Capability building through Workplace Based Learning in Maintenance and Reliability Engineering (MRE) Postgraduate Programmes

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CONTEXT

Maintenance and Reliability Engineering (MRE) plays a significant role in engineering and infrastructure asset management for capital intensive industries, through balancing cost, risk and performance in informed decision making for maintaining and realising value from assets. Postgraduate programmes play an important part in capability building of professionals in maintenance, reliability and asset management in industries. Workplace-based assessments in postgraduate MRE Programmes using student-negotiated industry-based practical projects is value adding for the participants and their employers. This study explores how industry based MRE projects in student's existing industry setting, can achieve benefits for all involved.

PURPOSE OR GOAL

The central role of assessment within postgraduate engineering courses is preparing students to apply knowledge to meet contemporary and emerging professional engineering challenges relevant to the contexts of their professional development and needs of their organisations. Through embedding projects where students resolve authentic problems vital to their industry within the MRE programme curriculum, the assessment allows students to authentically demonstrate professional engineering practices delivering practical outcomes for their workplaces. This case study illustrates how the programmes at a Victorian Regional University can achieve this through student-negotiated workplace-based assessments.

APPROACH OR METHODOLOGY/METHODS

More than 300 professionals enrolled in MRE courses per year, solve authentic workplace problems in project-based courses relevant to their industries and aligned to the learning objectives. Students negotiate these projects to benefit their workplace and demonstrate assessable academic achievement supported by industry and academic supervisors.

ACTUAL OR ANTICIPATED OUTCOMES

Through the principles of authentic assessment, a diverse cohort of students in demanding working environments are engaged and motivated. Students take ownership and responsibility of their learning because they can tackle authentic socio-technical-cultural issues and challenges in discipline area. Industry benefits from practical solutions to real-life problems.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

This model of student-negotiated industry-based projects and partnership between industry and universities in learning and teaching using authentic assessments have provided mutual benefits for all stakeholders.

KEYWORDS

Project based learning, Authentic assessment, Postgraduate Engineering.

Introduction

Maintenance and Reliability Engineering (MRE) plays a significant role in engineering and infrastructure asset management for capital intensive industries, through balancing cost, risk and performance in risk-based informed decision making for maintaining value of and realising value from assets. Postgraduate programmes in Maintenance and Reliability Engineering build the proficiency and capacity of engineering professionals, often already working in an industry setting. These professionals and their employers are investing in capability building through postgraduate courses which best respond to their current and future needs and improves their professional practice. Industries want to support staff to formally upskill in Maintenance and Reliability Engineering, and participants want to enhance their professional knowledge and gain authentic skills aligned to their industrial priorities, leading to a knowledgeable and skilled workforce which contributes significantly to the success of the organisations they come from. With workplace-based authentic assessments in postgraduate MRE programmes, a mutually beneficial partnership between all stakeholders is established.

This paper presents a case study of the range of benefits created through utilising student-negotiated industry-based MRE projects for assessment within a suite of online postgraduate MRE programmes offered by a Victorian Regional University. The courses have a variety of entry and exit pathways (as illustrated in Figure 1) and have been successfully offered through remote study modes (i.e. correspondence, then online) since the 1980s. These programmes are tailored to engage and motivate a diverse cohort of students in demanding working environments in remote places, often working extended shifts and fly-in-fly-out mode, by adapting their learning within their distinctive working lives and challenges.

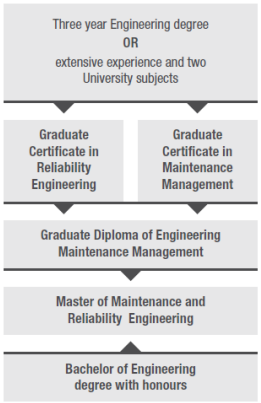

Figure 1: Maintenance and Reliability Engineering (MRE) programmes

The central role of assessment within postgraduate engineering courses is preparing students to apply knowledge in a way that meets contemporary and emerging professional engineering challenges relevant to the contexts of their professional development and needs of their organisations (Thorpe, 2012). Through embedding projects where students resolve authentic problems vital to their industry within the MRE programme curriculum, the assessment allows students to authentically demonstrate professional engineering practices in context (Chandrasekaran et al., 2012) and results in tangible and profitable outcomes for industries.

