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Embedding a Management System for Engineering Education (MaSEE) into Curricula

Bernadette Foley[1], Tiffany Gill[1], Edward Palmer[1], Stephanie Eglinton-Warner[1], Bouchra Senadji[2], Elisa Martinez-Marroquin[3]
[1]*The University of Adelaide,* [2]*Queensland University of Technology,* [3]*Canberra University*
Corresponding Author Email: bernadette.foley@adelaide.edu.au

STRUCTURED ABSTRACT

CONTEXT
The Management System for Engineering Education (MaSEE) project has been developed to address the varying level of knowledge regarding key management system processes, with which graduates enter the profession, as identified by industry. The MaSEE project promotes problem-based learning and assessment, which integrates peer feedback and experiential learning in context and closely simulates authentic professional practices. Stakeholders informing the project and its outcomes include: industry, educators and students.

PURPOSE
This paper outlines the activities leading to the development of MaSEE. It provides an overview of resources, pedagogy, and examples of how it can be embedded into engineering curricula. It also explores how the use of defined processes enable diverse internal and external perspectives to be considered within engineering practice.

APPROACH
This study has received funding from the Australian Government Department of Education and Training and uses an action research approach to develop, trial and refine teaching resources that enable adapted industry management system processes to be used as learning and teaching tools within the engineering curriculum. Each process is aligned with established pedagogy, with resources to support implementation and assessment. The processes include meeting minutes, design verification, design review, document control, risk assessment, project planning and request for information.

RESULTS
Outcomes from project activities have indicated a positive correlation between the use of the adapted processes and improved student learning. The analysis in this paper has also identified the potential for MaSEE resources to aid the development of professional communication skills, and to appreciate diverse perspectives.

CONCLUSIONS
This project provides the opportunity to improve the teaching of engineering undergraduates and provide them with skills that are translatable to industry and address the diverse range of workplace scenarios. In addition, educators are provided with a set of tools and a sound pedagogy to support their teaching.

KEYWORDS

Curriculum, industry, employability, professional skills, authentic learning.

Introduction

The Management System for Engineering Education (MaSEE) comprises a series of resources for students and educators and has been developed with the support of the Australian Government Department of Education and Training. These resources have been developed to address the varying levels of knowledge regarding key management system processes with which graduates enter the profession, as identified by industry.

The MaSEE project promotes problem-based learning and assessment, integrating peer feedback and experiential learning in contexts that simulate authentic professional practices. The aim is to educate engineers preparing to enter industry and for the future. Stakeholders informing the project and its outcomes include industry, educators and students.

This paper outlines the development of resources, provides educational justification for the processes and then demonstrates how their use develops competence through consideration of diverse perspectives.

Management System for Engineering Education resource development

The development of resources for MaSEE has been informed through consultations with industry (Foley et al., 2017), educators and student perspectives. The resources have adapted industry management system processes for use as learning and teaching tools, and include: student guides, templates for student use and educator implementation guides. The resources provide an opportunity to increase the authenticity of learning activities, particularly within a project based learning environment, and meet an identified need.

The value of aligning engineering curricula with professional practice is well established (Mills and Treagust, 2003; King, 2008; Male and King, 2014; Stevens, 2014; Jollands, 2015; Naylor, 2016; Graham, 2018). A key premise for embedding MaSEE resources and processes within the curriculum is that they replicate how engineers approach practice. Industry work within a Management System framework to manage and improve the quality of their services and deliverables. When learning activities within curricula are structured to enable student engineers to approach their studies in a similar manner, there is the potential for improved learning outcomes. MaSEE seeks to aid the transition from the learning environment to industry, by providing a greater understanding of the profession.

In the broader field of education research, there is additional support and recommendations for the use of authentic, experiential learning, particularly where it includes peer to peer learning and feedback, and reflective self-evaluation. Boud, Cohen and Sampson (2006), Biggs & Tang (2007) Boud (2010), and Scott (2016) promote the use of project or problem-based learning and assessment tasks, which simulate, or where practicable include, relevant professional practice. They emphasise the need for scaffolded learning and the positive impact of well-designed assessment. Peer learning and feedback, reflective self-evaluation, scaffolded project/problem based learning and assessment both of and for learning are integral to the design of the MaSEE resources.

