Innovative 3D Virtual Electrical Safety Case Studies for Immersive Engagement

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Introduction

Work integrated learning (WIL) programmes are the core of engineering education. Universities in Australia usually have a mandatory 60 days of industry training for program accreditation. However, not all postgraduate coursework programs have the WIL requirement. The students in these programs are 95% international and hence come from diverse cultural and social backgrounds. International students do not generally have any opportunity to have direct industry partnerships during their postgraduate degree. Knowing that an essential requirement of WIL programmes is establishment of partnership with industries that will ensure that experiences, knowledge and resources are shared (Cooper et al., 2010), a postgraduate course on “electrical safety” was developed at the University of New South Wales (UNSW), Sydney, in 2010. This course is very popular among postgraduate students and the enrolments in this course have gone up from 47 in 2010 to 200 since 2017.

This course was conceived with WIL at its heart, and therefore was designed with curriculum input and guest lectures from practising senior power engineers. The idea is to enable students’ practical understanding and networking with industries. These guests are able to explain electrical safety in the context of the workplace and provide students with real world experiences (Metrejean, & Bollinger, 2001). The reflections of the guest speakers for this course indicated that they not only had the satisfaction of giving back, but also helped to develop their presentation skills (Ravishankar, & King, 2013). Interacting with the students offers other benefits to the industry speakers, like identifying talented students and generating fresh ideas (Atkinson, & Stanwick, 2015). In addition to technical knowledge, the industry guests are able to showcase other soft skills that include interpersonal, oral communication and leadership skills. These are required to lead and influence constant use of safe work practices (Aeiker, 2011).

Although the guest speakers from industry provide an important learning benefit by giving students real world knowledge, students can treat them as passive lectures. Additionally, there is a lot of uncertainty associated with relying on guest speakers being able to attend, as this is purely voluntary for them. Another way of improving the practical understanding is to enable field trips for students to relevant sites. Again, this is challenging as the student numbers are about 200 every year and sites are limited in the number of people that can attend at any given time. These challenges provided the motivation to create on-site 360 degree images of relevant sites. Videos of industry guest lectures and interviews were then added to create web-based interactive virtual reality (VR) simulations using the H5P Virtual Tour (360) tool, thus creating an immersive learning experience for students. These virtual tours allowed students to identify electrical hazards and determine safe solutions to remediate the identified hazards.

This paper outlines the approach used for creating the VR tours, the in-class collaborative activities and the evaluation whilst focusing on improving students’ ability to work in diverse teams by helping them to connect with each other, irrespective of their cultural backgrounds.

Virtual Reality (VR) Simulations

VR training systems have been found to be particularly useful in delivering an effective, convenient, and cost-effective way to provide active engagement through experiential learning. They use three dimensional real environments with interactive tools added to create an immersive and engaging learning experience (Sherman, 2018). VR in education can increase the collaboration between peers (Lin et al., 2013) and can also excite students to learn, eliminate distractions and make difficult concepts easier to learn (Abulrub et al., 2011).

According to Dale's (1969) cone of experience model, people remember 10% of what they read, 20% of what they hear, 30% of what they see, 70% of what they write and 90% of what they do. In engineering education, getting students to do an activity can be easily achieved using laboratory simulations. However, the course considered in this work is electrical safety, where students need to identify and offer solutions to safety hazards. These unsafe scenarios cannot be recreated in a lab. The purpose of VR simulations here is to provide this learning experience more safely and cost-effectively.

Our Approach

The main features that are required in the design of VR system are presence, navigation, scale, interaction, autonomy and cooperative learning (Sanchez et al., 2000). To make the virtual tour available to students to access at any time after the tutorial without the need for headsets or other custom devices, we went for a web-based approach. As reviewed by Manseur (2005), there are several web-based tools that can be integrated to generate VR models in engineering. The system we used was the H5P Virtual tour (360) tool. H5P is a free HTML 5 based authoring and presentation virtual tool that allows the creation of a virtual tour of an environment using both 360 and regular images (Joubel, 2019). Users can move through the environment as each of these images can be linked into a sequence of scenes. Users interact with the environment using a variety of interactive hotspots that contain text explanations, embedded video, audio and questions. The H5P virtual tour (360) tool is designed for any educator to be able to create virtual tours using a simple drag and drop authoring interface and is used by an increasing number of educators (Wilkie et al., 2018).

