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Virtual Reality for Continuing Professional Development

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Abstract

Virtual reality (VR) is a powerful training tool because it can simulate very realistic conditions that may be difficult, expensive, and potentially dangerous to replicate in actual practice. This paper reports the results of using a fired heater simulator to train engineers and engineering students what to do and not to do when a heater gets into a condition that could lead to an incident. This particular simulation was a scaled-down version of a much more extensive simulation being used in a refinery. The version used here had no provision for user interaction, unlike the one being used in the refinery which is interactive. The simulation was shown to 33 working engineers, some of whom were taking a continuing professional development class on fired heaters. It was also shown to 19 engineering students to see if their feedback differed from the working engineers. A survey was given after each participant viewed the simulation. The results of the survey are reported here.

Introduction

The use of virtual reality has been growing rapidly as the costs of hardware and software continue to decline, mostly driven by the gaming industry [1]. VR is well known for its use in airplane simulators where conditions can be simulated that pilots rarely and hopefully never encounter while flying planes full of passengers. However, if those conditions should arise, the pilots are prepared to handle them because of the exceptional realism of the flight simulators. Those simulators are beyond the reach of most training budgets so an alternative is needed to make VR a viable option for continuing professional development.

VR is particularly well-suited for training situations involving very large (e.g., large building projects) or very small (e.g., nanotechnology) scales which may be very expensive and logistically challenging to replicate in a training environment. Another situation where VR is preferred is in dangerous environments such as chemical plants [2]. These may be difficult if not impossible to reproduce in live training because of the costs and potential danger. That is the type of training that will be considered in this paper. VR can be used to improve the effectiveness of operator training [3].

Lau et al. (2018) showed experimentally that immersive VR improved learning in an organization by about 9% [4]. An experimental study by Makransky et al. (2017) showed that university students felt higher presence when using immersive VR to simulate a science lab, but they learned less and had a significantly higher cognitive load [5]. This suggests that VR may not be appropriate for all learning contexts.

Simulation

A simulation of a fired heater explosion was developed to help operators avoid potentially disastrous conditions that could produce severe injuries and even fatalities in addition to significant equipment damage. Unfortunately, these explosions continue to occur in the industry despite more focused attention to prevent them from happening. While there are many possible explanations for this, an important mitigating factor is proper training. It is not possible to produce the conditions in fired heaters in an operating plant because that might lead to an incident. This would unnecessarily expose plant personnel and equipment to potential harm, in addition to adversely affecting production which would be very costly. Instead, a VR simulation was developed to demonstrate dangerous conditions that could arise during fired heater operation. This simulation is currently being used to train operators in the plant. Results have shown a statistically significantly higher performance for operators training with the simulation compared to those training with conventional classroom techniques.

A shorter (approximately 3.5 minutes) and non-interactive version of that simulation was developed for use in a continuing professional development (CPD) class on fired heaters. This class is designed mostly for engineers who will not actually be operating heaters but will be monitoring performance and recommending changes to improve the performance. The engineers need to know how the heater operates and what happens if a heater gets too far out of its design operating envelope.

The VR simulation includes a narrator who explains to the viewer what is happening. An avatar appears early on who represents a plant operator. The heater pressure begins to fluctuate and a pulsing or "woofing" sound is heard. This simulates running a heater out of air for combustion. That creates a flame pulsation which causes the pressure fluctuations and the woofing sound. This phenomenon is referred to as heater flooding [6]. The correct response to this situation is to reduce the fuel gas flow rate until the flames no longer pulse.

In this simulation, the avatar operator makes the wrong move and adds air to a heater starved for air. The excess fuel in the heater then rapidly combusts and causes an explosion. A fireball and explosion sound are produced in the simulation. The avatar operator vanishes. Note that precautions are taken to warn those who may have experienced such an incident or know someone who did as the VR simulation could induce a type of post-traumatic stress response by reliving such a past incident.

Procedure

The research reported here occurred in two steps. The first step involved participants watching the VR simulation. They wore Oculus Go wireless headsets (see Figure 1) and used the wireless controller to start the simulation when they were ready. They were given some brief verbal instructions on how to operate the equipment and had the option of sitting or standing, at their preference. It was recommended that they move their heads around to see the entire scene which completely surrounded them virtually. There were five headsets so there were up to five simulations going at any given time.

Figure 1. Watching the simulation on Oculus Go wireless headsets.

The second step was for the participants to take an anonymous survey immediately after completing the simulation. The VR portion of the survey is shown in the Appendix. There were no incentives for taking the survey.