For each adapted industry process, the potential educational value and aligned professional competencies have been identified (Table 1). The professional competencies are derived from industry input and are a mix of capabilities, competencies and skills. While all are relevant to the engineering profession, many are also applicable to other professions and industries which aids the development of transferable skillsets.

The resources have been developed for flexible and scaffolded integration within the curriculum and assessment activities. Developers have been mindful that there is significant variation in the structure of engineering programs and the capacity for inclusion of additional learning resources. The resources have been designed to complement this variation, giving engineering educators control of how much, how little, how and when to embed these resources. However, it is proposed that the processes are introduced progressively through a program, with repeated and increased utilisation. Integration in this manner should better prepare students engineers to use all of the processes within their capstone experiences. This assertion requires validation, and further evidence of the educational value of these processes is also required. The evidence base for this will be investigated through the further trialling and evaluation of the MaSEE resources processes in 2019.

Table 1 MaSEE Process summary

PROCESS	EDUCATIONAL VALUE	PROFESSIONAL COMPETENCIES
1. Design Verification	Capabilities to generate, interpret and apply peer feedback and to develop self-evaluation capabilities Informed decision making	Application of technical knowledge in authentic contexts Ability to give and receive feedback / aid for collaboration Quality control – review validity and accuracy of plans
2. Project Meeting Minutes	Tracking of group and project work Concise expression Group decision making	Collaboration/teamwork Accountability for actions Effective meeting outcomes
3. Design Review	Generate, interpret and apply peer feedback Evidence based evaluation and decision making Development and expression of argument	Application of technical knowledge in authentic contexts Ability to give and receive feedback / aid for collaboration Consideration of socio-technical factors that impact work including safety / end users Quality control – review design suitability, adequacy and effectiveness
4. Document Control	Organisation of work Drafting and editing written communications Explicitly acknowledging collaborations and responsibility for contributions	Organisation of work for traceability and effective, clear, transparent communication Tracking development of ideas
5. Project Planning	Identification of tasks and efficient project completion Personal and time management Organisation of work Communication and collaboration with diverse others Group decision making Problem solving	Organisation and management of self, others and tasks Effective, detailed, clear documentation Record keeping for accountability, traceability and quality control
6. Risk Assessment	Identification of risk Evidence based decision making Exercise professional judgement Critical and systematic analysis of evidence	Application of technical knowledge in new and authentic contexts Appreciation of risk factors and control measures
7. Request for Information	Seeking further information/identification of requirements Clear, concise, focussed and professional written communication	Information collection to inform planning and design

Valuing communication and diversity to develop competence

Development of professional competencies, and aligned employability skills, are key objectives of embedding MaSEE within the curriculum. Reviewing each process and its alignment with Engineers Australia Stage 1 competencies (Engineers Australia, 2011) has identified a further opportunity for adding breadth to competency development, through the use of the adapted processes. It has highlighted the extent to which the identified processes rely on effective communication skills and the consideration of diverse perspectives and stakeholder needs. The under-development of written and oral communication skills in engineering education, including varying levels of digital capabilities for communication, is commonly identified as needing to be addressed (Riemer 2007; Nylen and Pears, 2013; Naylor, 2016; Goldsmith, Willey and Boud, 2017). Goldsmith et al., (2017) includes 'invisible written practices' needed within the profession such as the completion of 'forms'. The ability to genuinely consider and take account of multiple perspectives is an overlooked competency, closely linked to effective communication skills and essential for professional practice. It is also required for collaborative learning which includes effective questioning and feedback loops, developing critical reflection and analytical skills, and is grounded in mutual trust and respect (Boud 2010; Biggs & Tang 2007; and Scott 2016). The resources developed all include forms of professional communication, and in most instances, require consideration of diverse perspectives. For each process an overview of these skills is provided below.

Design verification

Design verification is a peer review activity which requires an independent lens for assessment whether the inputs and outputs meet requirements. Perspectives requiring consideration include: the customer/client, the designer and verifier. Communication is in the form of reviewing/inspecting documentation, completion of verification templates and discussions.

