DEVELOPING A MANAGEMENT SYSTEM FOR ENGINEERING EDUCATION (MASEE)

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SESSION C1: Integration of theory and practice in the learning and teaching process

CONTEXT Increasing the authenticity of the engineering curriculum through engagement with industry has been recognised as essential to aid transitions from education. Exposing student engineers to, and requiring studies to be undertaken within, an industry adapted Management System for Engineering Education (MaSEE) is proposed as a means of increasing this authenticity. The concept has been developing over the past five years to address an identified gap in the curriculum with regards quality management processes. Quality management processes provide the opportunity for socio-technical considerations to be integrated into the design process and reflect how engineers operate in practice.

PURPOSE This paper furthers the development of MaSEE. It explores perceptions from industry on critical processes to embed into the curriculum, outlines trials of the processes and resources that will be available to engineering educators.

APPROACH This project is funded by the Australian Government Department of Education and Training and uses an action research approach to develop, trial and refine six teaching resources that will enable adapted industry management system processes to be used as learning and teaching tools. Industry participants have provided input into identification of the processes and will also be given the opportunity to review the developed resources for authenticity.

RESULTS This project is the extension of an exemplar trial of a design verification peer review process. The trial demonstrated that students were able to appreciate the adapted industry process, and its use enabled an increased understanding of technical content. Industry participants have now validated which other processes should be adapted for use. These include design review, document control and project planning.

CONCLUSIONS This paper identifies the value of student engineers using industry adapted management system processes within their studies. It also outlines further work to be undertaken on the project.

KEYWORDS

Curriculum, industry, employability.

Introduction

The approach to work adopted by professional engineers is different to the engineering student's general approach to their learning of the fundamental technical skills required to practice professionally. The approach used by professional engineers is informed by management system frameworks which provide consistent protocols and processes for use. The ability to appreciate and work within these protocols provides transferable skills that are directly related to the employability of a graduate, and engineers more broadly. These skills are recognised competencies, which are well defined for engineering programs.

This paper reviews the professional competencies and transferable skills required by graduate engineers and proposes the introduction of adapted industry management system processes as a means of development.

Professional competencies

Over the past one to two decades there has been an increasing emphasis on defining what competencies are required by engineering graduates, and university graduates more broadly. From an engineering perspective, the first competency Standard was introduced in 1993 and each subsequent revision (1998, 2003, 2006, 2011 and 2013) has shaped our understanding of the learning outcomes to be considered, developed and assessed within progressive engineering curricula. The revisions made to the Standards between 2006 and 2011 were significant and informed by national Australian Learning and Teaching Council (ALTC) funded projects defining the future of engineering education, including: the landmark Addressing the Supply and Quality of Engineers for the New Century report (King, 2008); and the Threshold Learning Outcomes (TLOs) developed by the ALTC Discipline Scholars in Engineering and ICT (Wright, Hadgraft, & Cameron 2011). A key feature of the 2011 revision to the Standard was the inclusion of a specific Indicators of Attainment for each competency with more depth than had previously been seen. These indicators are provided for guidance, but explicitly characterise professional engineering practice.

A challenge for engineering educators relates to the complexity of devising curricula to develop these non-technical competencies when, traditionally, the curriculum was designed to develop the technical/analytical knowledge base that provides the foundation for engineering practice. This is particularly the case at present as the programs go through re-accreditation using the revised Standards. If more time is dedicated to the development of non-technical competencies, which core technical knowledge content is removed? Or, should educators attempt to just squeeze the content and fit everything in? The answers to these questions are not clear and necessitate the need for further investigation of pedagogical approaches that appropriately blend academic and practical learning experiences, and which see students prepared for work with the right mix of practical and theoretical/academic skills.

In many engineering programs non-technical competencies are developed in 'professional practice', 'management' or 'communication' units of study, which are bolted onto the core discipline knowledge, and often perceived by students to be less important than the development of technical skills (King, 2008). Chanda and Nicholls (2006) suggest that there is some merit in this. However, to aid the development of the skills there is also merit in curriculum design that incorporates a mix of bolted on, embedded and integrated approaches. An embedded approach incorporates non-technical competencies into curricula but there is no direct reference or assessment of their development. An integrated approach seeks to develop the competencies in parallel with technical content. An example is Project Based Learning (PBL), which has been shown to be appropriate for engineering (Mills & Treagust, 2003; Maier, 2008; Schaller & Hadgraft, 2013). The success of PBL activities can be related to the selection and authenticity of the project to be undertaken, with industry inspired projects being preferred.

The use of industry inspired projects, and greater engagement with industry more broadly, is strongly advocated by Engineers Australia, was a key recommendation of King (2008) and has been explored by the Australian Government Office for Learning and Teaching (OLT) commissioned projects (Jollands, 2015). The Best Practice Guidelines for Effective Industry Engagement in Australian Engineering Degrees is another recent publication that was an outcome of an Australian Council of Engineering Deans (ACED) project (Male & King, 2014). The guidelines were well received and articulated the need for, challenges and best practice examples of industry engagement. The content of these guidelines confirms that the project proposed in this paper, and the work carried out within the seed project, is innovative, needed, and has the potential to lead to significant and positive change.

