Teaching Safety in Design in Large Classes using VR

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STRUCTURED ABSTRACT

CONTEXT
Safety in design is an important topic in engineering education for which practical experiences are likely to be beneficial but logistically difficult, and high risk. Virtual reality (VR) offers the possibility for students to learn from an interactive experience without the inconveniences and safety hazards in real site visits. However, one of the challenges of using VR is providing learning experiences to large classes of students.

This study investigated the efficacy of VR for teaching safety in design, and an approach to accommodate VR with large numbers of students. Students learned about safety in design in workshops, using a VR environment. They worked in groups in which only one member wore the VR headset and others observed.

PURPOSE
The research question addressed by this study is ‘How can VR be used for teaching large cohorts?’

APPROACH
The second author developed a VR environment in which students operate a vehicle loading crane, based on a design that had been associated with fatalities. Workshops were held in two 5th year engineering design units (one electrical stream and one mechanical stream) taken by 280 students in total. Students completed a standard construction hazard analysis implementation review (CHAIR). In each group of three to eight students, one student used the VR and others observed that student and their VR headset view displayed on a screen. Each group then extended their CHAIR taking account of learning from the VR activity.

The completed CHAIR templates, participants’ demographics and evaluations were collected from consenting students and teaching team members, and the researchers recorded notes during the workshops.

RESULTS
On average students agreed that they identified additional risks after the VR experience regardless of whether they wore the headset. Teaching team members reported that usually quiet students, who were often international students, participated more actively in the group discussions than in their usual weekly group meetings. Analysis of the completed CHAIR templates will be reported elsewhere.

CONCLUSIONS
It is feasible to use VR with large cohorts by offering the immersive experience to a sample of students. The other students can learn by observing both the student wearing the headset and that student’s VR projection.

KEYWORDS
engineering education, safety in design, virtual reality, large cohorts

Introduction

Safety in design is an important topic in engineering education (Foley, Howard, Toft, & Hurd, 2016) for which practical experiences are likely to be beneficial but logistically difficult, and high risk. Virtual reality (VR) offers the possibility for students to learn from an interactive experience that simulates a real environment without the inconvenience or safety hazards of real site visits (Garrett & McMahon, 2013).

One of the challenges of using VR is providing learning experiences to large classes of students. The number of students that can concurrently experience a VR simulation is limited by the number of available VR sets of equipment along with other resource limitations such as space, time, and staff. All these limitations have economic implications.

This study investigated the feasibility of using VR for teaching safety in design with large numbers of students. Students learned about an authentic safety in design process, by working in groups in which only one member wore the VR headset and others observed. We addressed the question: 'How can VR be used for teaching in units with large student numbers?'

Background

The second author developed an activity using VR for learning about an authentic process for identifying and analysing risks. To identify a suitable case we worked with Safe Work Australia, who introduced us to people in regulatory authorities in Queensland and South Australia. The VR simulation case involved a vehicle loading crane corresponding to a design that had been associated with fatalities (Kenworthy, 2017). The authentic hazard identification and analysis process called Construction Hazard Assessment Implication Review (CHAIR) (Australian Safety and Compensation Council, 2006, pp. 28-29) was used. CHAIR is a risk assessment technique which involves a brainstorming activity that uses a set of guidewords to prompt identification of potential hazards, as well as their causes and consequences.

Method

Workshops were held in two 5th year engineering design project units. In the workshops students completed a series of activities involving CHAIR and VR simulation, and were invited to provide data for the study.

The first set of workshops was held for 131 Electrical & Electronic Engineering (EE) students in a unit coordinated by the first author. The second set of workshops was held for 149 Mechanical Engineering (ME) students in a unit coordinated by the fourth author. Safety in design is a topic common to both units.

Venue

The workshops were held in a large studio capable of seating a class size of approximately 20 students with remaining free floor space. Each group of 3-8 students sat at a shared table. Each group also had approximately 3m x 3m taped-off floor space for the VR operator. The room was equipped with an overhead projector.

Hardware

HTC Vive™ headset and controllers were used to provide full tracking and interactivity within the VR simulation. Each HTC Vive kit required a computer with a high performance graphical processing unit (Nvidia™ GTX 1070). Team-members who were not wearing the VR headset were able to see a mirrored display of the simulation on a flat screen via either a computer monitor or the overhead projector.

Software

The VR simulation was purpose-built to demonstrate safety-in-design concepts to engineering students. The simulation presents a vehicle loading crane with a poorly-designed lever control system and the user is tasked with operating the crane through two hazardous manoeuvres. The VR simulation is designed to enhance students' ability to complete a CHAIR of the crane's design.

