Developing industry-aware engineering students in the classroom: The role of desktop site tours

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Abstract

In recognition of the importance of interpersonal and professional skills, Engineers Australia (EA) have made it an accreditation requirement for all tertiary engineering students to engage with industrial practice throughout their degree. This experience is obtained through work-integrated learning (WIL) activities, including completing relevant internships, participation in site visits, and enrolment in industry-based learning (IBL) courses. Even prior to the COVID-19 pandemic, increasing numbers of engineering students have made it more difficult for individuals to secure internships. It is also not possible for large numbers of students to visit most industry sites due to remote locations, visitor limits and/or safety restrictions. In fact, a study from 2019 of final year students across 11 Australian institutions reported that 29% of final year students had not completed their industrial practice, and hence were unable to graduate despite completing their studies. The COVID-19 pandemic has further exacerbated these issues, with a transition to online learning causing decreased student attendance and participation.

This has required innovative approaches to integrating WIL into engineering courses to provide students with industry exposure. From four authentic learning practices, virtual work integrated learning (VWIL) was selected as the best choice for students to achieve the WIL objective of exposing students to relevant real-world experience. It was also the most robust option for an online learning environment and was adaptable to changing course learning outcomes. A review of popular VWIL implementations identified desktop site tours (DSTs) as a flexible, user-friendly and time efficient method for academics to increase student exposure to industry. This study follows the implementation of a DST in undergraduate chemical engineering courses, evaluating its capacity to help students achieve professional competencies.

Students spent two hours in a sustainable engineering design course observing the various types of chemical engineering flow diagrams. Afterwards, they asked to identify unit operations from the DST that could be classified as raw materials, production, or finishing. Prior to and after the tutorial, students were asked to indicate their agreement to a series of survey statements to observe their response to the DST's ability to aid their professional development. Students' responses to these statements were mixed. Over 90% of students reported that they found the module effective in improving their understanding of sustainable product design and engineering processes. However, at least 15% of students disagreed that it helped to improve problem solving, teamwork, and communication skills, with significant differences observed between pre- and post-survey responses ($p < 0.05$).

Recommendations for future study are to assess improvement objectively by incorporating DSTs into student assessments, and to observe the impact of the DST on improving student professional skills over a longer period.

Keywords: virtual work integrated learning, professional development, virtual field trips, desktop site tours

Introduction

In recognition of the importance of interpersonal and professional skills, Engineers Australia (EA) have made it an accreditation requirement for all tertiary engineering students to gain exposure to industrial practice prior to graduation [1]. Typically achieved in the form of internships, participation in site visits or enrolment in industry-based learning courses, engagement with professional practice has been shown to assist students in bridging the gap between theory and application [2, 3]. Performing, observing, and interacting with engineering practices additionally helps students transition from tertiary education to graduate employment [2].

With engineering student enrolment numbers increasing annually, it has become difficult for individuals to secure relevant discipline specific internships. A survey conducted by Male and King [4] in 2019 found that 29% of final year engineering students across 11 Australian institutions had not completed their required industrial experience and were thereby ineligible for graduation despite completing their coursework. The recent COVID-19 pandemic further exacerbated this figure, with newer generations of engineering students becoming more susceptible to timely industry learning experiences [5]. This can be predominantly attributed to the transition to online learning, which made student development of relevant interpersonal skills more difficult, particularly as students became more disengaged with coursework [6, 7]. The pandemic also limited the number of opportunities available for students to participate in relevant engineering work experiences, with the cancellation of internship and job offers becoming more likely due to site restrictions throughout the pandemic [8]. Thus, a focus on improving student professional development through exposure to real world engineering practices is needed.

Several strategies have been employed by academics to improve student exposure to industry practices. Most notably, authentic learning (AL) has been used across several fields of study (including those outside of engineering) in replacement of industrial experiences. This is because AL is widely defined as student learning situated in the context of future work [9-11], which strives to achieve the same purpose as industrial training and site tour experiences. However, AL is a broad learning style and consists of varying practices.