Management System for Engineering Education (MaSEE)

The project described within this paper advocates the development of a Management System for Engineering Education as one mechanism to increase the authenticity of engineering curricula. Within the professional environment, engineers work within a controlled management system framework which requires the application of formal protocols and processes on all projects, to maintain standards and improve outcomes. These processes relate to how work is planned (approached), controlled (progress monitored) and peer reviewed. By contrast, within the learning environment students typically have freedom to approach and control their work as they see fit. Learning support services do provide useful guidance for students wanting to improve their study skills and work-integrated learning activities enable students to experience how engineers approach their work. However, the study guidance may not be provided within an engineering context, and the effectiveness of work-integrated learning activities can vary. MaSEE identifies and exploits similarities between the professional protocols and effective learning and teaching strategies. The result is that students are given the opportunity to develop their professional identities and to approach their work as student engineers. This allows them to learn the necessary protocols, develop a broader employability skillset and, importantly, apply the protocols in a manner that allows them to engage with technical content at a deeper level.

Design verification exemplar process

A design verification exemplar process was trialled to determine if previous pilot projects could be transferred to other disciplines and institutions. Design verification is a form of peer review and is undertaken before any engineering outcomes are provided to the client. It can be considered as a peer review process for learning (Figure 1). A teaching resource consisting of a teacher implementation guide, student online module and adapted industry template were packaged for the trial. The trial involved two institutions, 4 engineering disciplines and 6 courses. For each course, an assessment task was adapted to include a design verification step, and students applied the adapted industry template. In some courses, an online learning module complemented the template. The outcomes of the trial (Foley and Willis, 2015) were assessed through a student perception survey, which used a seven-point Likert scale for responses, and showed:

- 86% broad agreement that the applied process improved the understanding of how designs are verified in industry
- 85% broad agreement that the applied process improved their understanding of the technical concepts in the course.

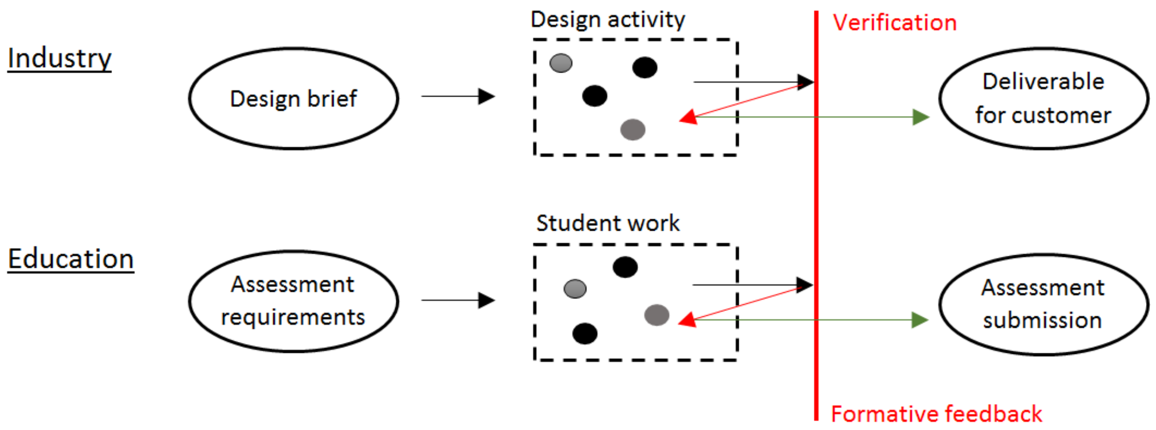

Figure 1: Design verification as cyclical formative feedback

The project team is now expanding the concept and developing resources for a further five processes through engagement with industry and further trials. The additional five processes were identified for development by the project team and relate to aspects of quality, safe design, planning, documentation and project control (Foley and Willis, 2013). This is consistent with the management system frameworks that engineers operate within, which include processes related to financial, quality, environmental and health & safety requirements. A management system in industry can include 100+ processes, to cover all business activities. However, the six processes for this project are considered to be of relevance to engineering graduates with broad applicability. These are summarised in Table 1 with respect to potential educational value and employability skills being developed.

Table 1: Identified management system processes

Industry process	**Educational value**	**Employability skills developed**
Design verification	Cyclical peer feedback	Ability to give and receive feedback / collaboration
Design review	Cyclical peer feedback	Consideration of socio-technical factors that impact work including safety / end users
Project Minutes	Tracking of group and project work	Improved teamwork Improved accountability for actions Improved meeting outcomes
Document Control	Organisation of work	Organisation of work for traceability
Project Risk Assessment	Identification of risk	Appreciation of risk factors and control measures
Project Planning	Identification of tasks and efficient project completion	Organisation and management of self, others and tasks

Industry validation

To validate the selection of processes to be adapted, an online survey was developed and released through project team networks. 43 responses were received from the professional engineers in all disciplines, distributed throughout Australia and New Zealand. Table 2 outlines the distribution of responses. The survey sought to understand whether management systems were used and which processes were most relevant to graduates. The responses indicated that all operated within a quality, environmental, health and safety or integrated management system and Figure 2 the perception of respondents as to how important it is for graduates entering an organisation to be able to operate within a management system framework.

