Quality Outcomes of Learning and Teaching in Final Year Engineering Projects

M.G. Rasul[a], J. Lawson[b], R. Jarman[b], R. Hadgraft[b], P. Howard[a], F. Martin[a], C. Kestell[c], F. Anwar[d], A. Stojcevski[e], A. Henderson[f] and A. Kootsooks[g]
Central Queensland University[a], University of Technology Sydney[b], The University of Adelaide[c], Curtin University[d], University of Tasmania[f], RMIT University[g]
Corresponding Author Email: m.rasul@cqu.edu.au

CONTEXT
The final year engineering project (FYEP) is the culminating learning and teaching experience of engineering programs to demonstrate that students are capable of personally conducting and managing an engineering project at a standard expected of graduates. The introduction of the Australian Qualifications Framework (AQF) required new thinking about the ways in which FYEPs enable students to develop and demonstrate level 8 outcomes (AQF8), including those related to autonomous learning and research. These requirements are also required from international Engineering accreditation agreements such as the Washington Accord from the International Engineering Alliance. An Office for Learning and Teaching (OLT) project on FYEP brought together a team of academics from seven universities across Australia, successfully producing real outcomes for the partner institutions as well as Australian and New Zealand universities more widely.

PURPOSE
The purpose of this paper is to present outcomes of the successfully completed OLT project on assessing final year engineering projects to ensure learning and teaching standards and quality outcomes are achieved from FYEPs. Furthermore, the paper aims to disseminate the project outcomes since completion in January 2015

APPROACH
The project's most significant achievements are threefold, namely (i) production of guidelines for curriculum, supervision and assessment together with exemplar practices; (ii) meaningful dissemination workshops presented at a couple of earlier AAEE conferences and in different states and territories of Australia and New Zealand; and (iii) scholarly outputs. These will be elaborated in the paper. More specifically, the ways in which curriculum designers, project supervisors and subject coordinators have worked together to address AQF8 requirements within FYEPs using the guidelines will be addressed. Some gaps have emerged that suggest scope for further work.

RESULTS
The project provided a mapping and review of existing learning and teaching practices followed by the development and promotion of guidelines to assist engineering disciplines to improve FYEP learning and teaching methods and assessment. Lessons learned and recommendations for achieving quality outcomes from FYEPs will be discussed.

CONCLUSIONS
The outputs from this project are expected to continue to assist FYEPs coordinators in meeting curriculum, supervision and assessment requirements stipulated by AQF level 8.

KEYWORDS
Australian Qualifications Framework (AQF), Final year engineering project (FYEP), capstone, research, graduate outcomes, assessment.

Introduction

Final year engineering projects (FYEPs) are the culminating learning and teaching experience of engineering programs to demonstrate that students are capable of personally conducting and managing an engineering project at a standard expected of graduates. The introduction of the Australian Qualifications Framework (AQF) required new thinking about the ways in which FYEPs enable students to develop and demonstrate level 8 outcomes (AQF8), including those related to autonomous learning and research. These requirements are also required from international engineering accreditation agreements such as the Washington Accord from the International Engineering Alliance. AQF presents new challenges to undergraduate engineering degrees and in particular, how honours degrees are awarded. The compliance of AQF level 8 now means that all students enrolled in four year embedded honours degrees will graduate with honours. FYEPs should enable students to demonstrate program exit outcomes (Lawson, Hadgraft, and Rasul, 2014). Inconsistent practices in managing FYEPs and new levels of compliance created a space in which this study is based.

FYEPs provide students, project supervisors and assessors, professional accreditation bodies and industry project sponsors with many challenges. They require students to conduct and manage engineering projects as demonstrable skills upon entry to the engineering profession (Lawson, Hadgraft and Rasul, 2014). There is a considerable variation in how they are prepared for the skills and experience and how they are supervised and assessed (Rasul, et al., 2009). As a culminating learning experience, the FYEP is typically the last checkpoint before students graduate into the engineering profession. Graduates are expected to use the project to demonstrate that they can apply the knowledge, skills and attributes developed during their study at a professional standard (Lawson et al, 2014).

