# The Emerging Suite of Virtual Work Integrated Learning Modules for Engineering Students

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## SESSION S1:

Is Integrated Engineering Education Necessary?

## CONTEXT

Students of accredited engineering programs in Australia must engage with practice. In most universities in the country this has been achieved through placements of at least 12 weeks. It is becoming increasingly difficult for students to secure these opportunities and consequently universities must complement placements with other opportunities.

## PURPOSE

We identified the requirements and learning outcomes to design a suite of virtual work integrated learning modules to complement opportunities for engineering students to engage with professional engineering practice. The modules are virtual in the sense that they provide electronic interaction with real and/or simulated practitioners, and access to workplaces using virtual reality and other simulations. We outline the planning and the suite of modules.

## APPROACH

Descriptions of four hypothetical modules were developed. Engineers, university staff members, Engineers Australia staff members, and engineering students reviewed the modules at workshops in Melbourne, Perth and Brisbane. Responses to the modules were analysed to identify the important stakeholder requirements and also potential solutions to meet these. The suite is currently being developed and tested. Discussion or workshops were also held at the Australasian Association for Engineering Education 2016, and meetings of the Australian Council of Engineering Deans, Associate Deans Teaching and Learning, and the Australian Council of Deans of ICT.

## RESULTS

Key requirements are that modules must include disruption and uncertainty, and support structured progression from first to final year. The suite should include some modules that can be integrated into credit-bearing units in addition to modules that stand-alone.

Learning outcomes include professional elements of the Stage 1 Competences, especially those related to decision making and ethical responsibilities; items to support motivation and skills for students to become self-directed learners; and items to support career literacy.

## CONCLUSIONS

A suite is being developed including: modules to be adapted for integrating in first, second, and third year units; and more authentic modules in which senior students will work in groups on authentic engineering tasks such as tendering with electronic meetings with engineers.

## KEYWORDS

Work integrated learning, virtual reality, practicum

# Introduction

Students of accredited engineering programs in Australia must engage with practice. In most universities in the country this has been achieved through placements of 12 weeks or longer, and these placements have been reported by students to support them in developing competencies and to increase their motivation towards becoming engineers (King & Male, 2014; Male, 2015). Kinash and Crane (2015) found that the most important strategy to improve graduate employability is participation in well-managed work experience and placements.

Unfortunately it has become difficult for students to secure placements. Consequently universities must complement workplace experience with other opportunities for engaging with practice. Several projects have developed immersive environments and shown that these support students' learning (Cameron et al., 2009; Savage, McGrath, McIntyre, & Wegener, 2010; Shallcross, Maynard, & Dalvean, 2011). Smith, Ferns, Russell, and Cretchley (2014) recommended future research into simulated work integrated learning.

We are developing a suite of learning modules to complement existing opportunities for engineering students to engage with professional engineering practice. The modules provide electronic interaction with real practitioners, and/or simulated practitioners, and access to workplaces using virtual reality and other simulations. We are working with Engineers Australia to develop a pool of engineering mentors to interact electronically with students in the learning modules. Students from universities across Australia should be able to undertake the modules.

This paper reports on the planning phase in which the learning outcomes and requirements for the modules were developed, and outlines the planned suite of modules.

## Principal requirements

Principal requirements for the modules were based on literature and the goals of the project. The first requirement was that modules should be consistent with the accreditation requirement that students engage with engineering practice (Engineers Australia, 2011). Beyond this, we began with learning outcomes, consistent with the curriculum development principle of constructive alignment (Biggs, 1999).

*Learning outcomes*

1. Learning modules in the suite should contribute to students developing the learning outcomes consistent with the Stage 1 Competency Standards (Engineers Australia, 2011, p. 2), which are central to program accreditation criteria, and include: "1. Knowledge and skills", "2. Engineering application ability" and "3. Professional and personal attributes".
2. Generic engineering capabilities that are most difficult to achieve without work integrated learning should be included among learning outcomes for the suite of modules. Examples are capabilities to take account of contextual factors such as environmental, financial and social issues, to take account of practical issues such as constructability and maintainability, and to function effectively in a workplace.
3. Some of the modules should support students to develop career literacy, meaning capability to secure or create employment and develop a career.

*Learning activities*

4. Learning activities in the modules should be authentic, meaning that students engage in tasks that are part of engineering practice.
5. In the modules, students should interact with real engineers, to enhance authenticity and support identity formation and motivation as student engineers. Engineers spend

60% to 80% of their time in collaborative work (Trevelyan, 2014). Although geographically disparate, it was planned that students undertaking the learning modules would spend much of their time interacting with each other and with real engineers. Students should use authentic digital communication methods as might be used by engineers.

