2020). Additionally, its unique features, such as the sense of presence and the immersive experience of losing connection to the physical world, have led to creating new interest for users (R. Jaziar et al. 2020 and W. Peng 2018).
It is worth noting that the non-prohibitive cost of such technologies has allowed researchers to use and work on developing specific applications suitable for use in academic environments (Y. Zinchenko et al. 2020 and D. Carruth 2017). In addition, these technologies represent a good alternative or complementary solution for some complex, sensitive and expensive engineering devices and laboratories (Z. Zacharias et al. 2014, K. Winkelmann et al. 2020 and G. Mosquera et al. 2018).
This research work presents the means by which the VR equipment (i.e., the Oculus Quest 2 system consisting of a VR headset (head-mounted display) and two controllers) was used as a support tool in engineering education to enhance the current learning approach. Also, the work focuses on how to incorporate learning theories during the selection or design of virtual reality (VR) applications. Equally, this would allow for the development of a general framework for building, managing, examining and evaluating VR technologies that are designed within specific areas of engineering education.
The promising results of this work may open creative ideas towards establishing the technical and educational foundations for remote learning, which provides an opportunity for higher education institutions (HEIs) to engage in knowledge sharing and co-creation on an international basis.
In that respect, there are potential benefits from an educational perspective of integrating virtual reality technologies into the curricula. In terms of context, the current work sheds light on the benefits and challenges that the students faced during training sessions, as a case study in the Faculty of Engineering, South East Technological University (SETU), Carlow, in Ireland.
The work will focus on addressing the following sub-questions in the context of the current work under the project name “CarlowENG-VR1.0”:

1- From the perspective of the students, what is the effect of using virtual reality on their motivation and engagement?
2- In terms of educational setting and preparations, what should be considered when developing educational programmes that employ virtual reality?

3- What are the additional and unique features that VR environments offer in terms of pedagogical ?
4- How will the VR headsets (i.e., head-mounted display "HMDs" combined with multi-axis inertial measurement unit "IMUs") support the learning process and the development of attendant exploratory skills, from the perspective of the students?

In the next section. the project details and selected results will be presented, based on the experience gained, and the possibilities to employ a suitable digital reality system will be explored.

2 MATERIALS AND METHODS

2.1 Participants: Undergraduate Students

Undergraduate students from a range of engineering-related programmes, inter alia, electronics, and aerospace engineering, were notified regarding this project and were invited to participate on a voluntary basis. The invite was circulated to a total of 35 students, of which 25 opted to be involved and we can be confirming that informed consent was obtained from all 25 participants for these experiments. SETU Carlow Research Ethics Committee confirmed this project is compliant with statutory requirements and is conducted to the highest ethical principles.

2.2 Research Design

Each student who participated received project information and data collection debriefing over a number of days, in the second semester of the academic year 2022-2023. Each session lasted approximately 30 minutes and included the following activities:
1- An initial project information session by means of a short PowerPoint presentation (approximately 5 mins);
2- An initial individual, paper-based survey that had to be completed by each participant before using an immersive VR training session – survey completion time (5-7 mins);
3- A demonstration of the handling of the VR equipment (5 mins),
4- Individual guidance with the VR equipment according to the required training task (10-15 mins); and
5- A second individual, paper-based survey and a short interview with each participant (5-10 mins).

2.3 Contents and Framework of the Training Session

There are several educational perspectives that can be considered in engineering education and in this context, the chosen topic of the training session was selected based on the following two criteria:
(1) It should be of interest to prospective engineering students; and
(2) It should be based on digital reality (i.e., VR tools), in that it should have the ability to add notable and value, in terms of simplifying the contents and being more flexible and accessible than traditional teaching methods.

To match the students' profiles, which included electronics and avionics engineering majors, the chosen topic centred on the experiments and mission exploration being performed on the International Space Station. This was seen as a suitable case study which could provide new information, knowledge and skills.

It is worth mentioning, that NASA uses these technologies for training purposes in their own Virtual Reality Laboratory (VRL), which is an immersive training facility providing real-time graphics and motion simulators, integrated with a tendon-driven robotic device. This provides the kinaesthetic sensation of the mass and inertia characteristics of any large object (around 500lb or 226 kg) being handled (A. Guzman 2022), as shown in Figure 1a.