FYEPs enable achievement of a range of technical, professional and personal skills. Sohel et al. (2011) point to the achievement of generic attributes such as communication and interpersonal skills. Similarly, Schmid, Meaker and Thomas (2012) point to teamwork and other professional attributes enabled by projects. They add that the networking opportunity with industry presentations enhances employability which can be facilitated through organising graduating engineers conferences or project showcases The authenticity of project work is also seen as a means for preparing students for the world of work (Hogan, 2012; McKenzie et al., 2004; Schmid, Meaker and Thomas, 2012). This study recognised that there are both nationally common and locally unique pressures facing universities as they develop curriculum, assessment and supervision practices related to FYEPs. Figure 1 shows a schematic representation of the FYEP guidelines in local and national contexts. This suggests a need for the explicit and appropriate teaching and support for FYEPs students throughout their program of study.

Universities offering engineering degrees are subject to both internal and external accreditation requirements. “Internal and external accreditations are not always competing demands but might manifest as variations in the development and delivery of project subjects across institutions” (Lawson, Hadgraft and Rasul, 2014). The three discrete sets of guidelines for curriculum, supervision and assessment developed in this study are interconnected and best viewed as a whole as shown in Figure 1. In the figure, the outer circle of the diagram represents the common broader university contexts of external accreditation and regulation that impact on curriculum, supervision and assessment decision making. The middle circle captures those local contextual influences which acknowledge the uniqueness of each university’s FYEP courses.

This research project was a partnership between seven universities – Central Queensland University (lead), University of Technology Sydney, University of Adelaide, Curtin University,

University of Tasmania, Deakin and RMIT. They were successful in securing an Australian Government Office for Learning and Teaching (OLT) grant in 2012.

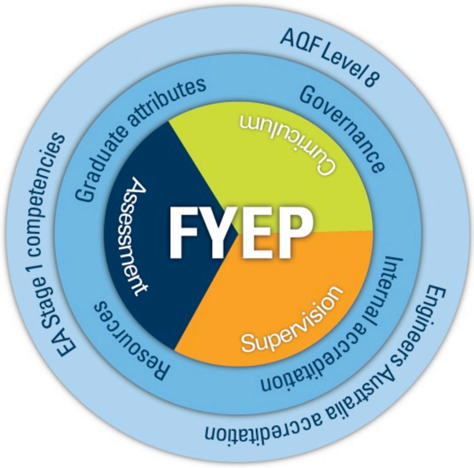

Figure 1: Schematic representation of the FYEP guidelines in local and national contexts

The purpose of the project was to develop good practice guidelines to assist engineering educators to improve FYEP practice and assessment including supervision and curriculum development and to ensure that they meet AQF8 outcomes. The project was completed in 2015. The project targeted to develop guidelines for the three areas at the centre of Figure 1, i.e. curriculum, assessment and supervision. This paper has been produced as a dissemination activity of project outcomes.

Methodology

Methodology included a mapping and review of existing assessment and supervision practices at the Australian and New Zealand Universities, then the development and promotion of guidelines to assist engineering educators and disciplines to improve FYEP delivery, supervision, curriculum design and assessment. Data from phase one included the collection of documentation from 16 universities from all states and territories of Australia. Table 1 shows the details of data collection. Documentation included course profiles, student guidelines, marking rubrics, schedules, and teaching resources and exceeded 100 documents. In addition, semi-structured interviews were conducted with 16 individual coordinators of FYEPs courses across a range of ten Australian Universities. The wider project team members approached coordinators from their own institutions and institutions in the state where they live and those with whom they were connected. The research officer conducted interviews. In the interview the participants were asked to explain their documentation and their practices, and in particular to articulate the strengths and challenges of assessment and supervision. Interviewees were prompted with questions such as what are the challenges they face with their FYEPs course, what are the strengths of the way they do things, how are supervisors involved in the assessment and why do they do things this way?

