Development and assessment of the final year Engineering projects - a review

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Structured abstract

BACKGROUND
Accreditation requirements for undergraduate programs for professional engineers require final year students to complete capstone projects, but currently there is no gauge or guarantee of consistency. Practices differ greatly between universities and little work has been initiated that seeks to identify good practice. The literature shows that there are no definite or guaranteed assessment criteria for assessing the Final Year Engineering Projects (FYEPs) highlighting the need for the development of guidelines for the FYEPs and assessment criteria.

PURPOSE
This paper presents a review on the FYEPs learning and teaching methodologies as employed across several universities at national and international levels and is part of a wider Office for Learning and Teaching (OLT) commissioned study - Assessing FYEPs: Ensuring Learning and Teaching Standards and Australian Qualification Framework (AQF8) Outcomes. This study is intended to promote quality practice amongst supervisors and academics involved in teaching and facilitating FYEPs in Australian universities. This preliminary literature review comprises one part of this wider study.

DESIGN/METHOD
This paper reviews national and international literature into FYEPs, summarises the current practices at different universities and outlines the importance of developing guidelines for development and assessment of FYEPs. A number of studies related to FYEPs reveal that there are both common issues and points of difference across institutions, highlighting the need for greater consistency and transparency in this field. This review seeks to promote national awareness of the need for consistency and standards in assessment and evaluation in engineering education. Reliable and valid assessment practices, and learning and teaching methodologies of FYEPs, should be implemented for the integrity of the qualifications offered at universities in Australia.

RESULTS
The literature supports the need for the wider study that seeks to provide shared understandings of requirements of good projects and standards of project work that final year students are expected to demonstrate in their assessment. The effective use of FYEPs would be the vehicle for assessing student ability across through expected learning outcomes.

CONCLUSIONS
Insight into the purpose of development and assessment of the undergraduate FYEPs is presented in this paper. Extensive literature has been reviewed at national and international levels. The paper outlines a variety of information regarding the final year project's structure and key elements of its assessment criteria. The assessment criteria reviewed in this study would help increase the general quality of the process of assessing FYEPs. The wider study is positioned to increase awareness of the standards agenda and promotion of dialogue, collaboration and scholarship across institutions and industry for refining and improving the standards of professional engineering education.

KEYWORDS
Assessment, Development, Final Year Engineering Projects

Introduction

Final Year Engineering Projects (FYEPs) represent the culmination of students' collective learning experiences during their undergraduate education and training. FYEP is an opportunity for students to apply technical engineering knowledge and skills acquired during their studies. It should be able to show students' capability of applying the technical knowledge and project management skills in engineering. The quality of learning and teaching is a focal point in the educational institutions in engineering programs for preparing undergraduate students in their professional engineering practice. One aspect of engineering education receiving attention is the capstone engineering project as the graduating engineers can apply their professional skills to solve the real world challenging problems (Todd et al., 1995).

A number of international studies reveal that the FYEP or capstone course is designed as an integrated, culminating experience for students with significant assessment purposes (Jawitz, et al., 2002; Valderrama, et al., 2009; Vernon, 2007). Jawitz et al., (2002) for example, noted that in the Built Environment program at the University of Cape Town, South Africa, the final year project was used as an indicator of the quality of the program overall. Similarly, in another study in Spain, Valderrama et al., (2009) reported that the engineering curriculum included the development and assessment of a Final Year Engineering Project (FYEP) that represented the culmination of the student learning process; where students put into use their previously learned engineering and personal skills. Valderrama et al., (2009) went on to investigate the complexity of the assessment process noting its influence on the decisions regarding a students' readiness to graduate. So projects are seen as vehicles by which students are given the opportunity to apply and demonstrate what they have learnt to this point in their degree, particularly in relation to engineering methodologies, but also to enable critical and reflective thinking and the deployment of professional skills.

It is common for universities in New Zealand to establish links with local industry in order to encourage professional development of students. Particularly, final year projects have traditionally focussed on students utilising techniques learned throughout their course to produce real outcomes for industry sponsors within the Auckland University of Technology (AUT) (Beckerleg & Collins, 2007). These capstone projects are seen as an important opportunity for students to interface with industry, providing them not only with vital professional experience but also exposure to prospective employers (Littlefair & Gossman, 2008). On the other hand, students are prepared for their final year undertaking throughout their whole engineering program. Project work is introduced in Year Two of the program, and is continued in Year Three with a semester length project and in Year Four with a yearlong project at AUT (Beckerleg & Collins, 2007). It is recommended that preparing students adequately to undertake their final year of study, and capstone assessment, is essential for their success. Therefore, there are a number of different strategies employed in universities offering Engineering courses which aim to achieve this (Littlefair & Gossman, 2008).