In all of the educational experiments conducted as part of this study, the Oculus Quest 2 system was used, which itself is a rather recent technical development. It was introduced to the markets as Meta Quest 2 at the end of November 2021. Oculus Quest 2 is a virtual reality (VR) headset that allows users to work, study, and engage in numerous life-imitating and imaginative simulations (H. Valentin et al. 2021 and A. Diar et al. 2022). In the visual output of the device, artificial objects and information can be displayed in the wearer's visual field, which can be interacted with via various gestures as shown in Figure 1b.

The selected VR training software (Mission:ISS) was designed by the L.A.-based Magnopus studio, in collaboration with NASA, the European Space Agency, and the Canadian Space Agency, where these virtual experiments create a true-to-life simulation which lets users visit and explore the International Space Station (ISS) within digital reality and feel what it is like to be in space in a way never before possible (P. James 2022).

(a) **(b)**

Fig. 1. (a) part of a training sessions at the 3D virtual reality laboratory at NASA's Johnson Space Centre in Houston (A. Diar et al. 2022), (b) Use of cases for Oculus Quest 2 as part of Livestream of the users' view in SETU-Carlow Campus.

Based on NASA's Space Station models, as well as discussions with multiple astronauts and the VR Laboratory at NASA's Johnson Space Centre in Houston, Mission:ISS recreates the International Space Station in painstaking detail. Whilst the idea of becoming an astronaut may be a pipedream for most, with these advanced digital technologies, the trainers can use their virtual hands to do several tasks such as, docking incoming cargo capsules, conducting spacewalks, and performing mission-critical tasks, virtually (A. Diar et al. 2022).

Through the training sessions, this visceral and interstellar experience signifies a new cornerstone of interactive education. The students have the chance to learn the history of the ISS and hear the inspiring stories of several astronauts in a series of immersive videos. And there is another educational component to the experience, most explicitly in terms of the optional pop-ups to be found. If something is highlighted in yellow when the trainee points at it – a spacesuit, say, or a control console – they can hold the trigger to reveal text and a photo or sometimes a video. Furthermore, a NASA astronaut will talk briefly about their experiences that can help and guide the students in their first-time training sessions.

In addition, a wide range of different representations can be shown, which is not as easily possible with the more traditional basic models. The Mission:ISS software was designed to display different representations, and create different user sessions as well, which gives them opportunities to extend the training sessions and add more flexibility to select a wide range of options (A. Diar et al. 2022 and P. James 2022).

In order to be able to work with this digital environment, the training session started with a short presentation of basic concepts for graphical user interface (GUI), controller options and keys. This section was followed by an introduction to the different representations which the Mission:ISS software can display. The designed sequential procedures can be visualized in Figure 2.

Following the introduction and initial survey, the student had the chance to handle the VR equipment and work through the user interface training session of the Oculus Quest 2 device, helping them to be familiar with gestures requisite to executing a Virtual Reality HMD and two controllers.

Through the demonstration session, the students were shown how to operate the Mission:ISS software. Once the software user interface was explained, the students then worked on the specific tasks individually for approximately 10-15 minutes before completing the second paper-based survey and a short interview.

The directives given to the trainee students within the teaching/training sessions were as follows:

(a) Allow the trainee to wear a helmet while looking at computer displays, whilst simulating actual movements around the various locations on the station hardware where the real astronauts were working.

(b) Visualize and test, a zero-gravity environment using the Touch controllers, as well as examining the effects of zero-gravity on human spatial awareness and balance.

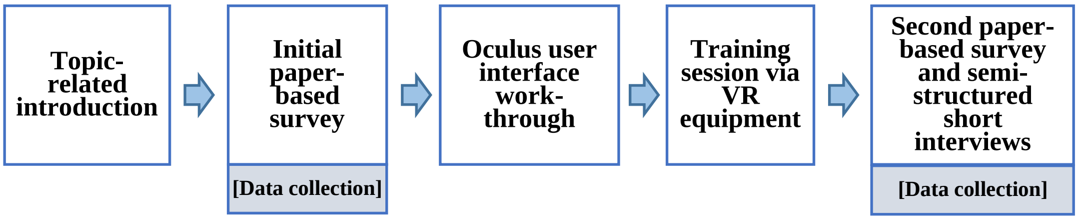

Fig. 2. Structure of the participants' programme.