(Speaking, Listening and Writing – giving and receiving feedback, expressing point of view and/or position professionally: Reading and Writing - interpreting and evaluating information, completing templates: Other Aspects of Communication – flexible thinking, adaptability, comparing, interpreting and evaluating perspectives)

Project meeting minutes

Project meeting minutes provide transparency for the project team and enables progress and actions to be reviewed. Engineering project meeting minutes are action-oriented and different to parliamentary or transcript style meetings. Documenting minutes enable meeting participants and external stakeholders to have a shared understanding of discussions and resulting actions. Perspectives requiring consideration include project team members, relevant stakeholders and project objectives. Communication is in the form of discussions, listening and documenting.

(Speaking and Listening – expressing point of view and/or position professionally: Writing - completing templates: Other Aspects of Communication – making decisions, determining what to record)

Design review

Design review is similar to design verification in that it is a peer review activity. However, it has broader objectives and therefore takes into account additional perspectives. These perspectives relate to the overarching project requirements and are more diverse. Design reviews require the implications of a project to be considered and takes into account socio-technical considerations such as environmental, legal, community and operational requirements. These perspectives are developed by reviewers over time and informed by external needs of clients and end users. Communication is the form of conducting and recording meetings, and interpretation of documented design inputs, outputs and user needs.

(Speaking, Listening and Writing – giving and receiving feedback, expressing point of view and/or position professionally: Reading and Writing - interpreting and evaluating information, completing templates: Other Aspects of Communication – comparing, interpreting and evaluating perspectives, making decisions, determining what to record)

Document control

Students approach document control in diverse ways, often not self-consistent and once students are in groups they can struggle to ensure they are all working on the appropriate version of documents. Versioning can aid communication and minimise repetition and wasted work. Communication in this process focusses on application of consistent tracking details, suitable for all document types and users.

(Writing – consistency of documentation: Other Aspects of Communication – considering needs of users, transparency and accountability)

Project planning

Project planning ensures a shared understanding of the project's scope and requirements. Resources can be made available in the right quantity and with the correct timing to ensure the project moves smoothly. Planning requires communication through groups about the needs of the project. Critical to the planning process is setting goals and documenting intentions in a manner that is accessible to all required users.

(Speaking, Listening and Writing – giving and receiving feedback, expressing point of view and/or position professionally: Reading and Writing - interpreting and evaluating information, completing templates: Other Aspects of Communication – comparing, interpreting and evaluating perspectives, making decisions, determining what to record)

Risk assessment

Assessing and mitigating risk are key aspects of many engineers. An understanding of risk often requires communication with groups of people and then requires appropriate written communication to ensure project owners are aware of them. It also requires the competencies to interpret data, make viable predictions of cause and effect, and envisage potential responses. Communication in this context centres on the expression, interpretation and evaluation of ideas, knowledge and perspectives.

(Speaking, Listening and Writing – giving and receiving feedback, expressing point of view and/or position professionally: Other Aspects of Communication – comparing, interpreting and evaluating perspectives, making decisions)

Request for information

Students are used to requesting information from teachers and lecturers in a voice which may not be appropriate for their profession. Successful outcomes in requests for information will often depend on the clarity of the request as well as the tone. Communication is in written form and requires a balance of detail, clarity and professional curtesy. It also enables an evaluation of the appropriateness and timeliness of the request.

(Writing – clarity of expression, professional style, format and language used, anticipating needs of others for information on which to act)

Results

Outcomes from previous project activities (Foley and Willis, 2015) have indicated a positive correlation between the use of the adapted processes and improved student learning of both technical content and awareness of industry management system processes. The analysis in this paper of the potential for MaSEE resources to develop communication skills and to appreciate diverse perspective provides an additional hypothesis for evaluation in 2019 planned trials.

Conclusion

The resources developed through this project provide the opportunity for adapted industry processes to be embedded within the engineering curricula. The resources provide flexible learning activities and tools to increase awareness of industry practice, and to develop critical professional communication skills. The resources have been adapted from industry to leverage sound pedagogy. Further trialling of the resources is required to evaluate the pedagogic merit. This will be undertaken in 2019.

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