Table 1: Data collection

Data	
Documents (profiles, rubrics, guides, teaching resources)	n>100 Universities providing this data n=16
Semi-structured interviews with coordinators	n=16 Universities providing this data n=10
Feedback from national workshops	Workshops n=8 Total participants n=102 Universities participating n=26

The project team wanted to collect data on current practices of FYEPs from as many universities as possible throughout Australia and New Zealand. However, only a little more than 100 documents were received for analysis from 16 Australian universities. It was really difficult to get hold of institutional champions and respective coordinators/head of programs/associate deans. Another challenge was maintaining team momentum when not together. The most significant progress was made when the team was able to work together in a face to face environment over a sustained period of days. Having people contribute outside of these times was a challenge resulting in greater responsibility for deliverables falling to fewer team members.

Table 2: Thematic codes in data analysis

Deductive Codes	Inductive Codes
Students Supervising academics Industry partners Project assessment Curriculum Project selection Standards Staff development needs	Application of knowledge Purpose Authenticity Research skills Challenges Definitions Strengths Preparation for enrolment Professional skills Technical knowledge Project skills Reflective practice Project type

This data was thematically coded as shown in Table 2. Using the data from phase one, the project team developed draft guidelines in each of the areas of curriculum, supervision and assessment. These guidelines were then presented at seven workshops throughout Australia and feedback from participants sought, recorded and analysed. Using this feedback a revised set of guidelines was presented and evaluated at a final workshop at the 2015 AAEE conference. The revised guidelines were also distributed for comment to all previous participants. This second phase drew feedback from over 100 people from 26 universities. The final set of guidelines responded to the final feedback set. This paper presents some of the findings from the project.

Findings and Discussion

The data was analysed and broadly clustered into three main areas, namely curriculum design, assessment practices and supervision responsibility. These are briefly described below.

Curriculum Design

There was no clear idea in all universities of the ways students are enabled to suitably select and prepare project work, although literature points to the need for preparedness for project work in the years preceding the FYEP (Hogan, 2012; Nepal and Jenkins, 2011; Hassan et al, 2013). In our data and interviews, it was identified that the expectation was that the FYEPs are a natural culmination of work previously undertaken, but there was no clear articulation of where students might have learnt about research. It is important for curriculum designers to see where they expect AQF8 to be taught and demonstrated in their courses/programs as well as where within the FYEPs.

Preparation for enrolment and selection of the project and its type is also an important area which should be taken into consideration. There were concerns expressed about logistical aspects of sourcing, allocating and administrating projects. Our data showed that there were a variety of ways that these tasks are undertaken. For example, in some universities there was an extensive pre-enrolment process where students chose topics suggested by their supervisors. However, other universities invest a significant amount of time in preparation for FYEPs subjects where subject coordinators assume the primary responsibility for the organisation of projects, supervisors and overseeing how projects are allocated to students. Nepal and Jenkins (2011) suggest that student involvement in project scoping and direction is important, and at least one of the universities in our data set had moved towards reducing prescriptive topics in favour of negotiated ones.

There were lots of concerns at the institutional level about what constitutes an appropriate project. Project types across our samples included industry based, design, experimental, multidisciplinary, student initiated, interdisciplinary and supervisor initiated research projects. An industry project is an authentic engineering experience that highlights the value of both industry and multidisciplinary projects (Hogan, 2012; Bramhall et al., 2011). Projects could be undertaken individually or in groups. Workshop participants were in agreement that the type of project and whether it is individual or team based is less important than the degree to which the professional judgement of academics (curriculum designers, advisors, and assessors) focused on overarching AQF8 considerations. This means that, with appropriate curriculum design, quality assessment and supervision, it is potentially possible for any project to enable students to achieve and demonstrate AQF8 outcomes.