An assessment of literature found that virtual field trips (VFTs) were the most appropriate AL method for assisting students in developing relevant EA competencies [3, 12-15]. Although it is not useful in assisting in student professional development on its own, it can be easily used as a supplementary material in course assessments and is consequently extremely adaptable to various learning outcomes [12]. It is also the most robust to an online learning environment, providing a more level playing field for students studying remotely [12, 14]. However, its effectiveness in improving student professional identity and developed has not been thoroughly explored in literature.

Two types of VFT implementations commonly appear in literature: virtual reality head-mounted displays (HMD), and desktop site tours (DSTs). Whilst the former provides a fully immersive experience and is most like physically being on site, DSTs are easier to implement due to minimal equipment to create the digital assets and can be used remotely. However, DSTs have the lowest levels of interactivity and were the least conducive to deeper learning and exploration - this means they should be paired with scaffolded activities for it to succeed [12]. In turn, this widens the scope DST use cases, allowing it to be adapted to various course requirements. Turn-around between courses can additionally be achieved faster, with feedback from previous teaching periods more readily influencing activities in subsequent DST iterations. Despite this flexibility and ease of implementation, DST usage has not been commonly explored in engineering education research and has consequently become the focus of this study.

In our previous work [16], we evaluated the usefulness of a DST module in enhancing student understanding of course and discipline outcomes, as well as evaluated student enthusiasm towards using it in their coursework. The key outcome from this study was that DSTs are a useful learning tool, as 100% of students participating in the research agreed or strongly agreed that it enhanced their understanding of course outcomes and relevance of their studies to real life scenarios. However, the effectiveness of the DST module was not evaluated. Effectiveness is defined as the degree of which something is successful in achieving a desired result [17], and hence in this context, refers to the degree to which the DST can be used to achieve EA professional competencies.

It is hypothesised that the module will be somewhat effective in improving engineering competencies. This is because it provides exposure to industrial practice, however compared to a real field trip or extended industry experience, it may be more difficult for students to understand how course learnings can assist with professional competency development.

Methodology

Human research ethics

Ethics approval was granted by the Human Research Ethics Advisory Panel at UNSW to enable the collection of research participants' data. All data was collected anonymously.

Desktop site tour creation

The DST used for this research explored a brewery site in Sydney. Created in conjunction with immersive experience creators, the tour contained a series of short 360-degree videos and an interactive web-based 3D menu developed using Three JS (Figure 1). This format provided information about all major operations on the site, encompassing the three main process areas of raw materials, production (brewing and maturation), and finishing (bottling and packaging). Figure 1 is an overview of the landing page of the DST module which can be accessed via: https://vantageinteractive.com.au/UNSW/SCE/virtual_tour/Tooheys/