Approach and Methodology

Project based learning is increasing in undergraduate Engineering studies and is generally designed to give students professional exposure to the industry in which they will work (Chandrasekaran et al., 2012). In reviewing the use of projects within undergraduate Engineering programmes in Australia, Chandrasekaran et al. (2012) found project-based assessment was primarily group-based and collaborative and found within capstone design courses. University-based projects predominate in undergraduate Engineering with only 5 out of 29 universities describing industry or community-based projects in an audit of courses. The

use of student-negotiated industry-based projects within the MRE postgraduate courses is distinctive from what is demonstrated in undergraduate engineering. Postgraduate MRE students work individually, but collaboratively within their industry context, to negotiate a project that addresses an authentic industry concern, producing an outcome assessable against required academic benchmarks whilst meeting the needs of their industry client, their employer.

There is limited literature exploring industry-based projects for postgraduate Engineering in general, and almost none for programmes catering for the complex situation of busy students already working in industry. Asset Management and Maintenance Engineering is a unique context within Engineering. Little has been written on authentic learning exploiting real-life industrial problems and related project-based assessment, getting students to demonstrate the complex informed decision making required for asset management and meeting the expectation of their industry sponsors. An exception is the preliminary work of Thorpe (2012, 2013), auditing the alignment and underlying pedagogical foundation of assessment within postgraduate engineering courses in Asset Management and Reliability Engineering at the University of Southern Queensland. Thorpe (2012) concludes that assessment within postgraduate Engineering must enable students to fulfil the professional demands of their industry stakeholders, not only just now, but also into the future.

Boud & Falchikov (2006) suggest that assessment has a key role in fostering life-long learning and preparing students to be an objective assessor of their own learning. Boud (2000) describes four main purposes of sustainable assessment. Assessment facilitates learning and certifies achievement. It is embedded in professional practice or local context and allows for identification of task limits and standards for good work. It provokes discussion of learning even after the formal learning task is completed. There is a natural alignment between Boud's concept of sustainable assessment, and the common principles of project-based learning observed in Engineering. Project based learning investigates a real-life problem in a context that reflects the students' future career pathways. Students consult with advisors for guidance, discipline knowledge and feedback and are supported appropriately to challenge and extend their skills. The final products of project-based learning are designed for an audience beyond the learning institution, fostering ownership of the problem-solving and responsible citizenship (Chandrasekaran et al., 2012).

In advocating for authentic assessment as an appropriate pedagogical foundation for postgraduate engineering assessment, Thorpe (2012, 2013) argues students should be assessed by performing real-world tasks that demonstrate meaningful application of essential knowledge and skills (Gulikers et al., 2004; Mueller, 2005). Wiggins (1998, in Svinicki, 2004) outlines six characteristics of authentic assessment.

1. The assessment reflects the ways the skills would be applied in the real world.
2. The assessment uses unstructured questions where evaluative judgment needs to be made to justify informed choices.
3. The assessment required application of discipline-based context – in effect, assessment by 'doing'.
4. The assessment is as similar as is possible to the authentic contexts in which the skills are applied.
5. The assessment is designed to allow students to demonstrate a range of skills related to the issue, including evaluative judgment.
6. The assessment process allows for feedback and iterative improvement.

Newmann, Secada and Wehlage (1995, in Svinicki 2004) propose three facets be addressed in authentic assessment; construction of knowledge, disciplined inquiry and value beyond the educational institution. In constructing knowledge, the student must organise information using higher-order skills and evaluate alternatives. Authentic assessment is a form of disciplined inquiry drawing on core discipline knowledge and processes and written communications are created to further enhance understanding. It has intrinsic value beyond the educational context, linking problems to the real world and written to service an external stakeholder,

industries, society and wider communities. Authentic learning involves integrated challenges that require the learner to assemble components into the final product and builds motivation for students if they can choose something meaningful to meet their own interests (Svinicki, 2004). We contend that the student-negotiated industry-based projects with the MRE programmes exemplify the application of authentic assessment within postgraduate engineering in maintenance and reliability engineering domain.

The exploratory research methodology is a case study, a type of empirical inquiry producing a close-up and detailed descriptive analysis of an educational practice situated within its context. We draw on an existing extensive collection of qualitative and quantitative data and artefacts, including formal course documentation and curriculum, the student experience and stakeholder feedback, collated for the purpose of an external review of the MRE programme. Our motivation was to identify the aspects of the use of project-based assessment within the MRE program that were different from the undergraduate programmes as described in Chandrasekaran et al. (2012) and explore and describe these nuances.