Assessment Practice

Although assessment practices vary across universities, typical assessment submissions included project plans and proposals, literature reviews and final reports or thesis documents. Assessment of FYEPs has pointed to the importance of having well defined projects, good communication with students as to what is expected, and clear guidelines for assessment by staff as an assessment process should be coherent and consistent in the light of good practices. A pilot investigation by Rasul et al*.,* (2010) indicated that assessment practices must have some common features such as self-assessment, assessment moderation, assessment criteria, and an assessment component matrix.

Our data showed that one university had recently introduced a journal style paper together with supporting documentation as the final submission. In some other assessments, students were expected to undertake presentations, conference style seminars, some of which were large public events such as project expos, showcases or exhibitions.

It was found that the weighting for the project/thesis varied from 40% to 100% of total available marks, and the number of assessment tasks varied from three to seven. Although the project subject duration is usually one year, and it is divided into planning project and implementation project and culminates in a final submission, there is often close attention to formative assessment. Indeed, improved student engagement and enhanced student interest and learning are possible with strong formative assessment (Gardner and Willey, 2012; Jiao and Brown, 2012). Some project subjects also included peer and self-assessment.

The marking criteria against which students are assessed are broadly technical (engineering knowledge and skills) and professional (application, communication, teamwork). Some coordinators articulated the challenges posed by the conflation of these criteria, suggesting that seeing the product in isolation to the work conducted or the process undertaken is problematic. Some FYEPs include criteria like diligence, which is arguably effort, whereas others are more tightly focused on product only. Whilst criteria sheets or marking rubrics were widely supported and a sample of one is provided in our exemplar practices document, it should be noted that the use of pre-set criteria is problematic and can result in anomalies (Sadler, 2009).

The interview data revealed considerable variation in marking and moderation practices and some coordinators expressed deep concern about supervisor bias and variation. There was also some contention about how to and whether to assess process as well as product. These sub-themes were seen as important but beyond the scope of the guidelines because they fell within the local context. However, the data in this area was extensive and is more fully explored elsewhere (Lawson et al., 2014).

Supervision Responsibility

None of the participating universities provided systematic support for supervisors beyond documentation. In most instances, supervisors were given the same materials (outlines, handbooks, etc.) as the students. In some cases, a separate supervisor's handbook was provided and in others, those academics new to supervision would be given fewer projects to supervise or be placed in co-supervision arrangements. There was no consensus on matters of how to best supervise (with groups of students or individuals) or how regularly. At one university, the social moderation practices (where staff met to discuss and compare marking both at planning and implementation stages of the project) presented an opportunity for supervision guidance and support.

Issues around quality supervision were related to assessment (knowledge of the student, bias, general inflationary marking) and there was some concern about variation in supervision style. Some of this however is related to systemic and widespread problems rather than an issue specific to the FYEPs. Finally, whilst most supervisors worked within their area of technical expertise, there was recognition of the value of supervising multidisciplinary projects outside of one's own area of technical expertise.

Outcomes

There was considerable language variation in assessment practices of FYEPs. Some documents used simple descriptions such as, 'design', 'implement', 'perform', 'prepare" as shown in Figure 2. Others offered qualifications: 'produce *high quality*' 'apply *original* thinking", etc.' In addition, some coordinators were able to articulate the types of outcomes and benefits students were expected to achieve from their FYEPs. These outcomes included independent and advanced thinking of methods of problem solving, and synthesising different areas of knowledge and integration of professional and technical engineering skills. These outcomes are consistent with the literature that points to the variety of outcomes enabled by FYEPs (Hogan, 2012; McKenzie et al., 2004; Schmid, Meaker and Thomas, 2012; Sohel et al., 2011).

Figure 2: Language variation in assessment practices of FYEPs

It was revealed from the interviews that the familiarity with AQF8 varied from some coordinators not being aware of it and having given no consideration, to some having given deep consideration and embedding AQF8 language into project outcomes. Most coordinators considered AQF8 to be a compliance and documentation issue rather than requiring a fundamental shift in practices. For many coordinators and educators the challenges were: What is Honours? Who is eligible and when? How is post-graduate study impacted by AQF8?