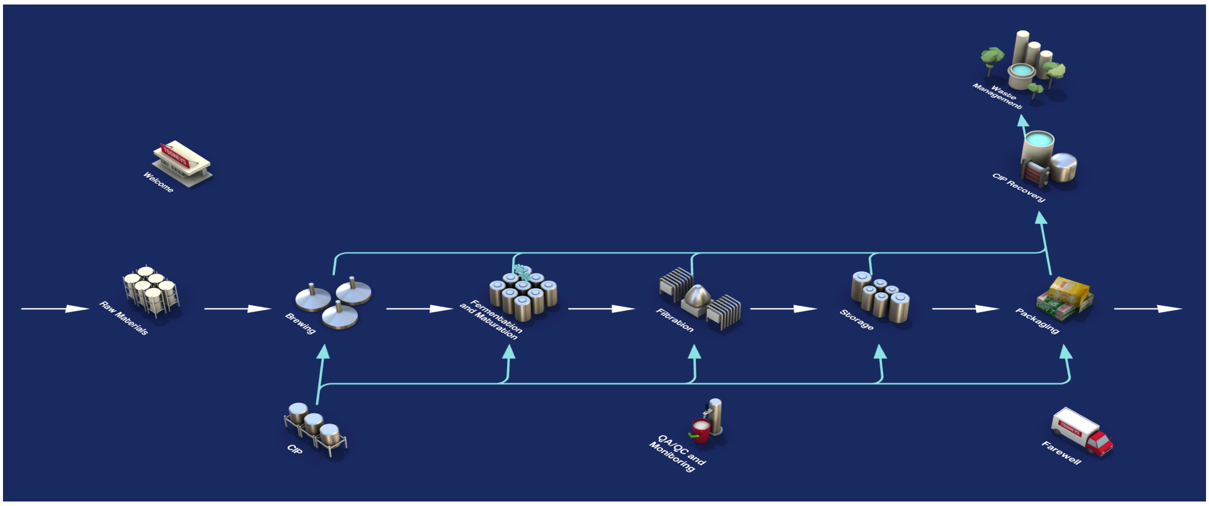

Figure 1 – Interactive web-based 3D menu for brewery DST

Each of the items in the flow diagram above contained one to five videos approximately 3 minutes in length, with each video showcasing the machinery and processes involved with the major operations. These were led by a student tour guide, who asked site operators questions about various plant processes and equipment. By filming these in a 360-degree format, students had the ability to explore the surroundings of the recorded area. This allows them to appreciate the scale of the plant, as well as observe the site layout.

Survey development

Semi-qualitative survey methods were used. Students were asked to anonymously indicate a level of agreement to each survey statement using a 4-point Likert scale, where: 1 = strongly disagree, 2 = disagree, 3 = agree, and 4 = strongly agree.

Two anonymous surveys were developed. The pre-DST survey intended to measure student perception of their own professional skills prior to using DST module.

Statements for each survey can be found in and Table 1 and
Table 2. These statements were developed based on statements 1.6, 2.1, 3.6, 3.2 and 2.3 found in the EA Stage 1 Professional Competencies [18] respectively.

Table 1 – Student survey statements for pre-DST survey

No.	Statement
1	I understand what sustainable product engineering is
2	I am competent at identifying and solving practical problems
3	I can work well in a team
4	I can easily communicate my ideas and knowledge
5	I understand engineering design processes

Open ended questions were included at the end of the post-DST survey to obtain qualitative information regarding student positive and negative experiences with the module, as well as develop recommendations for future implementations of DST modules.

Table 2 – Student survey statements for post-DST survey

No.	Statement
1	The desktop site tour helps to enhance my understanding of sustainable product engineering
2	Using a desktop site tour allows me to identify and solve practical problems
3	The desktop site tour tutorials enable me to work as part of a team
4	The desktop site tour helps me to better communicate my course learnings
5	Watching the tour helped me to understand engineering design processes.

Survey deployment

Students spent two hours in a sustainable engineering design course observing the various types of chemical engineering diagrams and how they applied to real operations in the DST. They were then tasked with identifying unit operations from the DST that could be classified as raw materials, production, or finishing. Finally, students were asked to watch the wastewater treatment plant videos, before discussing how this process had been sustainably designed. Each of these activities were completed in groups of 5; students were encouraged to watch the videos and discuss answers to each activity with their peers. At the conclusion of each task, students were asked to communicate their findings back to the wider tutorial group for further discussion with other groups and the tutor.

The theory associated with the tutorial was provided in the preceding lectures. Prior to engaging with the activities, students were asked to complete the pre-DST survey, and then were asked to complete the post-DST survey after the tutorial. Of 81 students enrolled in the course, 62 students completed the surveys (77%).

Data analysis

Data was analysed in Qualtrics Experience Management, with MATLAB R2022a and Microsoft Excel used for graphical analysis.

Results and discussion

Table 3 displays the descriptive statistics (average and standard deviation) of student responses to the pre-DST survey and post-DST survey statements. Figure 2 displays the percentage breakdown of student responses to the statements for both pre- and post-DST surveys.

Table 3 – Statistical description of student responses to pre- and post-DST surveys

Statement	Average		Standard Deviation	
	Pre-DST	Post-DST	Pre-DST	Post-DST
1	3.16	3.23	0.45	0.63
2	3.19	2.85	0.60	0.59
3	3.58	2.67	0.56	0.84
4	3.39	3.03	0.56	0.67
5	3.00	3.47	0.52	0.51