Survey Results

The survey was given to 33 working engineers and related professionals between November 2018 and April 2019. It was also given to 19 students from two different classes at a local university where one of the authors is an adjunct instructor. One of the classes was an elective called Combustion and the other was a required course called Experimental Methods. Fired heaters were discussed in both classes prior to seeing the simulation.

The genders of the participants are shown in Figure 2. As is typical with engineers and engineering students, most of the participants were male.

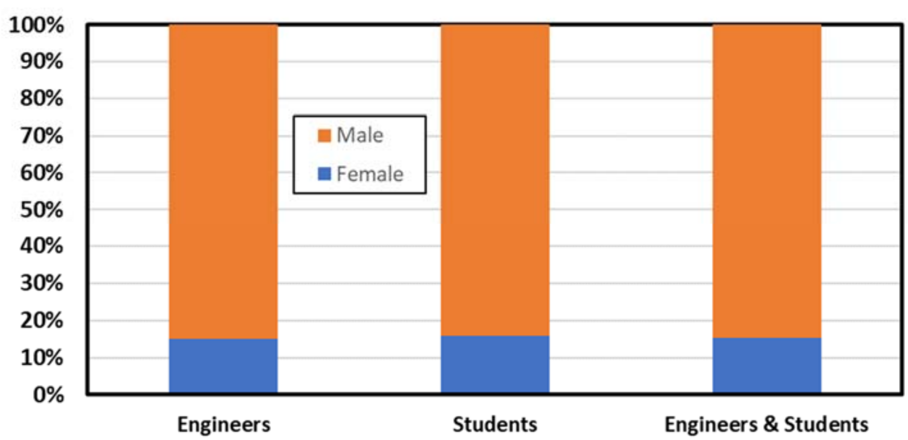

Figure 2. Gender of the participants.

The ethnicity of the participants is shown in Figure 3. The vast majority of the participants were Caucasian/white. There was more diversity in the students sampled compared to the engineers.

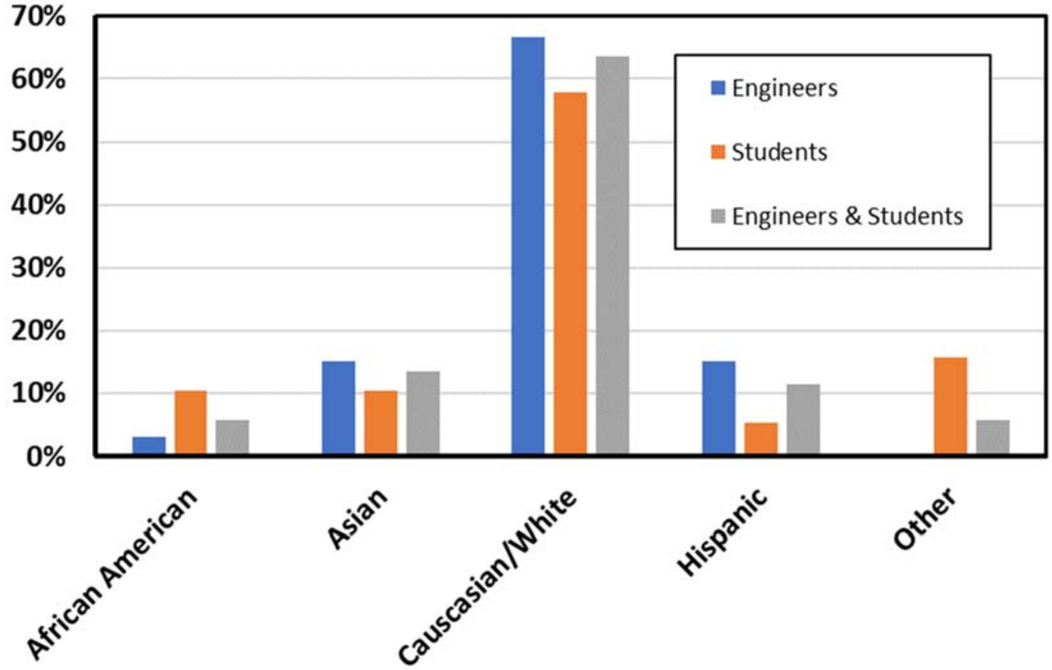

Figure 3. Ethnicity of the participants.

Figure 4 shows the native country for a significant portion of both the engineers and the students was not the United States. All non-native-US participants provided their native countries. The following non-US countries were represented: Brazil (3), Canada (4), Ethiopia, Japan, Malaysia, Mexico, Netherlands, Oman, Pakistan, Tanzania, Thailand (2), and Venezuela.