The simulation was developed using Unity, a game engine software with a free license option. SteamVR and the Virtual Reality Tool Kit plugins for Unity were used to rapidly build the VR functionality of the simulation. The majority of the 3D models used in the simulation were bought or downloaded from 3D-model database websites such as TurboSquid and CGTrader. Total time spent developing the simulation was less than 100 hours.

Workshop structure

For both sets of workshops, each student was provided with the following materials:

- Participant information, consent and evaluation forms;
- 1-page introduction to CHAIR technique, including example;
- A3-size empty CHAIR template, and blue, black and red pens for completing it.

The single template was completed using different pen colours so the researchers could track the progress of the students throughout the workshop.

The first set of workshops, with the EE students, were held over 45-minute periods:

1. Researchers/authors presented the purpose of the workshop, invitation to participate in the study, an introduction to vehicle loading crane design, and an introduction to the CHAIR process. (5-10 minutes)
2. Students completed an initial CHAIR analysis, using a representative still image of the vehicle loading crane with parts labelled, and enlarged image of the control, also labelled - the same crane as used in the simulation. (5 minutes)
3. One student from each group used the VR simulation while other students from their group observed them and the VR mirrored display. (5-10 minutes)
4. Students made a second attempt at CHAIR analysis of the vehicle loading crane, this time considering hazards realised following the simulation. (5 minutes)
5. Students made a final attempt at the CHAIR analysis of the vehicle loading crane, as a group brainstorming activity. (5-10 minutes)
6. Students completed research evaluation questionnaires, and were debriefed on the real problems experienced and improvements made to the design. (5 minutes)

After the workshops with the EE students, changes to the workshop were made based on student feedback and researcher notes. Researchers had observed that the students did not have enough time to complete their CHAIR templates at each stage. The simulation was also updated with the intention to reduce distractions and increase engagement for the VR user. The key changes for the second set of workshops with the ME students were:

1. Total workshop time was increased from 45-minutes to 105-minutes;
2. Students were given reading and a practice CHAIR to complete before the workshop;
3. The simulation was updated by the second and fifth authors:
    a. The teleportation movement was disabled;
    b. Virtual objective markers, notifications, and limits on crane movement were introduced to reduce the need for external instructions from researchers;
    c. Written instructions were provided inside simulation via a clipboard;
    d. The crane and control models were improved to more accurately reflect real cranes in the case study; and
    e. The simulated control system was improved by introducing haptic feedback.

Participant demographics

In the first workshop, 117 (89.3%) of students among 131 attendees consented to their data being analysed for the research project. In the second workshop, 140 (94.0%) students participated in the research, among 149 who attended (Table 1).

Table 1: Participant demographics

Demographic Characteristic	*Values*	*Electrical & Electronic Engineering Students*		*Mechanical Engineering Students*	
		n	*%*	*n*	*%*
Gender	Female	20	17.1	20	14.3
	Male	97	82.9	120	85.7
	Other	0	0	0	0
Enrolment	Domestic	58	49.6	100	71.4
	Exchange	0	0	0	0
	International	59	50.4	40	28.6
Demographic Characteristic	*Unit*	*M*	*SD*	*M*	*SD*
Age	Years	22.8	2.4	23.3	2.3
Prior Engineering Workplace Experience	Months	5.2	12.9	7.9	11.6

Data collection

The completed CHAIR templates, participants' demographics and evaluations were collected and teaching team members and the researchers recorded notes during the workshops.

Analysis and Results

This paper focuses on students' level of agreement that the VR simulation helped them to identify hazards and researchers' observations of this.

Students' ratings

Within the responses from any one group, the demographic data were separated from the other responses so that the responses from individual students could not be identified.

On the evaluation questionnaire, students who indicated that they had watched another student wearing the VR headset during the workshop rated their agreement with the statement

By watching another student wearing the virtual reality equipment I believe I identified a safety hazard I had not before identified.

Students who indicated that they had worn the VR equipment during the workshop, rated their agreement with the statement

By wearing the virtual reality equipment I believe I identified a safety hazard I had not before identified.

In both sets of workshops the students who completed the activity in the VR simulation and those who observed a student completing the VR activity rated their agreement with the statement that they had identified a safety hazard after the experience on average above 4 on the five-point scale (1 = *strong disagree*; 5 = *strongly agree*) (Figures 1 and 2).