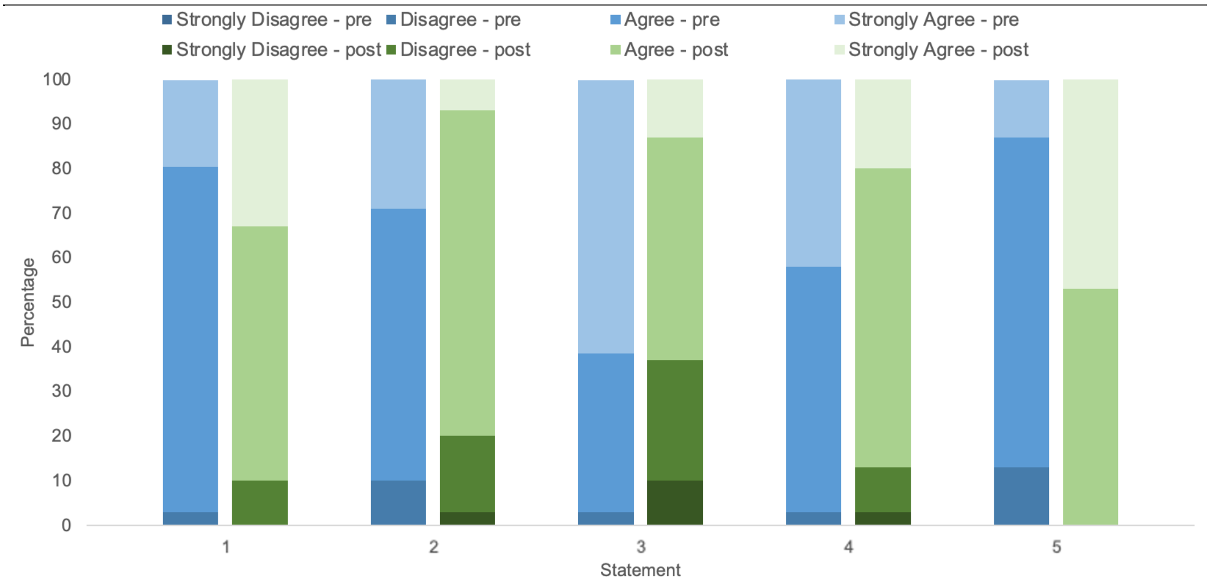

Figure 2 – Student responses to pre- and post-DST survey statements

The average responses to all pre-DST survey statements and most post-DST statements are greater than or equal to 3, with low standard deviations ($\sigma < 1$) across all responses. As a score of 3 indicates agreement, these results show that students are confident in their professional abilities and believe that the DST helps to improve some of these skills. Average scores to statements 2 and 3 in the post-DST survey are below 3 however; whilst Figure 2 displays that both statements still have a high percentage of agreement, there is clearly more disagreement to these statements in comparison to the others. Reasons for this are further discussed in the following section.

An analysis of the spread of scores for both surveys, shown in Figure 3, finds that most responses are centred between 3 and 4 which demonstrates a strong level of agreement with the statement. It is clear from this figure that average responses only increased for survey statements 1 and 5 (technical understanding related questions); this implies that the DST was not effective in improving problem solving, teamwork, or communication skills according to the students' perception (which were based on the professional development related questions 2, 3 and 4, respectively). A study by Kumar, et al. [12] found that DSTs are not conducive to deeper leaning and exploration, and as such need to be paired with appropriate learning activities to promote professional skills development. Consequently, the module can only be deemed to be somewhat effective, as there is no evidence of significant improvement across all professional competencies.