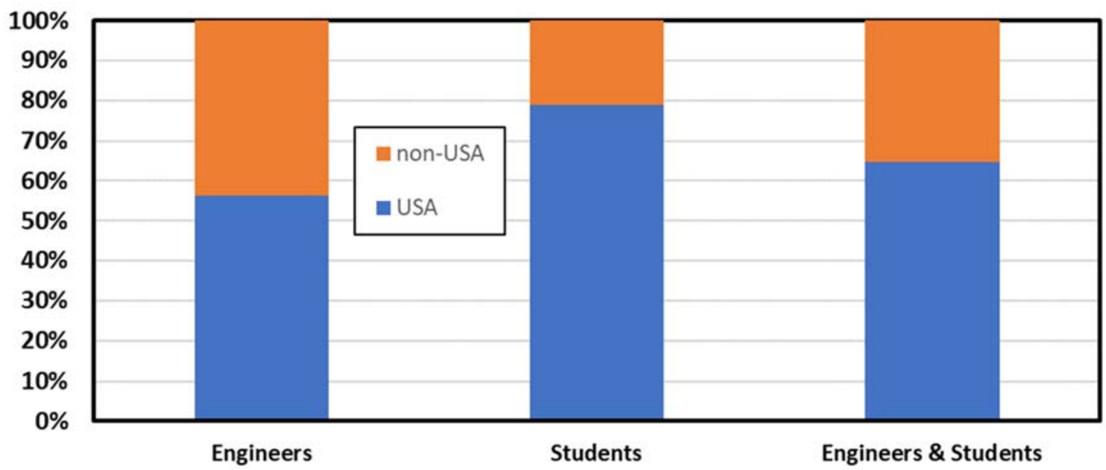

Figure 4. Native country of the participants.

The VR simulation included American English text and American English narration. English was not the native language for some of the participants as shown in Figure 5. All non-native-English speakers identified their native language. The following non-English languages were represented: Amharic, Arabic, Chinese, Dutch, French, Japanese, Portuguese (3), Spanish, Swahili, Thai (2), and Urdu.

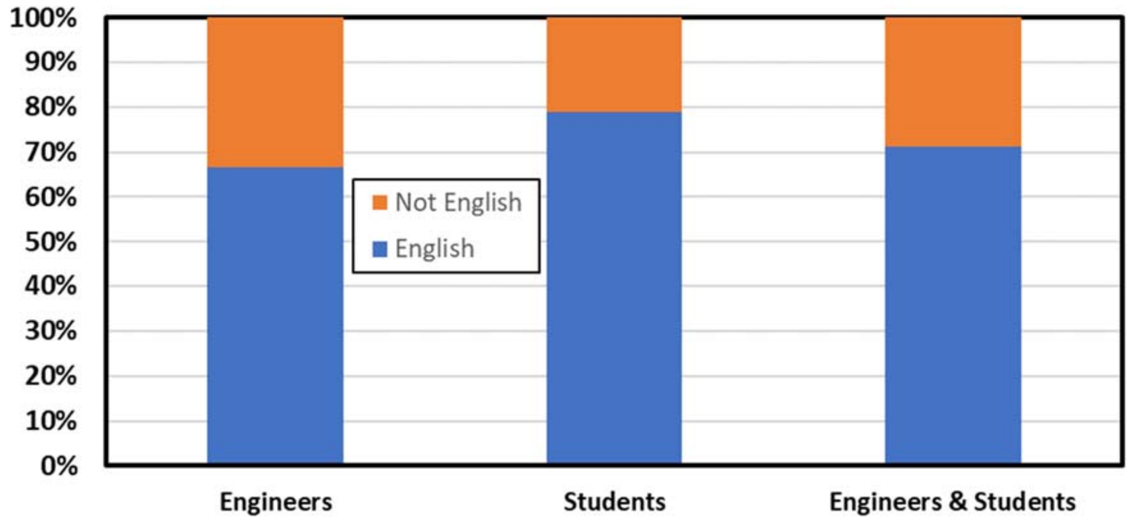

Figure 5. Native language of the participants.

As shown in Figure 6, the vast majority of students and a high percentage of engineers had already seen some type of VR simulation prior to seeing this fired heater VR simulation.