2.4 Data Collection

The two written paper-based surveys were conducted as the main components of the data measuring and collection stage before analysing the research data using the standard validated tools and techniques. The essential goal of a questionnaire was to monitor and measure the participants' motivation and engagement as well as their experiences before and after using VR tools in the field of engineering education.

The two surveys contained several questions. Generally, there are three recommendations for evaluating user interface: efficiency, multiple perspectives, and tailoring which were proposed by Brooke (1996) (J. Brooke 2018 and J. Lewis 2018).

A System Usability Scale (SUS) questionnaire set for the first and second surveys was created based on these recommendations. A series of questions with multiple choices, some with a 5-point Likert scale (A. Joshi et al. 2015) response and some with text input response was created. A few examples are shown below;

1- Before testing the VR headset; In your Initial opinion, do you think this VR method is better than the traditional method of learning about concepts such as working in gravity/space environments? (Likert scale)
2- After testing the VR headset; How do you rate the user interface of the 3D video? (Likert scale)
3- After testing the VR headset; In your opinion, would this kind of VR learning app improve student learning in engineering? (Likert scale)
4- After testing the VR headset; How do you rate your level of confidence in navigating/using the app? (Likert scale)

Typically, the survey questions evaluated the effectiveness in learning/training especially complex models, features, navigation, User Interface (UI), and overall usefulness of the VR tool in achieving the learning goals.

Most of the participant's educational backgrounds were STEM, 80% of undergraduate students were male and 20% were female. The 5-point Likert scale survey questions were then analysed. After the participants had completed the work phase separately, they were individually interviewed about their experiences, their motivation, and their interests by means of a semi-structured brief interview which detailed results will be published in a separate contribution (the work in preparation).

2.5 Data Collection

The results of the two paper-based surveys were transferred into a spreadsheet software program (Microsoft Excel). Using this tool as a statistical analysis software, the data were analysed on a descriptive basis and factor analyses and correlations were calculated.

The link between the students' opinions before and after the training sessions for VR experiments can provide quantitative data and the ability to measure some factors. Additionally, it allows for the evaluation of the effectiveness of the learning approach adopted, especially in relation to the acquisition of new digital characteristics, the ability to simplify navigation of complex models, and the overall usefulness of the VR tool in helping to achieve the learning outcomes.

3 RESULTS

The results of this research work focused on the users' opinions based on the written surveys. However, some outcomes of the students' reflections will also be presented. The training included a short video explaining what the space surrounding the Earth looked like, as well as an opportunity to look at Earth from the angle of outer space. The participants were unanimous in their opinion that such immersive technologies for displaying educational films were invaluable.

Another question asked to the students focused on their opinions regarding the possibilities of including immersive 3D videos in educational programmes in order to stimulate/encourage people to increase their knowledge of planet earth and new space technologies. Figure 3a shows that 76% agreed and strongly agreed, with 20% are still neutral. Watching movies with virtual, or might even augmented, reality technologies adds new features to exploring one's surroundings, and discovering more precise details. In total 92% of the students classified the 3D-immersive video User Interface as very good, as illustrated in Figure 3b.

Another question asked to the students before and after VR experiments centred on the potential of VR programs and apps to help solve problems/achieve the goals more effectively than traditional teaching and learning strategies. After using the VR immersive tools, student satisfaction increased from 12% to reach 52%, as shown in Figure 4, which leads us to the importance of effective design when it comes to creating learning experiences, which can in turn increase the student's interest and motivations.