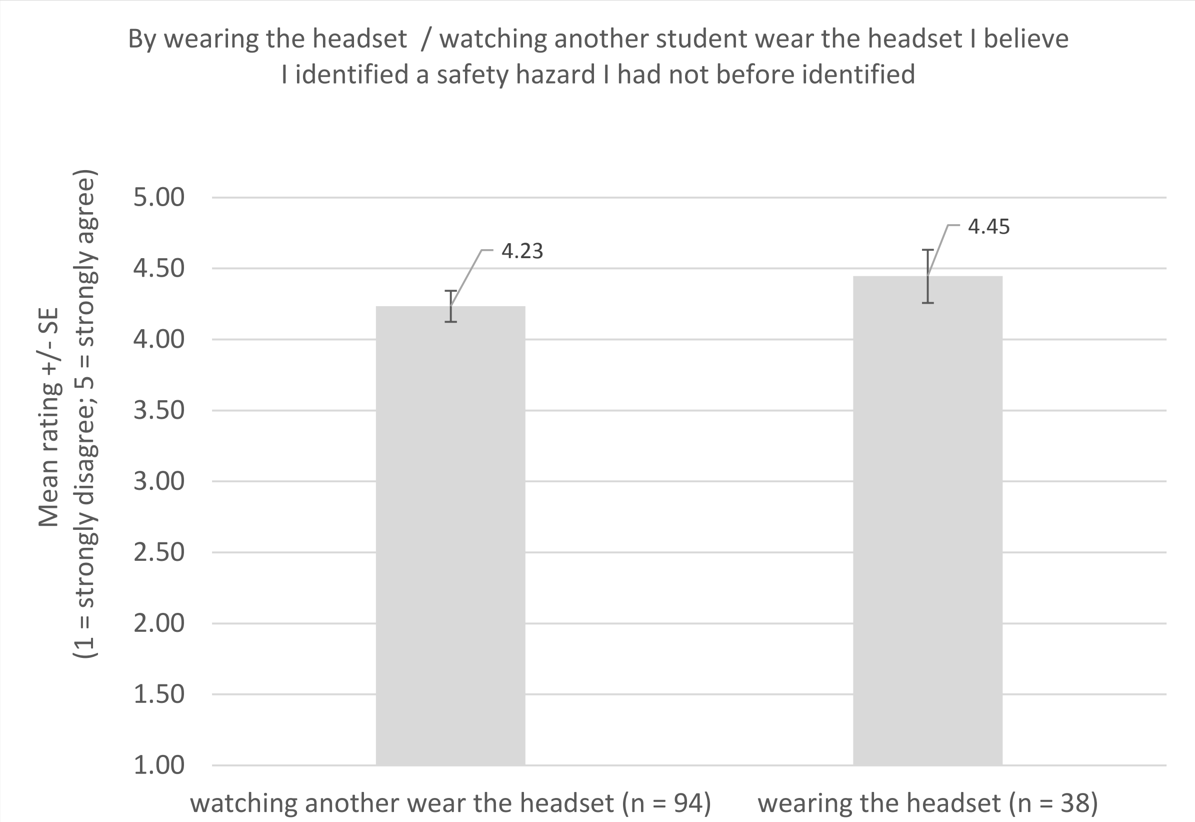

Figure 1: Electrical & electronic engineering students' agreement with the statement that after the VR activity they identified a safety hazard they had not before identified (*N* = 117)

Notes:

1. In some groups more than one student wore the headset.
2. Nine ratings were excluded because they rated an activity the student had indicated they did not do.

Researchers' observations

Nature of hazards identified

Researchers observed that after the VR activity students were more likely than before to identify hazards related to visualising the operator's perspective, especially operating the controls, and watching the controls and the crane.

Discussion between students

Researchers recorded that teaching team members commented on the increased participation in the conversation from students who were often quiet, especially international students. Students were observed to be more successful at identifying hazards if they talked with the VR operator and asked about the experience during the simulated activity and during the brainstorming. Many students observed the mirrored image of the view in the headset more than they observed the operator.

Discussion

Results indicate that it is feasible to use VR in large classes in groups with one operator and the others observing.