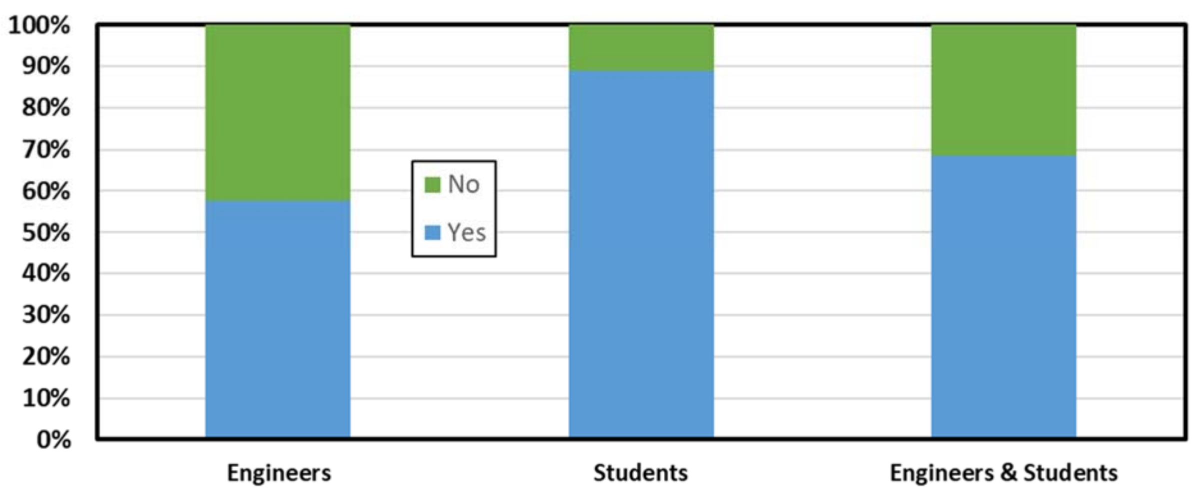

Figure 6. Percentage of participants by type who have seen some type of virtual reality before.

Very few of the participants had previously seen an educational VR simulation as shown in Figure 7.

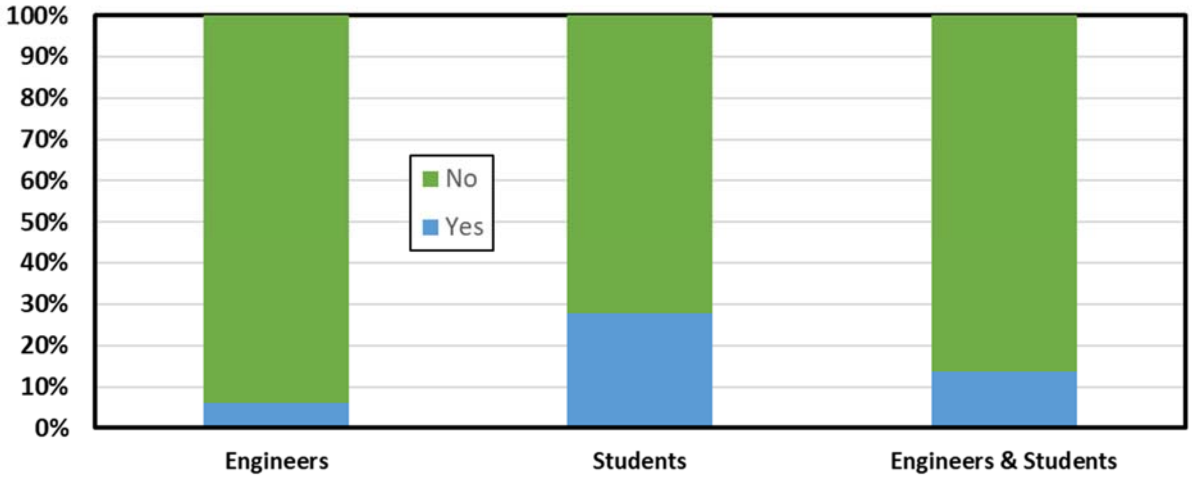

Figure 7. Percentage of participants by type who have seen some type of educational virtual reality before.

Most of the students and engineers found the simulation to be realistic as shown in Figure 8. While all of the participants had a least a basic knowledge of fired heaters, very few of the students had actually seen a fired heater in person. Most of the engineers had previously seen fired heaters and some of them work with those heaters regularly.