We developed five case studies for electrical safety in different environments: (i) Lab safety; (ii) Power line safety; (iii) Electrical safety in hospitals; (iv) Lightening safety; and (v) Solar farm safety. For each case study, the learning outcome was to identify all the engineering, administrative and personal protective equipment (PPE) solutions present in the environment. To achieve this learning outcome, we wanted to create an immersive environment for students to explore the electrical safety controls present in an otherwise inaccessible location. The design of the virtual tours for these environments allows for a curated interaction with highlighted features of the environment using text and image labels, and safety concepts to be explained using pre-recorded videos of the industry guests. To guide students in identifying safety controls, we made use of face-to-face sessions for students to work both by themselves and as a group.

Implementation

The process of developing the case studies involved careful planning of the tasks that needed to be done for pre-production, production and post-production (Figure 1). For each site, 360 images were taken with a Xiaomi Mijia Mi Sphere camera at several locations within a site. Close up images of points of interest and videos of subject matter experts explaining concepts were taken with a Canon 5D Mk II DSLR camera or Sony PXW-X70 Pro camcorder. Raw images and videos were edited for light levels and colour correction using Adobe Creative Cloud. Videos were also trimmed to correct length and for smooth transitions with Adobe Premiere Pro.

Pre-production
- Consultation
- Scope
- Planning/Design
- Storyboarding
- Scheduling

Production
- Scheduled time
- Gear
- Gear (set up time)
- Follow storyboard
- Extra footage if possible
- Back up data

Post-production
- Editing 360 images
- Editing images
- Editing Video
- Edit Audio

Figure 1: The virtual tour implementation process involved a series of tasks organised into three phases; pre-production, production and post-production.

The H5P Virtual tour (360) tool was used to add text and image hotspots (labels) to the 360 images to orientate students to the safety features of the environment (Figure 2). Recorded videos of subject matter experts were added as hotspots in different areas of the site to explain safety concepts. Additional scenes were added to allow students to move between different locations in the site.

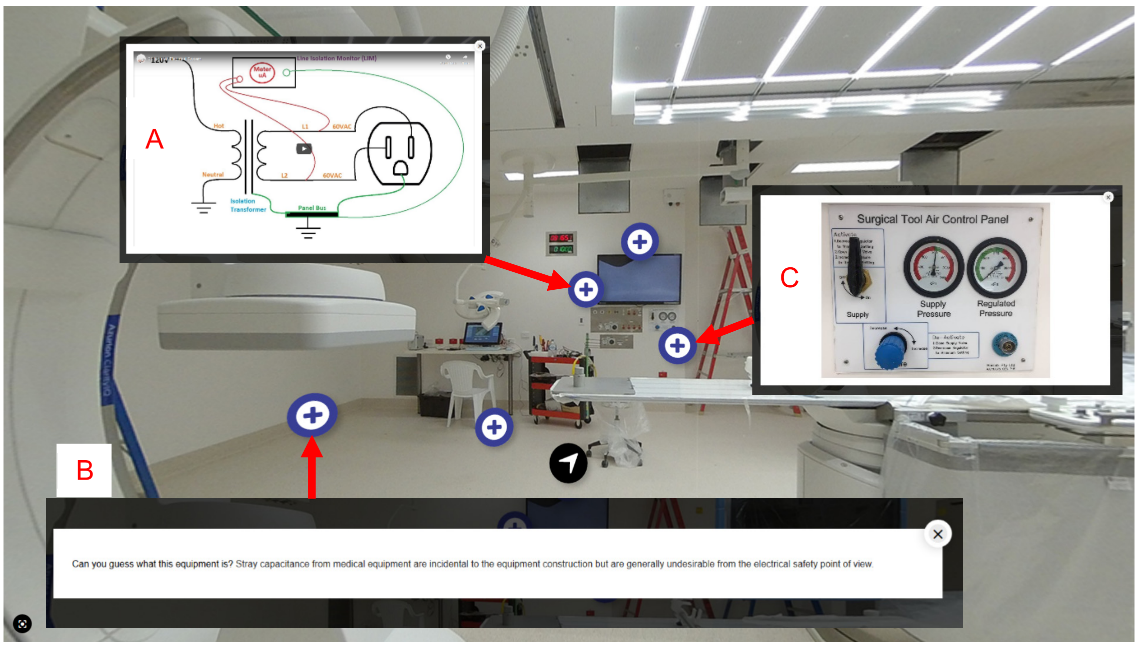

Figure 2: A virtual tour of a hospital operating theatre environment created using the H5P Virtual tour (360) tool. Students can interact with video explanations of the safety controls present in the environment (A), text descriptions of safety features (B), and close-up images of points of interest (C)