Note that the following apply regardless of the discipline and/or the project type. Research in engineering at AQF8 is (Rasul *et. al.*, 2015):

- Understanding the local context.
- Defining and identifying the open ended problem and its limitations/constraints relevant to the practice of engineering.
- Mapping the state of the art globally or broadly: asking the right questions, reviewing literature and current practices using quantitative and qualitative sources.
- Identifying and articulating gaps.
- Determining appropriate methodology and what constitutes evidence.
- Conducting systematic investigation, distillation and application to the engineering problem.
- Undertaking experimentation, design, modelling, problem solving, and data collection.
- Analysing and synthesising with critical judgement offering unique interpretation.
- Creating, innovating, publishing – communicating a contribution of knowledge or good practice or delivering novel outcomes in the local context.
- Autonomous learning and reflecting.

To meet AQF 8, all types of projects, such as design, research, experimental etc., should develop similar skills in definition (i.e. what is the problem?), literature and practice review (how this problem has been solved or addressed in the past), identification of feasible solutions, testing and investigating (in the laboratory or through model simulations) and the production of recommendations and local knowledge contributions (Lawson, Hadgraft and Jarman, 2014). The project report or thesis itself should be seen not as evidence of what the student has learned, but as a vehicle used by the student (with the supervisor as occasional passenger) to show how professional capabilities developed. This is consistent with the idea of Jenkins (2012) that students' critical reflection of their developing professional competencies is an integral part of quality assessment.

Conclusions and Recommendations

FYEPs are an ideal place for final demonstration of AQF8 outcomes because they are typically located at the end of the study program and act as an indicator of readiness for graduation into the profession. The outcomes of the study are a guide for use by final year engineering project subject coordinators whose primary responsibilities may include both operational and governance matters.

This project has made significant contributions to the field of engineering education and the learning and teaching of FYEPs. Specifically, it has presented outcomes related to curriculum, supervision and assessment of FYEPs (Rasul el al, 2015). This study has addressed the ways in which curriculum designers and project coordinators can work to address AQF8 requirements within FYEP subjects. The outcomes are useful for supervisors (or advisors), curriculum writers and those academics involved in assessment. This study identified the points of difference between AQF7 and AQF8 outcomes.

The study facilitated high quality workshops across Australia and New Zealand. These workshops had immediate benefit to the project itself by providing quality feedback on the assessment aspects of FYEPs. The workshops provided a forum for deep discussion around existing FYEP practices as well as understanding AQF8 and the research requirements of undergraduate engineering degrees. Of particular value was the opportunity for participants to share practice. The study has made scholarly contributions to the field of engineering education. Recommendations pertinent to the quality outcomes of learning and teaching of FYEPs are:

- Universities and faculties must recognise the increased workload for supervisors and coordinators of project courses. Recognition of workload is seen as adequate resourcing and support of staff.
- Marking and moderation practices in FYEPs must ensure quality and mitigate inequity. Calibration of markers should precede marking to ensure markers are assessing to a shared understanding.
- Research into how universities are ensuring programs meet AQF8 should be undertaken.
- Research into student perspectives and achievements in FYEPs and AQF should be considered.

References

Bramhall, M., Short, C., Hoque, A., Blohm, J., Campbell, L. & Young, A. (2011). *Multi-disciplinary and cross year mentoring: the development of an eco-house and a sustainable marriage.* Proceedings of the 2011 Australasian Association of Engineering Education (AAEE) Conference, Fremantle, Western Australia.

Gardner, A. & Willey, K. (2012). *Student participation in and perceptions of regular formative assessment activities.* Proceedings of the 2012 AAEE Conference, Melbourne, Victoria.

Hassan, N.M.S., Rasul, M.G., Lawson, J., Howard, P., Martin, F. & Nouwens, F. (2013). *Development and assessment of the final year engineering projects – a review.* Proceedings of the 24th AAEE Conference, Gold Coast, Australia.