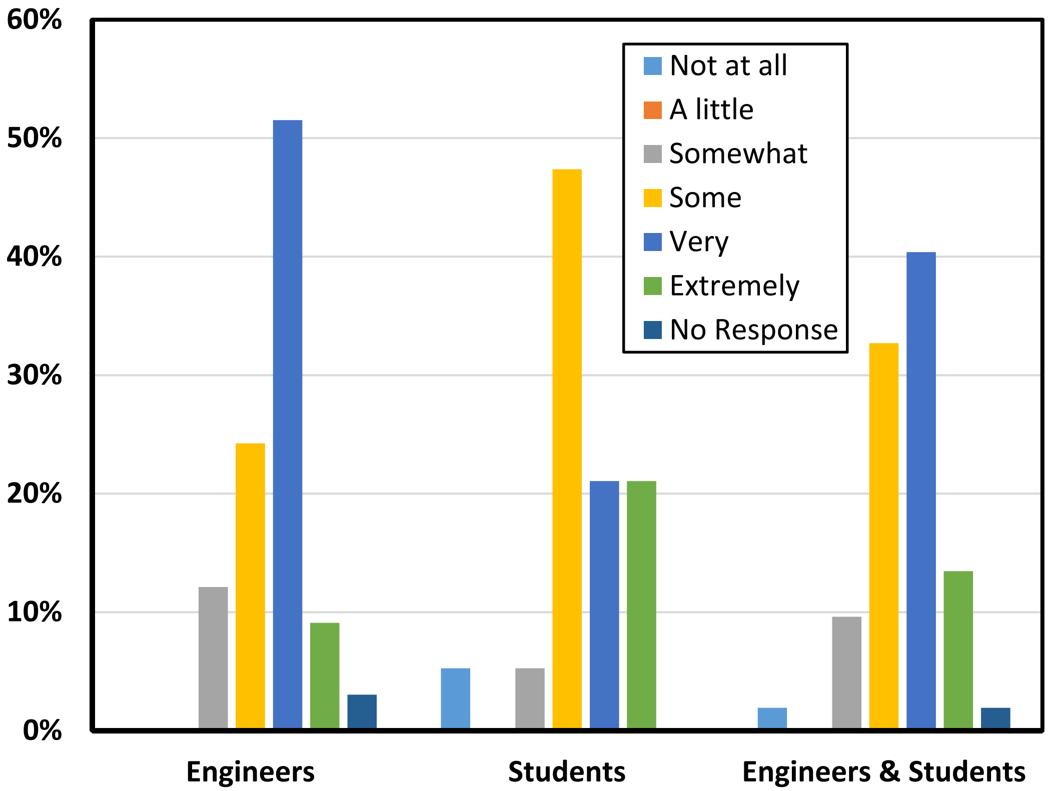

Figure 8. How realistic the participants found the simulation.

Most of the participants found the video quality of the simulation to be good or better as seen in Figure 9. In general, the students rated the video quality higher than the engineers.

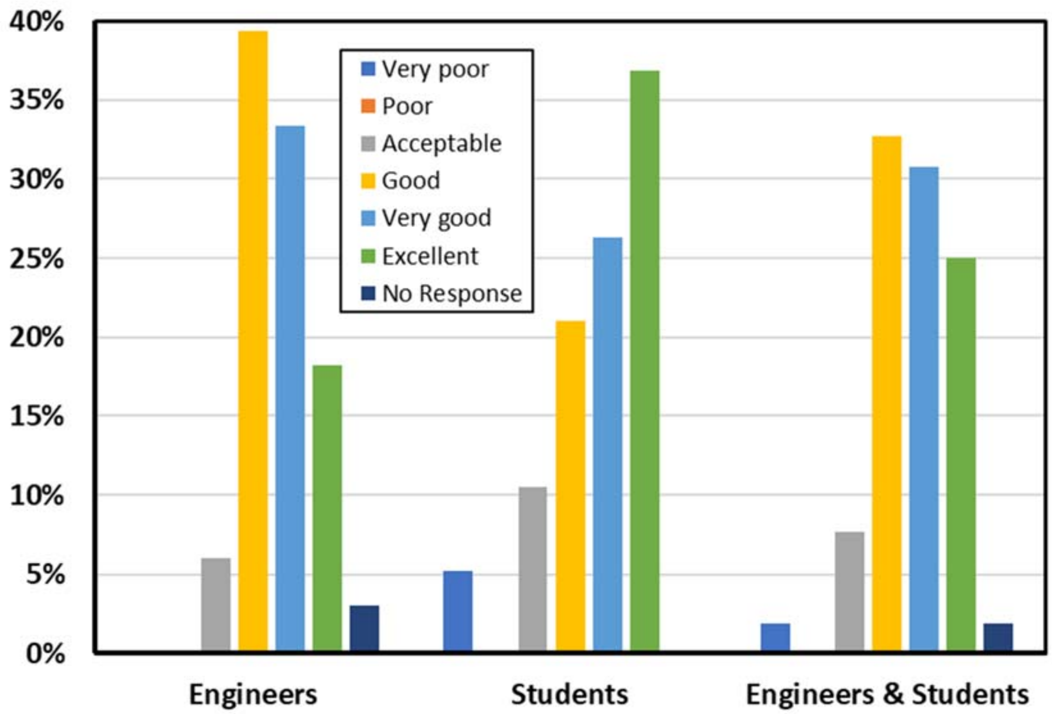

Figure 9. How participants found the video quality of the simulation.