Industry videos

We recorded the videos of the guests in several formats based on the preferences of the guest speakers and to prevent repeatability: (i) guests explaining the concepts directly in the site, (ii) video recorded in the university media room through a regular power point presentation, (iii) Q&A video of the guests and (iv) video in video formats where the guest speaker was able to add a case study and field measurements from the industry. The videos were recorded in a media studio with the speaker in front of a green screen. Camtasia video editor was used to remove the green screen and replace with PowerPoint slides and images given by the guest speakers. Care was taken to restrict each video length to a maximum of 15 minutes, as shorter online videos have higher acceptance and students feel motivated to watch them to completion (Berg, 2014). The videos took a significant amount of planning and resources. Additionally, considerable resources are always required to engage industry partners in academia (Armatas & Papadopoulos, 2013), However, now that the videos exist, they can be added to the VR scenarios as hot spots.

Apart from the industry videos, we added other hot spots including YouTube videos, specific information as text, required close-up shots of important devices, points to ponder and questions that students could think about.

Teamwork activity and assessments

Regular contact with industry professionals helped us understand that achieving innovative solutions to complex problems in the workplace relies heavily on effective teamwork and leadership skills. How could we develop these skills in our students? Since 2017, we have been embedding leadership/teamwork skills in this large postgraduate course through team-based activities. This was especially challenging as this course is culturally diverse, giving rise to challenges for students learning in teams, in terms of different understanding of professional etiquette and conflicting working styles.

We involved group work for in-class activities (three hours per week) and assessments, allowing students to interact and work together. With enrolment numbers of 200, we made twenty groups of ten students each at the beginning of the course. When creating the groups, care was taken to ensure that each team had a good mix of students from different cultural and social backgrounds to enhance diversity. Gender mix was also ensured. Research shows that students learned the most about diversity through team projects in the courses (Atadero et al., 2018).

We then introduced student mentors to monitor and support the groups. The mentors were high achieving students from the previous offering of the course. The large class became much easier to manage as in-class group work had direct support and all queries were answered promptly both online via Moodle forums and in-class through facilitation by student mentors. Student mentors were allocated to specific student groups, to help us identify the individual contributions of each student in a group. An unforeseen benefit was the mentors indicated that they developed their leadership skills.

At face to face sessions, students were briefed on the purpose of using virtual tours and given time to initially explore each case study individually. To structure the students' exploration of the case study, they were given instruction to identify all the engineering, administrative and PPE controls offered in each environment. As a group of 10 students (Figure 3), they discussed their individual observations on each of these controls and each group recorded their discussion of the controls present in an online forum. Following this face to face session, they were given three days and three attempts to complete a summative quiz individually, to assess their knowledge on the controls offered in each environment. The quiz was setup online via Moodle and was opened for a specific time period. The question order was randomised and answer choices were shuffled to prevent student collusion and sharing answers. Assessment marks were awarded according to their individual preparation, how much of the simulation they were able to complete, their understanding of the scenarios, and their understanding of the topic covered by the simulation. Each simulation along with the quiz was assessed at 5% making a combined total of 25% towards the final course grade.

After students had completed all five sessions for identifying the safety controls in each of the case studies, they were asked to submit a group report on one selected case study. The case study included the details of the safety hazards involved and suggestions for improving electrical safety highlighting all the three measures, namely engineering, administration and PPE. The team mark for the report was worth 20%.

Figure 3: Students working in groups with the support of student mentors

The team mark was then individualised based on each of the student's contributions, measured via an evidenced-based VALUE rubric (Rhodes, 2010) and team evaluation. The method uses calculation of normalised personal result (NPR). The NPR is proven to effectively reward those students who contribute more to the project than the others and penalises the disengaged students (Peer Assess Pro, online). This is calculated as,

$$NPR = TR + (IPR – AIPR)$$

where,

- TR – team result, which is the teacher's mark assigned to the team's results;
- IPR – Individual personal result, which is given by, IPR = TR * individual mark from the team rubrics;
- AIPR – Average IPR.