6. In the modules, students should use authentic engineering processes for managing systems and for approaching tasks, such as minute-taking resources developed by (Foley, Gill, Senadji, Palmer, & Martinez-Marroquin, 2017).
7. In the modules, students should actively participate in interactive teams, with cycles of individual and group reflection, and feedback from professional engineers, consistent with recommendations for work integrated learning (Cooper, Orrell, & Bowden, 2010).
8. In the modules, students should be supported to develop inclusive learning communities (Wenger, 1998), especially for female students who are under-represented in engineering.
9. To be inclusive, the modules should be designed such that participating students and engineers need no more equipment than are commonly available to students in Australian universities.

# Method

Workshops were held with stakeholders in order to refine the requirements to meet their needs. One-page descriptions of hypothetical modules were developed for review based on the principal requirements. The modules involved (A) a decommissioning process, (B) competing to win a tender, (C) planning a maintenance event, or a root cause analysis for a safety incident or a failure and (D) working with others.

Each module description included

- learning outcomes
- year level of students for whom the module would be designed
- whether the module would be stand-alone, or integrated into a relevant unit
- duration
- learning activities
- any interaction with a virtual environment
- how students would interact with engineers
- how and with whom students would reflect on their learning, and
- assessment mechanisms.

In modules A and B, students would be given a period of weeks to work in a student team on a task presented to them by a senior engineer, and with the opportunity to interact electronically with a junior engineer during the task. Module C would be integrated into a relevant unit. Students would visit a virtual site and work together on a task for which practical features of the site are important. In Module D students would communicate with others in a simulated workplace. They would try to complete tasks that require them to make decisions about how to communicate with other students who have competing priorities.

Engineers, university staff members, Engineers Australia staff members, engineering students, and a senior recruitment manager in an engineering company, participated in workshops in Melbourne, Perth and Brisbane ($N = 43$). At the workshops, groups of participants each reviewed two modules, and addressed the following questions:

1. How can you see this working, if at all?
2. What are its strengths?
3. What concerns would you have about it?
4. How could it be improved?
5. How does this compare with anything similar that you are aware of? Can either benefit from the other?
6. Any other comments?

Participants recorded hand-written group responses. Audio recordings and notes were also made during group reports and plenary discussion among participants. The workshops were three hours long including light refreshments. The recordings were transcribed.

Participants' responses to the modules were analysed to identify the important stakeholder requirements and also potential solutions to meet these. Minor revisions to modules were made between workshops to improve the alignment with stakeholders' needs and recommendations.

Discussion or workshops were also held at the Australasian Association for Engineering Education 2016 ($N$ = 25), and meetings of the Australian Council of Engineering Deans, Associate Deans Teaching and Learning, and the Australian Council of Deans of ICT.

# Findings, Discussion and Further Research

Responses were generally enthusiastic. Participants noted that working in geographically disparate locations is common in engineering practice. Engineers noted that many of the activities supported learning that was important and yet often received insufficient if any attention in engineering programs.

## Feasibility of recruiting engineers

Many stakeholders were concerned that it might be a challenge to recruit enough engineers to interact with students, and they recommended use of videos and other mechanisms as a backup plan. The first version of Module D involved interaction with engineers who were uncooperative. However it was noted that employers would not wish to risk their reputations but engaging in frustrating behaviour – however authentic. A possible solution to this problem is to use simulations. Students could reflect with a real engineer after completing an activity using a simulation.

## Structure of the suite of modules

University staff members recommended structured progression in the learning modules from first to final year with increasing authenticity, autonomy, and responsibility in the activities and assessments. University staff members also suggested designing modules in which senior students supported junior students. Students responded positively to this suggestion.

Participants agreed it would be beneficial to learning if students from multiple universities collaborated in each module. However, university staff members recommended starting trials with students from only one university at a time participating in any module, to simplify the first trials and maintain credibility.

## Authentic learning activities

University staff members and engineers were adamant that students should experience disruption and frustration in the modules, rather than the controlled environment more common on campus. Disruptions, or unexpected changes, are common in practice. Although unfamiliar with the protocol, participants responded positively to our suggestion to use Professional Performance Innovation and Risk (Warren Centre) as a process that would be encouraged or expected in many modules in order to perform professionally.