The audio for the simulation included narration and sounds from a heater having a problem. The speakers for the Oculus Go are located in the strap near where it connects on both sides of the headset. All of the participants rated the audio in the simulation at least acceptable and most rated it good or better as seen in Figure 10. In general, the students rated the audio higher than the engineers.

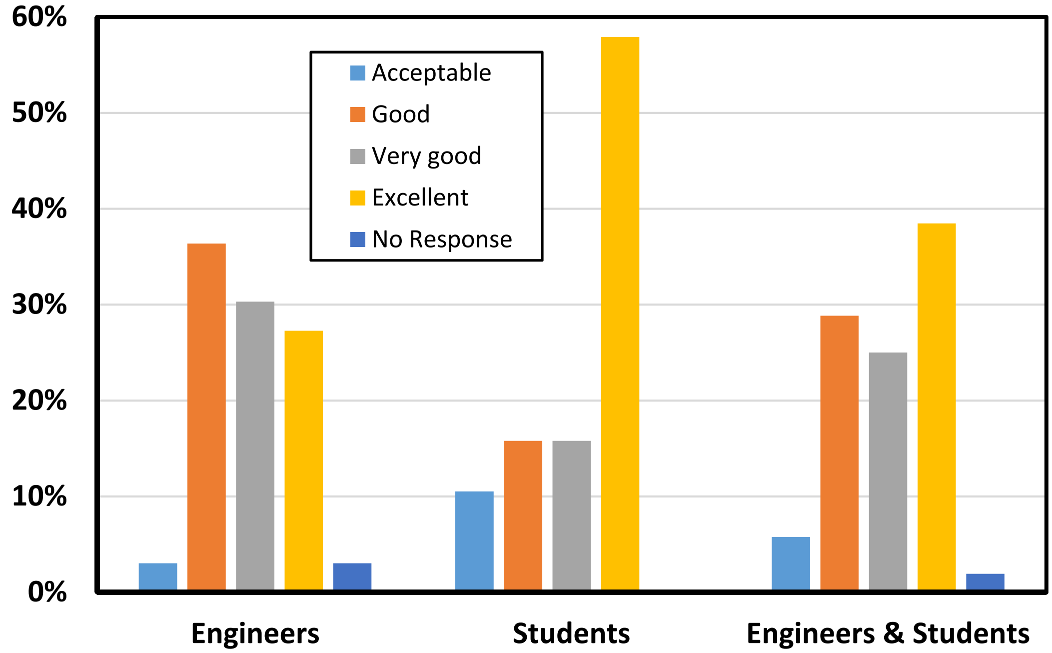

Figure 10. How participants found the audio quality of the simulation.

All of the participants found the navigation to be at least acceptable and most found it to be better than that as shown in Figure 11. The students rated the navigation slightly higher than the engineers with the majority rating it as extremely easy.