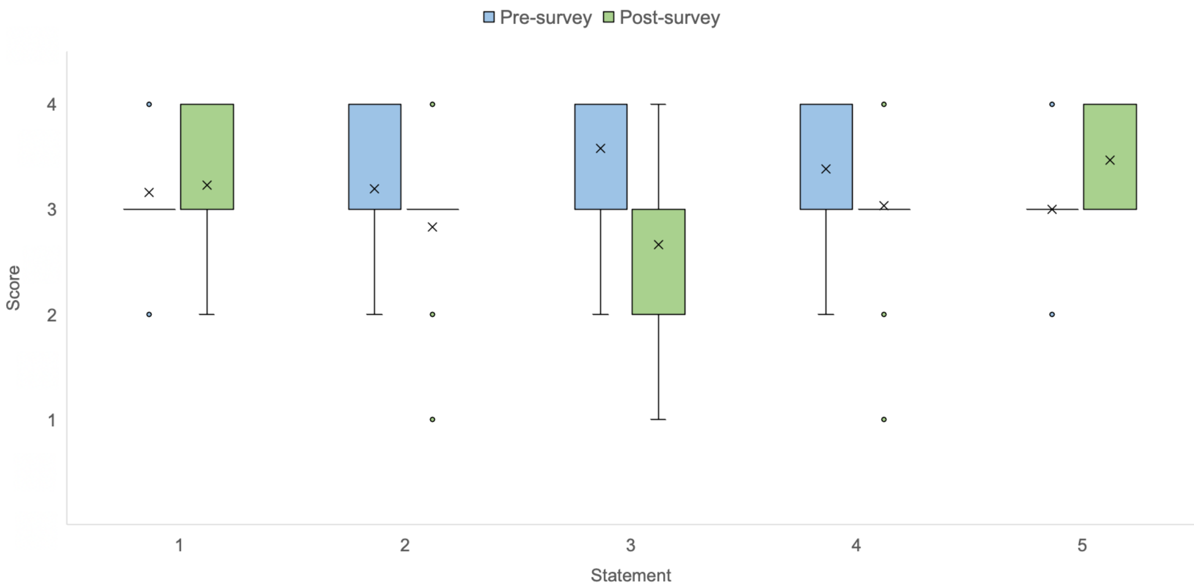

Figure 3 – Spread of student responses to survey statements

General qualitative feedback aligns with this; whilst students said they "*feel like I understand sustainable engineering a little more*", several mentioned that "*there wasn't enough time to make me feel like I improved my skills*". Of note, a student mentioned that they "*lacked the background knowledge to properly understand*", indicating that perhaps a knowledge barrier must first be overcome for students to improve their professional skills.

Comparison of survey statement responses

Figure 3 shows that student responses to the pre-survey for statement 1 are not significantly different to the post-survey ($p > 0.05$). This aligns with findings from Dada, et al. [15], who report that DST use did not have a significant impact on improving student understanding of specific course concepts. However, these results counter that of Leininger-Frézal and Sprenger [19], who find the use of a VFT did help to enhance student understanding. Common between ours and Dada, et al. [15]'s results are a high percentage (>75%) of agreement to the pre-survey statement, and thus it is more difficult to make a meaningful improvement on student understanding.

Comparatively, the remaining 4 statements showed significant differences between pre- and post-DST survey results ($p < 0.05$). Observations from Figure 3 in conjunction with this data implies the DST was ineffective in assisting students to develop problem solving skills, enabling teamwork, and improving their ability to communicate course learnings.

Statement 2 survey results contradict data from Eiris, et al. [20] and Potter and van der Merwe [21], who both report improvements in student problem solving abilities after the use of VFTs, Student feedback regarding their negative experiences with the DST found they "*lacked the background knowledge to properly address problems*", and they would have benefited from "*more class discussion*". This suggests that tutorial activities should be better developed to promote student problem solving and have more guidance and discussion; encouraging more collaboration in tutorials is a recommendation from Seymour-Walsh, et al. [22] to ensure activities are pedagogically rich.

Differences between pre- and post-DST survey responses are most prominent for statement 3, having the lowest p-value of 1.1e-11. This is supported by Figure 2, where 37% of students either disagreed or strongly disagreed to the post-DST survey compared to only 2% of students in the pre-DST survey. This is likely due to the DST being an individual experience – as there is no interaction between the user and the tour guides, or the user and other users, it is more dependent on the tutorial structure to help develop student collaborative skills. McNaughton [23] notes that to get students to work together effectively, they need to understand the importance of collaboration from an industry perspective. The provided tutorial activity evidently did not emphasise this, with students commenting that "*I did not understand what teamwork had to do with the activity*". This is one of the reasons why Spicer and Stratford [24] and Evelpidou, et al. [25] argue that virtual site tours cannot replace real site tours or industrial training; students miss out on opportunities to observe and participate in workplace collaboration.

Despite the comparatively large number of students disagreeing to statement 3 in the post-survey, most respondents still agreed or strongly agreed with the statement. Table 3 additionally indicates that responses to statement 3 were more spread out than responses to other statements, with a reported standard deviation of 0.84. Falls, et al. [26] and Ramdeo, et al. [27] both remark that the team member composition greatly affects student perception of teamwork. This justifies the diverse responses as some teams may have worked together well to complete the activities, with other groups having what Ramdeo, et al. [27] describe as "free riders", who negatively impact their opinion of teamwork.