How do the projects work within the program?

Students in the MRE postgraduate programmes complete one compulsory capstone project in the Graduate Diploma and Masters Programme and choose one or both from two optional project courses according to their major disciplinary study. The optional course projects demonstrate mastery of a major area of study; either management-focused Maintenance Engineering or technical and analytical focused Reliability Engineering. The assessment weighting of these industry projects varies from 50% for the elective courses to 100% for capstone course. We draw on affordances offered by having a student cohort already working within industry by making these projects student-negotiated and designed to address a particular challenge identified within their distinctive working environment. Students do more than demonstrate their acquired knowledge and skills in an academic sense. They apply their skills in Maintenance and Reliability Engineering in their existing workplace, working with their industry supervisors and employer to address key priority areas in an authentic way.

Student-negotiated authentic problems

A project is a negotiated collaboration between a student and their existing industrial employer, mediated by the academic requirements of the project assessment. Students construct problems in line with continual improvements in reliability, maintenance and asset management. They reflect from their experience, analysing gaps based on industry and international norms and standards, hypothesising potential solutions from research and reviews. They solve complex problems, generating new alternatives, analysing options and taking informed decisions for reducing costs, risks and enhancing performance relevant to their industrial setting. Constructive alignment of these project tasks begins by delineating the desired outcome for the students and the industries (Biggs, 2003). In this programme, the objectives for MRE Projects are expressed in terms of intended learning outcomes (ILOs) for applying knowledge in scoping, analysis and progression of tasks, and reporting, presenting and implementing project findings to their workplace. The student negotiates a task, supported by academic advice, that allows them to demonstrate mastery of these ILOs while provide an outcome of value using continual improvements for their workplace.

Most of the students are already working within industry and therefore we do not encounter many of the usual problems associated with managing industry-based projects. There is no additional administrative work for University in finding and matching students with industry placements with all administrative load managing academic aspects of projects undertaken by academics as part of the usual teaching and assessment processes. This is mainly because the students are already working in industry and their projects are those deemed useful to them for their normal work and to their employers for their business. In terms of liability, students are covered by their existing employers' insurance and occupational health and safety mechanisms. The students not in the industry or studying in between jobs,

undertake research based and publicly available data driven projects. Synchronising industry-based projects with university timelines remains a continual challenge. Therefore, the major capstone project was moved from a full year duration to half year duration in 2018.

The very small number of students who are in-between jobs or not currently working in industry (one to two per semester) due to downturns and/ or pandemic are managed on a case-by-case process. Students identify their desired career trajectory and preferred discipline and scope is matched with an appropriate academic stepping up as technical advisor. Their projects take one of three forms: critiquing existing tools / processes / approaches within that technical area of the discipline in a writing style for a trade magazine; drawing on students' previous industry experience to perform a 'post-mortem' analysis of a less than successful outcome, identifying key points and proposing improvements or updating a historical piece of work to review and reflect on lessons learned and opportunities for improvements using current and new approaches.

Expert domain and support

The MRE courses cover technical disciplines including Terotechnology and life cycle costs, Maintenance management, Quantitative techniques for asset management, Basic quantitative skills for reliability engineering, Understanding reliability, Industrial techniques in maintenance management, Asset management techniques, Machine condition monitoring and fault diagnosis, Risk engineering, Advanced reliability and Reliability applications as well the capstone Maintenance and Reliability Engineering Project. Academics and industry-based expert sessional staff act as academic advisors for these industry-based projects supported by supervisors from the students' industrial setting. Students get support from an academic advisory team who are subject matter experts in discipline areas of maintenance, reliability engineering, condition monitoring, risk engineering and asset management. Industry advisors provide day-to-day support for the progress of these real-life projects and comment on deliverables such as the project proposal, poster presentations, final project report and a Technical article as well as any supporting documentation relevant to the project. Technical discipline expert support of student projects is essential to effective project management. In 2018, a move to management of these projects by general undergraduate engineering academics who were not domain knowledge experts was criticised heavily by students for less than adequate specific support in implementing and developing the technical aspects of their projects. When commercially sensitive information needs to be used during project work, the sponsoring organisation request that their data is protected by a confidentiality agreement signed with the academic advisory team. Effective teamwork between industry supervisor/s, students and the academic advisory team is found vital for the student, industry and university for building ongoing relationships and trust. Many of the industry sponsors / industry supervisors are graduates of the MRE programmes and recognise the benefit to their career and their organisations. They nominate their staff and subordinates as future students in the MRE programmes and use these as part of their performance review and promotions. Many of them also recommend MRE programmes to their professional colleagues to upgrade their knowledge and skills and further enhance their professional capabilities.