Table 2: Distribution of industry responses (n=43)

Discipline	% of respondents*	Location	No. of respondents	Sector	% of respondents
Civil	34.9	ACT	3	Engineering consultant	32.6
Mechanical	34.9	NSW	3	Government	9.3
Electrical and Electronic	39.5	Qld	4	Large corporation/ multinational	25.6
Chemical	11.6	SA	3	Small business	5
Petroleum	4.7	Vic	5	Utility	7
Mining	14	WA	7	Other	14
Software	14	National	16		
Other	34.9	International	2		

*respondents could identify more than one discipline

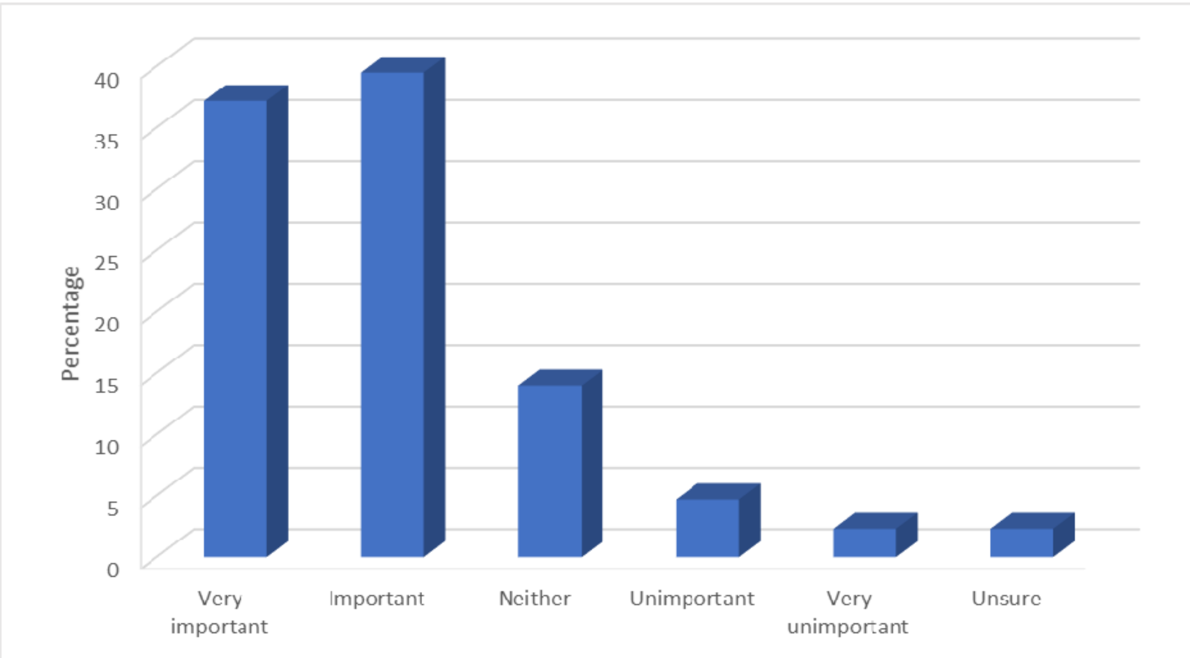

Figure 2: Importance of graduates being able to operate within a management system

The last of question results presented in this paper from the survey relates to the relative importance of the identified processes. Table 3 is less definitive and further analysis is required.

Table 3: Ranking on identified processes/activities

Processes/activities	Importance ranking (% of respondents - 1 highest)					
	1	2	3	4	5	6
Participate in design review	***25.6***	14.0	***30.2***	16.3	7.0	7.0
Undertake design verification	14.0	16.3	20.9	11.6	14.0	***23.3***
Project risk	4.7	7.0	16.3	11.6	***41.9***	18.6
Document / version control	20.9	***30.2***	11.6	23.3	9.3	4.7
Recording meeting outcomes	14.0	***27.9***	7.0	9.3	14.0	***27.9***
Project planning	20.9	4.7	14.0	***27.9***	14.0	18.6

Table 3 provides some unexpected results. The process developed initially, design verification, was not ranked as high as expected and this is being further investigated. One possible explanation is that design verification is more specific than design review and, to some, may be considered as a subset. It is also unexpected that project risk was ranked at the bottom end. This may be related to it not being the responsibility of the graduate to identify project risks. The data does show that different respondents have different views of what is and is not important for graduates.

Next steps and conclusion

Teaching resources for each of the identified processes have been developed and engineering educators are invited to trial the resources in Semester 1, 2018. The project team is seeking to understand how the resources can be used within different engineering programs.

The industry survey does indicate that an understanding of management systems is important. Further industry engagement is required to better understand the relative importance of the different processes.

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