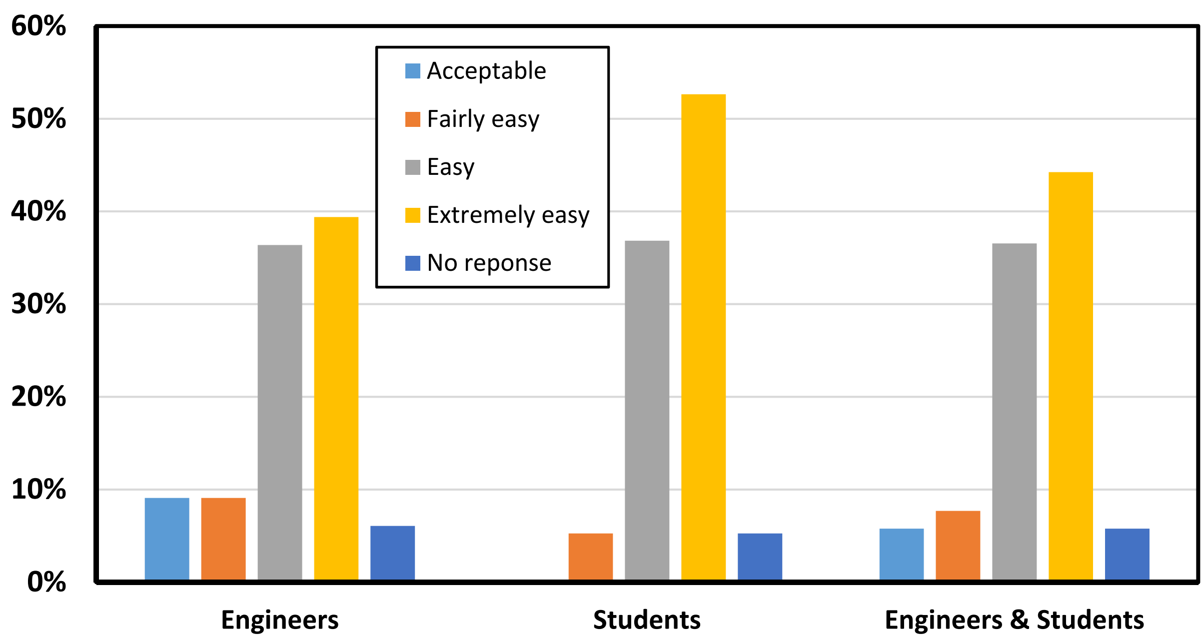

Figure 11. How participants found the navigation.

There were no headphones so participants could hear the audio from other participants' headsets if they listened for it. The participants were at least a few feet from each other but still close enough to hear background noises, which sometimes included other VR headsets playing. Most participants, both engineers and students, did not find the background noise to be too disturbing (see Figure 12).

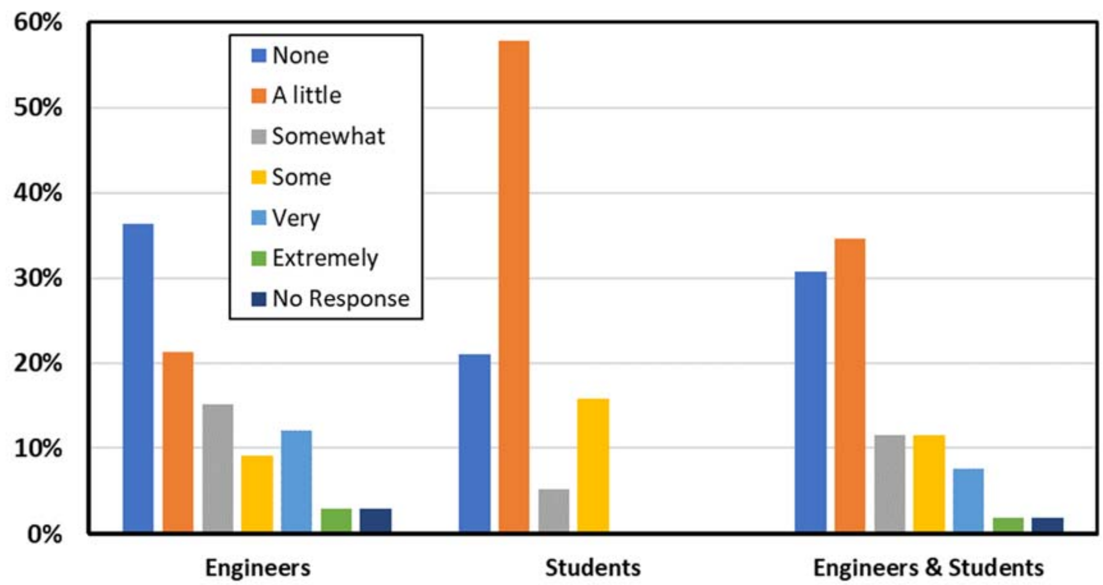

Figure 12. How much distraction there was in the room.

As shown in Figure 13, most participants found the length of the simulation (3.5 minutes) to be about right.