Results and Discussion

In a recent external review of the MRE postgraduate programmes, the panel affirmed the University's Maintenance and Reliability Engineering (MRE) programme as being the pre-eminent Australian programme in Reliability Engineering. Due to Postgraduate programmes such as the MRE Programmes, the University is ranked as the top in the ranking of Universities in Australia for Teaching Quality (Postgraduate) in the *Good Universities Guide 2021* ratings, and in Victoria for Skills Development (postgraduate), Student Support (postgraduate), Learner Engagement (postgraduate) and Overall Experience (postgraduate). Table 1 and Figure 2 illustrate the range and scope of industries who provide ongoing support, contributing significantly to increasing student enrolments in the MRE courses. There is an ongoing and

increasing enrolment of students from leading companies covering a significant number of sectors in private, government, defense and consulting industries where asset management is a core engineering priority for maintenance and reliability of capital-intensive assets.

Table 1: Sector of industries supporting MRE Programmes.

Sector Percentage	Sector Percentage
Aerospace 2%	Consulting 10%
Defence 8%	Mining 26%
Manufacturing 24%	Petrochem 9%
Service 8%	Utility 9%
Government 2%	Marine 2%

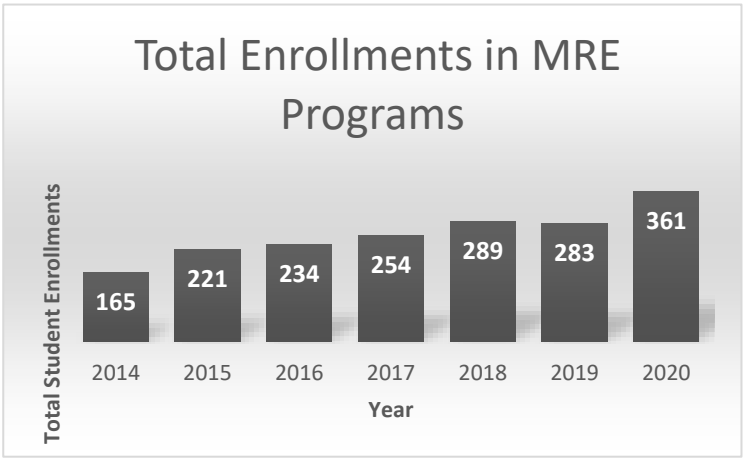

Figure 2: Student enrolment numbers for the MRE programmes

This model of industry-based projects provides benefits to all three stakeholders involved – the student, the industry partner and the university (Johns-Boast & Patch, 2010). Such projects allow academics to develop and strengthen meaningful relationships with industries and understand the real needs that industry face. Students demonstrate the application of their knowledge and skills, for authentic problems in their industrial context, as part of their assessment within their courses. The benefit to industry of those students' upskilling is not delayed until completion of their courses. Project/s address authentic industry problems through potentially novel and best practice theories, concepts and processes learned.

Benefits for students

Authentic problem-based assessments in learning positively contributes to students' motivation. Figure 3 shows the total percentage of students achieving Distinctions or High Distinctions (a score of 70% or more) for student-negotiated industry-based capstone project assessment in the MRE programmes since 2015. At least three-quarters of students perform well due to increased motivation linked to authentic learning using their choice of real-life problem-based projects and assessments, together with support from industry supervisors and academic advisory teams and constructive comments and feedback from peers who are also experienced industry professionals. In 2016, 2017 and 2019, 100% of responding students agreed or strongly agreed that they make best use of the learning experiences in the capstone project course. In 2018 due to changes to project duration and less focussed discipline supported this dropped to 75%. Implementing an industry experienced academic advisory panel resolved this issue.