Participants felt that it was important that students feel emotions such as anxiety in order to learn. Some participants described important experiences interacting with non-engineering members of teams. They recommended that students should learn to see the perspectives of workers with practical experience, who often perform physically demanding jobs, and with whom engineers are likely to interact in practice.

Practical, financial, and social capabilities were identified by participants as being difficult to teach or overlooked in traditional curricula. Engineers recommended that learning about safe and ethical decision-making and practice should be integrated into learning activities that are not primarily about these capabilities.

### Assessment

All groups of stakeholders reported that assessment of learning is an essential feature of the modules. University staff and students recommended providing flexible modules and assessment mechanisms that could be adapted for the diverse needs of universities. Consistent with this requirement, the learning activities and assessment should be sufficiently open that they can be used multiple times without students being able to copy the work of previous students in order to complete the activities and assessments.

### Revised learning outcomes

The learning outcomes and other requirements were revised to those listed below. Students who complete the modules should demonstrate:

1. development contributing to achievement of Stage 1 Competencies
2. capability and attributes for self-directed learning
    - understanding of engineering roles and value of engineering
    - motivation towards engineering studies
    - self-efficacy for working as an engineer
    - an identity as a student engineer
    - ownership of responsibility for learning
3. career literacy
    - improved capability to secure or create engineering work
    - understanding of the employment market in the student's discipline
    - capability to plan navigation of the employment market including lifelong learning, and
    - an expanded engineering network.

### Requirements for every learning module

Every learning module should:

4. contribute to engaging with practice for accreditation purposes
5. support at least one of the intended learning outcomes
6. be assessed with mechanisms that can be adapted for different universities
7. be inclusive
8. support students to receive feedback and reflect on their learning
    a. in notebooks or portfolios
    b. with peers and/or engineers
9. be suitable for use year after year
10. be robust to difficulties recruiting engineering mentors and
11. have evaluation processes.

### Requirements for the complete suite of learning modules

The suite of learning modules should:

12. include realistic disruption and uncertainty
13. be structured with progression from first to final year with increasing authenticity and autonomy
14. support development of sociotechnical learning outcomes including capabilities to practise ethically, safely and sustainably
15. support financial learning outcomes
16. develop practical engineering skills
17. use authentic engineering processes
18. use Professional Performance
19. include modules within units, and include stand-alone modules
20. be suitable for use in one or more universities concurrently and
21. support senior students to guide junior students.

### Future research

The modules in Table 1 are being developed.

**Table 1: Planned modules**

<table>
<tr><th>Module ID</th><th>Main learning activity</th><th>Proximity to workplace/practitioners</th><th>Implementation</th><th>Year-level</th></tr>
<tr><td>I</td><td>applying for engineering jobs</td><td>electronic interviews of and with engineers</td><td>integrated</td><td>1, 4, 5</td></tr>
<tr><td>II</td><td>communication/ self-management in authentic engineering scenarios</td><td>simulated workplaces and reflection electronically with team and engineer</td><td>integrated</td><td>1, 2, 3</td></tr>
<tr><td>III</td><td rowspan="2">safety in design exercises based on real cases</td><td rowspan="5">virtual site, and electronic meetings with students and engineers</td><td>integrated</td><td>2, 3, 4</td></tr>
<tr><td>IV</td><td>integrated or stand-alone</td><td>2, 3, 4</td></tr>
<tr><td>V</td><td>preparing a tender</td><td>stand-alone</td><td>3, 4, 5</td></tr>
<tr><td>VI</td><td>evaluating a tender</td><td>stand-alone</td><td>3, 4, 5</td></tr>
<tr><td>VII</td><td>pump isolation for maintenance</td><td>integrated or stand-alone</td><td>3, 4, 5</td></tr>
<tr><td>VIII</td><td>hazard and operability meeting meeting</td><td>Simulation, and electronic interaction with engineers</td><td>integrated or stand-alone</td><td>4, 5</td></tr>
</table>

# Conclusions

A fortunate consequence of the problem that engineering student placements in workplaces have become scarce is that educators are being forced to become innovative about integrating engagement with practice within engineering curricula. As a consequence students are likely to benefit from structured engagement with practice throughout the curriculum from first to final year, with strong scaffolding at the start and increasing responsibility, autonomy, and authenticity in the learning activities for students as they progress towards graduation.

This project aims to support educators in embedding engagement with practice from first year; providing capstone, authentic, learning opportunities; and developing a sustainable pool of engineering mentors.

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