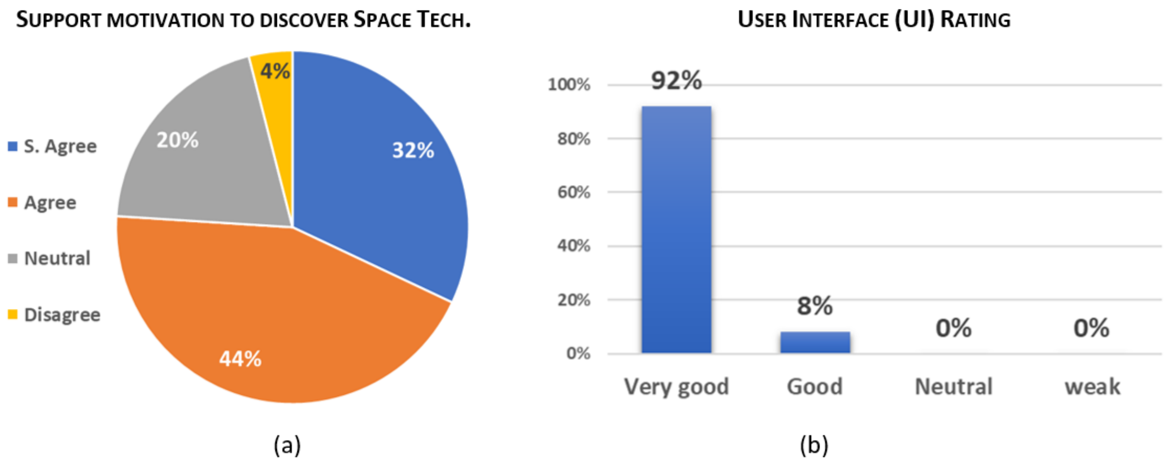

Fig. 3. Summary of the student opinions related to 3D immersive video.

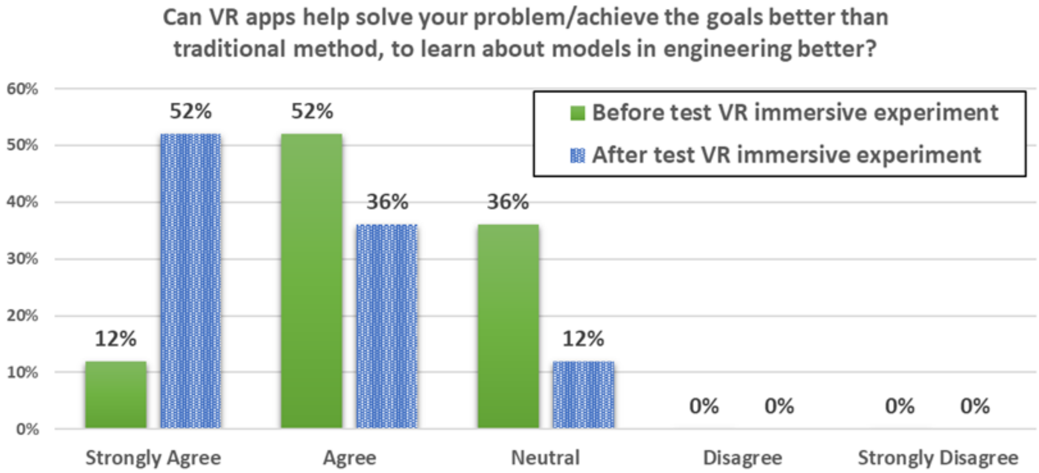

Fig. 4. User feedback before and after using VR headsets in engineering education.

4 DISCUSSION

The VR headset (head-mounted display) and 2 controllers (i.e., Oculus Quest 2 system) were used in this exploratory study as part of the engineering students' class sessions. This VR tool is a relatively new piece of equipment, having being first become available at the end of 2016. It includes a head-mounted display integrated with different high-tech sensors which can work together to support and provide innovative ways of teaching and learning. The exploration of new aspects of student engagement with VR was the focus of the study, which as noted, has been, for the most part, absent in the case of Irish engineering education. To date, there is limited research exploring the feasibility of using such wearable technologies such as bracelets, HMD (head-mounted displays) or gloves in field of higher education programmes.

The initial results related to the impact of virtual reality on learning, showed that the students enjoyed working with VR and they did not face major problems when dealing with it. The students' enthusiasm was observed during the VR sessions, particularly after completing the training part focusing on the Mission:ISS aspect and how to get around and interact with the station. Additionally, they appreciated the opportunity to employ VR devices in undergraduate education and they mentioned that their motivation and interest were augmented, and that their skills were enhanced, thereby illustrating that teaching and learning can be supported using different innovative means and employing digital reality technologies.

5 CONCLUSIONS

These kinds of training techniques and high-tech research using VR can increase knowledge creation and awareness by sparking learners' imagination, and supporting them to experience learning such as testing partial zero-gravity in the international space station, which would not have been otherwise accessible to them within the classroom.

Until the current study, there were a limited number of studies related to embedding virtual reality techniques in teaching engineering in Ireland. In this regard, the outcomes of this research work give new findings that might be related to the higher education sector in general or specifically to engineering fields. Mainly, the results explain that potential students or trainees are supportive of integrating VR technologies and related equipment in higher education programmes, especially as support tools in the laboratory.

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