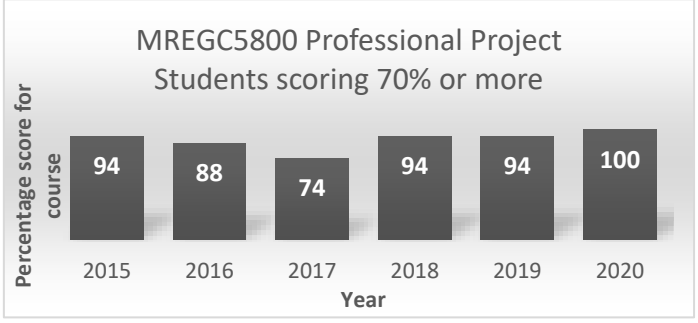

Figure 3: Student performance in the capstone industry-based project course

When asked “What are the most helpful aspects?” of the courses they had undertaken, students highlighted the alignment with “everyday life in our workplaces”.

> Application of the knowledge to the real work situation. Implementation of the project at work and being guided by the course coordinator helps to apply concepts learned in the overall Master courses to practical use.
>
> The highlight for me was the ability to build on fundamental engineering principles where I could challenge my abilities and my contribution in the workplace. There was clear value in the program for me and how I could relate what I was learning in the classroom to on the job learning and the exposure throughout the course to understand what other industries are doing and what I could do differently.
>
> The look and go see and touch verification go a long way to connect the dots between classroom learning and in field application.
>
> My project itself is related to my workplace and it would benefit the company after completion/implementation

Value to Industries

Students present findings from their projects to their industry supervisor, managers and colleagues. They often are asked to brief their company boards on opportunities for improvements, lessons learned and on the rollout of pilot projects within entire organisation for reducing costs, risks and enhancing performance. Past students share instances how their industry value the projects taken by their employees during their postgraduate studies in MRE programmes, for example, being highlighted in industry specific publications.

> This is excellent news as it shows the value to the business from my studies in Maintenance and Reliability Engineering!

Skills gained by students change the organisational culture, providing benefits to their industries as demonstrated by student.

> There was an instance where I was asked to do a renewal planning study on a 2km 500mm pipeline. Significant savings were made, as I was able to apply reliability concepts and techniques to determine sections requiring renewal and avoided replacement of pipeline.

These programmes were recently reviewed by panel members comprising of senior academics from reputed Universities related to this field, senior academics from other faculties within University, industry and professional body representatives. Past and present students and maintenance and reliability engineering staff briefed the review panel. The MRE programmes were affirmed for the value they place on communication and consultation with the various stakeholder groups, including the Industry Advisory Group. The panel commended the focus in the MRE on the project, in that it embeds a significant work-integrated learning component. Authentic assessment principles require that assessment is designed for an audience beyond the learning institution, industries, society and the wider communities. These projects are communicated not only within the University, but also at seminars sponsored by Professional bodies and at refereed international conference. Industry bodies support student’s work in their seminars, workshops and conferences. These include the Asset Management Council (Technical society of Engineers Australia) with MRE students presenting their work as oral presentations and in poster sessions of the AMPEAK conference and the Research and Industry Day (RAID) where academia and students meet industry to share the latest research and project findings in maintenance, reliability and asset management. Projects communication also occurs through formal academic channels; via journals and refereed international conferences including organised by IEEE. Students have presented their projects in international conferences in Australia, India, Macao, Bangkok, Singapore and many other places. Some of the students have continued onto PhD studies related to their issues in their industry after completing the MRE programmes.

Conclusion and Recommendations

This paper described how students under time-pressured working conditions can value add to their capability building and industries through solving workplace-based problems responding to their current and future needs. Students identify authentic problems in their workplace and take responsibility for their authentic industry-based problem-solving related to their field of study. Students apply their knowledge and skills to their workplace, reducing costs and risks and enhancing performance, including safety, through improved maintenance and reliability engineering and better asset management. Students are supported in their projects by industry supervisors and experienced University academic advisory team with industry experience. Capability building through workplace-based learning in maintenance and reliability engineering (MRE) postgraduate programmes adds value to the students' careers, benefits their employers for finding cost-effective solutions for their problems and the University for providing authentic learning experience. We advocate that such partnerships in learning and teaching between industry and universities have mutual benefits for all involved and has the potential to value add for all professional postgraduate level programmes if applied properly.

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