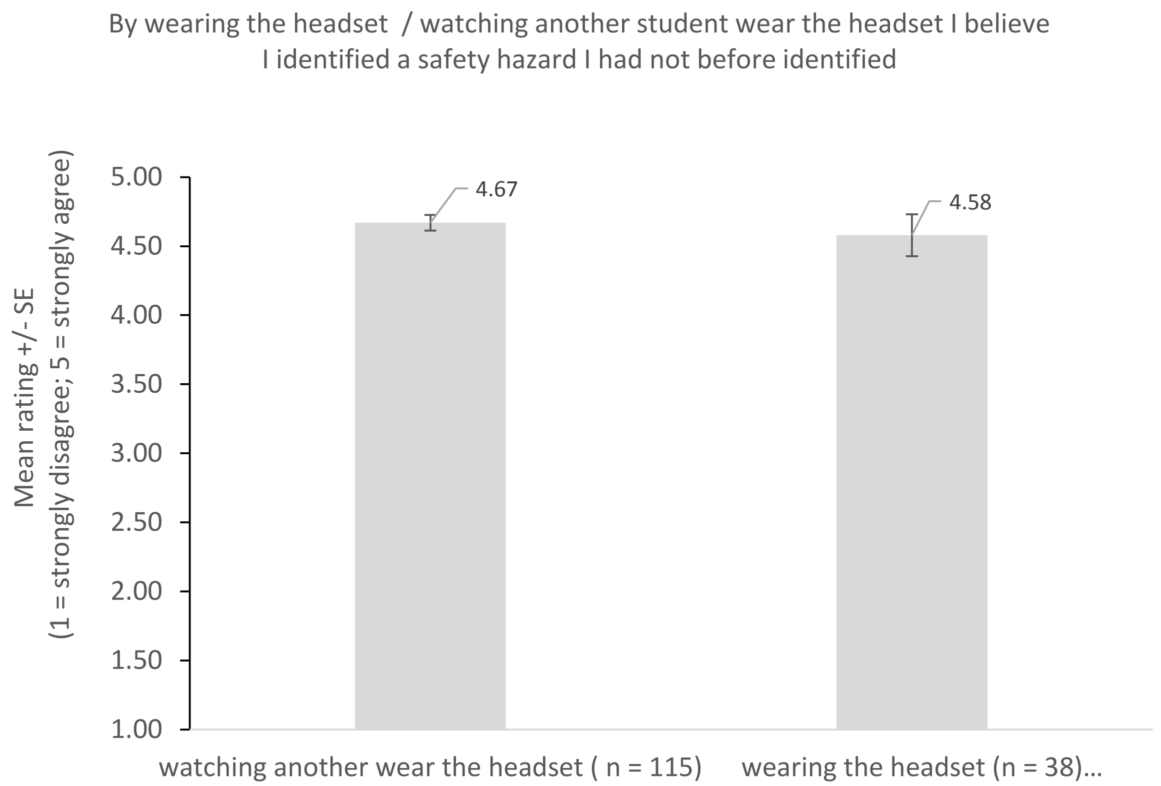

Figure 2: Mechanical engineering students' agreement with the statement that after the VR activity they identified a safety hazard they had not before identified (*N* = 140)

Notes:

1. In some groups more than one student wore the headset.
2. Eight ratings were excluded because they rated an activity the student had indicated they did not do.

Limitations

The EE students did not have enough time to record in the template all of the risks that they could think of. This may have affected the ratings presented in Figure 1. However it would have affected the operators and observers similarly.

Recommendations

The group method involving observations is recommended. We suggest encouraging the observers to talk with the operator during the simulated activity and to ask them questions afterwards.

Careful design is necessary. The improvements made between the first and second workshop will be described elsewhere. They were designed to improve authenticity, reduce the barriers to using VR and also reduce distractions. These, combined with longer workshops, and students preparing for class are all likely to have improved the students' learning and should be considered.

Further research

Remaining data will be analysed. The CHAIR responses will be coded by the nature of risks to compare those identified before and after the VR experience, and after discussion.

This study has addressed scalability. For educators considering using VR, there are key questions around feasibility, efficacy, and costs. Research on these topics will require frequent attention as VR rapidly becomes more accessible.

Authenticity of the approach, and relevance of the result in industry

Authentic learning activities, as used in the workplace, can be motivating for students and support them in preparing for the workplace. VR is already used to improve safety of designs before they are built (Sacks et al., 2015).

The second author has been employed to develop virtual reality simulations to improve designs by allowing operators to experience them before they are built. The experience of the second author in industry has been consistent with our workshops. One operator has used the VR simulation while the others watch and complete a safety in design brainstorming process together around a table. Problems related to resource limitations are faced by learning institutions and by other organizations. The research problem and our results are relevant, not only for learning in universities, but also for engineering practice in industry.

Conclusions

This study has indicated the feasibility of using VR in classes where only one student per group uses the VR and the others observe. The results are likely to apply in engineering practice as well as in education.

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