The teamwork rubrics helped students to assess if they have, (i) Fostered a constructive team climate; (ii) Contributed to team meetings; (iii) Facilitated the contributions of the team members; (iv) Made individual contributions outside of the team meetings; (v) Adapted to changing demands of the task; (vi) Demonstrated mastery of negotiation skills; and (v) Responded to conflicts.

Evaluation

Student feedback

Formal feedback on the use of virtual tours was collected from the students through a Qualtrics survey. Overall more than 98% of students found the components of each case study very or somewhat useful. These components include responses to the use of industry related video, quiz questions and group report (Figure 4).

Sample students' feedback:

- *The VR tool facilitated a clear understanding of the subject matter and was very useful to see the concepts implemented in a real-world environment*;
- *VR helps to translate text book knowledge to something we could understand and relate to;*
- *It is an efficient and interesting way that helps us remember the concepts.*

Student responses to a questionnaire on team evaluation indicated that they had an overall positive experience with learning using case studies and collaborating with their peers. For the 32 students who responded, 100% of students strongly agreed or agreed that they regularly contributed to group discussion and felt they added value to their team project; 91% strongly agreed or agreed that they learnt more from team work than they would have from learning alone; and students gave a mixed response on whether they had problems interacting with their team with 41% strongly agreeing or agreeing with the statement and 44% strongly disagreeing or disagreeing, indicating the challenges in diverse teams.

Informal feedback from the industry professionals confirmed the resources were highly engaging, and the concepts came together very well. The above strategies had a profound effect on students' learning with the in-class attendance going from 50% to 90%, compared to the previous offering of the course.

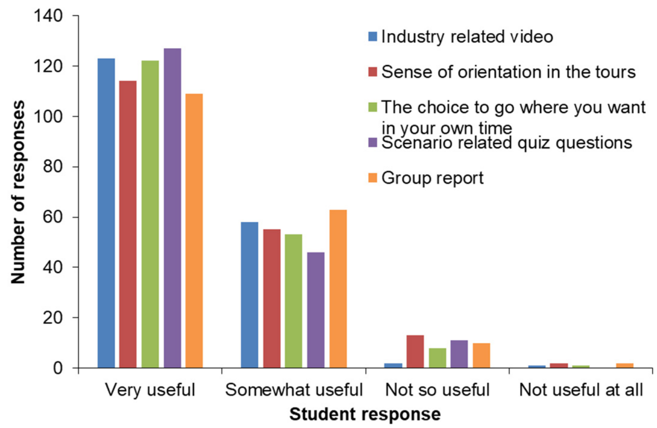

Figure 4: Students' feedback on the VR experience in response to the question: What aspects of the 360 virtual tours were most engaging and useful towards your learning? n=187 students.

Academic performance

The academic results of the students were compared between 2019 and the previous offering. The pass percentage in 2019 went to 100% while in the previous offering it was 96%. There was a specific question in the final exam based on the VR tours and it was seen that the class average marks for the VR based question was 26% higher than the other questions, indicating the impact of this strategy.

Conclusion

The web-based immersive experience employed in this work proved to work well in bridging the gap between industry and academia. Using cooperative learning, students achieved interpersonal and social skills, positive independence, individual accountability, and group processing abilities. Virtual reality tours in particular seemed to have increased performance and engagement of students. The following are summarised as key takeaways from this study:

- Students often do not get a chance to know what they may face in industry and why it happens. The VR tours give them a deep insight into such safety issues. For example, a student may tend not to comply with safety procedures in industry but after taking up this simulation and understanding how industry experts came together and chose certain methods, students may make safety a higher priority;
- The VR tours enhanced students' learning process in different dimensions. The teamwork promoted not only their understanding of the material, but also helped them to connect with each other, irrespective of the cultural backgrounds. This is an important criterion especially for postgraduate coursework students who come to Australia just to pursue a 2-year degree. It takes a while for them to settle down and make connections and by the time they create the network, they will be leaving the university already. This course therefore helped them to initiate this networking early on, especially if the students undertake this course in their first semester of their postgraduate program;
- The presence of mentors facilitated active learning, when students were not able to initiate discussions or if there was lack of interest.

Overall, the different group activities helped students improve their interpersonal skills. They learnt to take initiative, delegate tasks and achieve a common goal.

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