Despite t-test results and Figure 3 showing the DST did not positive improve student ability to improve course learnings, most students (87%) agreed that the DST helped them to better communicate their course learnings. This aligns with findings from Kundu [28], where the majority of respondents indicated they could "maybe" or "probably" identify real life applications of their course learnings. Student feedback indicated that the tutorial did "*not [have] many opportunities for discussion*", although "*it was useful to help me to understand*". Our previous research found the DST assisted students in digesting and reinforcing course concepts [16], and thus, the tutorial activities were likely the cause of this lack of improvement. Hence, like the results to statement 3, the results to statement 4 call for a reflection on the tutorial structure; perhaps a greater discussion between the tutor and class should have been held for students to practice communicating their learnings.

The significant difference between pre- and post-DST survey responses for statement 5 however indicate that the DST was effective in improving student understanding of engineering design processes. Most notably, Figure 2 shows that no post-DST survey respondents disagreed to statement 5. These positive results align with many findings from literature [3, 15, 19, 28, 29]. Students commented that "*seeing the design process applied to engineering was interesting*" and that it was "*helpful to see how the diagrams lead to the real equipment*". One key piece of feedback was that the tour was a "*bit information packed*", which may have hindered students from understanding on a deeper level. However, another student mentioned they would have understood the design process better if the tour "*had more detail*". This is an issue that Klippel, et al. [30] note is a delicate balance – to provide accessibility to students at all learning levels, the DST should remain general, yet a certain level of detail is required in order for students to properly understand key concepts.

Recommendations

From observation of student qualitative comments in this study, it is recommended that DSTs are only introduced after students have gained some background knowledge of the course content; several students mentioned they "*didn't have the background knowledge to understand the tasks*". Students also commented that "*there wasn't enough time to make me feel like I improved my skills*". To ensure they have sufficient academic knowledge to complete tasks and feel they have developed interpersonal attributes, it is consequently suggested that DSTs are also integrated more frequently throughout courses. This recommendation is supported by other implementations in literature [15, 19, 31]; by incorporating industry context into more tutorials, students can improve contextual course understanding and thereby are more likely to improve communication, teamwork, and problem-solving abilities.

Many students remarked they would have preferred if tutorials had more class discussion. One student mentioned "*I would have appreciated it if we worked through an example [in class] first before attempting the questions ourselves*." It is consequently suggested some examples are worked through as a class before working through activities. This will maximise the amount of tutorial time spent doing the activity and allow tutors to point out key features for students to pay attention to. Students also agreed that there could have been "*better communication about what the task is*", with some stating they "*didn't understand why we had to do this*". Hence, it is recommended that tutors make clear to their students what the purpose of the tutorial activities are and highlight the importance of the DST to their learning.

Conclusion

To help improve students achieve professional competencies in the classroom, desktop site tours were introduced to a first-year sustainable engineering course. These were used with the intent of helping students improve interpersonal and comprehension skills outlined in the Engineers Australia accreditation guidelines, by providing real world context to their course learnings. The results from this study find that this aim was only somewhat fulfilled, and consequently that DSTs are somewhat effective at assisting students to achieve EA competencies. Students were not positive about the ability of the DST on its own to develop their problem solving, teamwork, and communication abilities. Qualitative responses found students were unsure of how the DST helps develop these competencies, and that only using the DST on one occasion did not provide them enough opportunity to do so. The DST however was effective in improving understanding of sustainable engineering practices, and significantly improved understanding of engineering design processes. These are part of the competency standard for professional engineer as required by the EA in terms of establishing Knowledge and Skills Base and Engineering Application Ability [16].

To increase its effectiveness in improving student professional and personal attributes, it is recommended that tutorials incorporating DSTs contain more classroom discussion and emphasise the importance of interpersonal skills in real world contexts. Based on student perception, this study therefore concludes that the DST deployment did not increase EA competency in professional skills, however an increase of EA competency in technical skills was observed. Going forward to further understand the potential impact of using DST modules on student professional skills development, the study should be completed over an extended timeframe.

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