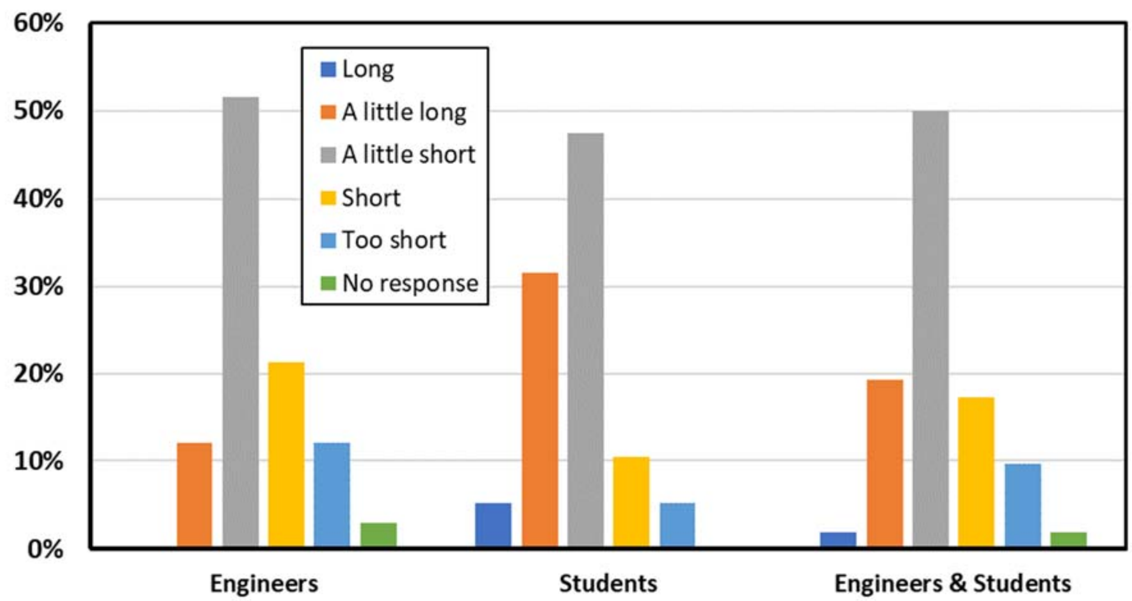

Figure 13.How participants found the length of the simulation.

The last three questions in the survey required write-in answers. The first of those three questions asked the participants what they liked best about the VR simulation. Seven participants particularly liked the 360° view and others said something similar about the ability to view an explosion from multiple vantage points. Others liked the realism as the simulation included both video and audio. The latter included sounds from the plant, the explosion, and narration that explained things as the simulation progressed.

The second write-in question concerned recommendations for improvement. The primary suggestion was more interaction, where the current simulation does not include any interaction once the participant starts it. Another suggestion was to have the avatar speak in the simulation. Some thought the avatar could have been more realistic as it currently looks a little like a zombie. Still others thought the simulation went a little too fast, since not everyone was familiar with a refinery and process heaters.

The last write-in question asked for any other comments. Several thought the VR simulation was great, while one thought it was dated. Some suggested adding more simulations.

Discussion

While most of the participants had seen virtual reality simulations before, relatively few of them had seen educational simulations. Most participants felt the simulation they saw was realistic, although it might be argued the students had never seen an operating fired heater so they did not have as strong a reference point as the working engineers, many of whom work with fired heaters on a regular basis. The participants found the video and audio qualities to be very good which is consistent with finding the simulation to be realistic. Most participants found the navigation to be easy. However, it should be noted that in most cases the simulation was queued up for the participant so, they merely had to point the laser at the forward arrow to start the simulation. There was no navigating once the simulation started as it played straight through until completed. It was a little surprising the participants did not find the room more distracting than they did because there were often multiple simulations going simultaneously that were out of sync so sounds could be heard that did not apply to the simulation one was watching. A possible explanation is that the participants were concentrating so hard on their own simulation that they were not bothered by the extraneous sounds. This is often referred to as *presence* where the participant becomes absorbed in the VR simulation [7]. Most participants found the length of the simulation to be about right. There was not a significant difference in the responses between the engineers and the engineering students.

Conclusions and Recommendations

This study showed that both working engineers and engineering students see the value in using virtual reality simulations for training purposes. This is especially important for certain scenarios that may be difficult if not impossible to duplicate in reality for a wide range of reasons including, for example, cost and safety. Developing more VR simulations is recommended.

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Appendix

Virtual Reality

Have you ever seen any type of virtual reality simulation before this one? Y N

Have you ever seen a virtual reality simulation used for training purposes? Y N

How realistic was the simulation? (circle one)

Not at all =	0	1	2	3	4	5 = Extremely

How was the video quality? (circle one)

Very poor =	0	1	2	3	4	5 = Excellent

How was the audio quality? (circle one)

Very poor =	0	1	2	3	4	5 = Excellent

How easy was it to navigate through the simulation? (circle one)

Extremely difficult = easy	0	1	2	3	4	5 = Extremely

How much distraction was there in the room? (circle one)

None = distracting	0	1	2	3	4	5 = Extremely

How was the length of the video? (circle one)

Too long =	0	1	2	3	4	5 = Too short

What did you like best about the simulation?

Any suggestions for improvement?

Any other comments?