Hogan, D. (2012). *Uncanned learning through an industry based FYEPs – food for thought.* Proceedings of the 2012 AAEE Conference, Melbourne, Victoria.

Howard, P., Kestell, C. & Rasul, M. G. (2014). *Guidelines for curriculum development of final year engineering projects to support achievement of AQF8 outcomes.* Paper presented at the 2014 AAEE Conference, 8-10 December, Wellington, New Zealand.

Jarman, R., Henderson, A., Kootsookos, A., Anwar, F., & Lawson, J. (2014). *Assessment of final year engineering projects – an AQF8 perspective.* Paper presented at the 2014 AAEE Conference, 8-10 December, Wellington, New Zealand.

Jiao, H. & Brown, N. (2012). *Providing the right feedback to the right students: applying an innovative e-assessment system in engineering education.* Proceedings of the 2012 AAEE Conference, Melbourne, Victoria.

Lawson, J., Hadgraft, R. & Jarman, R. (2014). *Contextualising research in AQF8 for engineering education.* Paper presented at the 2014 AAEE Conference, 8-10 December, Wellington, New Zealand.

Lawson, J., Hadgraft, R. & Rasul, M. G. (2014). *Final Year Engineering Projects: Improving assessment, curriculum and supervision to meet AQF8 outcomes.* Paper presented at the 2014 AAEE Conference, 8-10 December, Wellington, New Zealand.

Lawson, J., Rasul, M. G., Howard, P. & Martin F. (2014). *Getting it right: Assessment tasks and marking for capstone project courses.* Paper presented at Capstone Design Conference, 2-4 June, Columbus, Ohio, USA.

Martin, F., Hadgraft, R., Stojcevski, A., & Lawson, J. (2014). *Supporting students through the final year engineering project experience to achieve AQF8 outcomes.* Paper presented at the 2014 AAEE Conference, 8-10 December, Wellington, New Zealand.

McKenzie, L.J., Trevisan, M.S., Davis, D.C. & Beyerlein, S.W. (2004). *Capstone design courses and assessment: A national study.* Proceedings of the 2004 American Society of Engineering Education and Annual Conference and Exposition.

Nepal, K.P. & Jenkins, G. A. (2011). *Blended project-based learning and traditional lecture-tutorial-based approaches in engineering design courses.* Proceedings of the 2011 AAEE Conference, Freemantle, Western Australia.

Nouwens, F., Rasul, M G., Lawson, J., Howard, P., Martin, F., & Jarman, R. (2013). *Educational purposes of final year engineering projects and their assessment*. Proceedings of the 24th AAEE Conference, Gold Coast, Australia.

Rasul, M. G., Nouwens, F., Martin, F., & Greensill, C. (2009). Benchmarking in assessment of final year engineering projects: Guidelines for students and supervisors. CQUniversity Internal report.

Rasul, M.G., Lawson, J., Howard, P., Martin, F. & Hadgraft, R. (2015), *Learning and teaching approaches and methodologies of capstone final year engineering projects*, International Journal of Engineering Education, 31 (6B), 1727-1735.
Sadler, R. (2009). Indeterminacy in the use of preset criteria for assessment and grading. *Assessment and Evaluation in Higher Education*, 34 (2), 159-179.
Schmid, R. Meaker, N. & Thomas, D. (2012). *Engaging engineering students with the wider community: The Endeavour program at the University of Melbourne.* Proceedings of the 2012 AAEE Conference, Melbourne, Victoria.
Sohel, F.A., Thorne, C., Jegathesan, J., Sergeev, E. & Bennamoun, M. (2011). *Interdisciplinary learning for final year engineering projects: case studies.* Proceedings of the 2011 AAEE Conference, Fremantle, Western Australia.

Acknowledgements

The project team would like to express their gratitude to the Australian Government Office for Learning and Teaching for providing funding for this project.