Todd et al. (1995) studied many engineering programs which were using capstone-type courses to prepare students for engineering practice, and a significant number of institutions engaged industrial clients to sponsor capstone projects. In addition, a number of Schools were using undergraduate team based projects in their programs and a few were using interdepartmental undergraduate teams from different disciplines. The Todd et al. (1995) study is longstanding, comprehensive and highlighted the early commitment to the concept of a rigorous FYEP in engineering programs. Comparable attention however, was not given to the assessment practices associated with FYEP.

FYEPs are beneficial for graduating students as they are presented widely across Engineering Faculties due to the fact that:

> *the process of solving problems is one that demands full use of existing knowledge applied to solve a particular problem and which has the inherent characteristic of advancing or adding to the existing knowledge in the quest for a solution (McLernon & Hughes, 2006).*

FYEPs may be presented as either a group or on an individual basis. Several universities involved in the FYEPs, as well as many associated with Australasian Engineering Education (AAEE) are beginning to undertake FYEPs in a group setting. By grouping less experienced undergraduate students with postgraduate students in a non-hierarchical situation, it is also possible to both minimise project scoping and provide preparation and support for final year students by exposing them to an established research or design process. Additional support in the form of further technical training may also be provided (Beckerleg & Collins, 2007).

At the University of South Australia, group FYEPs are presented in the format of an entire design process undertaken by the entire group working as a design consultancy. This group method is similar in principle to that of the Australian Maritime College, where real industrial design problems are undertaken by teams of three or four students, grouped by lecturers without student input (Thomas et al., 2006). The interface with industry ensures a good grounding in professional engineering abilities. In the case of FYEPs conducted at the University of South Australia, students are encouraged to assess team members' performance within the group with respect to a number of key identifiers of work quality. Moreover, the accepted aim of a Bachelor of Engineering course is to produce graduates who are ready to use learned skills and attributes to succeed in the professional arena. It follows that interfacing with industry during the course is beneficial to the engineering student (Thomas et al., 2006).

However, in assessing FYEPs, the group dynamic supported in some universities may lead to subjectivity when assigning individual grades to students. Due to the necessity of dividing labour amongst team members, it may be the case that the work produced by each team member will address quite different outcomes from one another. It is necessary to also consider the collective outcomes of the FYEP as a whole, as the success of an engineering project is of great importance within an industrial context. Therefore it is necessary to conduct individual assessment of members of an FYEP group with consideration of both external factors and individual contribution (Mills, 2007). Furthermore, the School of Mechanical and Manufacturing Engineering within the Queen's University, Belfast adapts Conceive Design Implement Operate (CDIO) principles throughout the program which include an introductory design-build course, as well as a follow-up project of more complex technical requirements (Armstrong et al., 2005). Voorthess (2001) noted that assessment has to accommodate mandatory shifts such as outcome-based approaches to come into line with education and accreditation processes. However, assessment through a unique final milestone clashes directly with the formative purpose of assessment and can become high stakes and subjective.

Industry participants surveyed by the Australian Maritime College generally indicated that the university's Ocean Vehicle Design capstone course provided them a useful tool to evaluate the standard of work submitted by the students. The comment was also made that students benefit from interaction with industrial clients by gaining an insight into the naval architecture industry (Thomas et al., 2006).

Industry involvement in Central Queensland University's co-op program is longstanding, and provides Engineering students in their final year with the opportunity to undertake research and design projects based in industry. The significant influence of industry provides the benefits of professional experience and high employability. Some previous studies (Rasul et al., 2009, 2010, and 2012) have indicated a number of common issues within FYEPs. In particular, the following have been identified:

- There are generally inadequate guidelines for students to choose appropriate projects with sufficient scope to demonstrate development and assessment of graduate outcomes.
- There is an apparent need to develop strategies to improve consistency of expectations of students, project supervisors, moderators and industry partners.
- Conflict exists between intellectual property issues and assessment requirements (industry partners).

- There are variations in resourcing and workload allocations for supervisors and funding support for students' projects.
- There is a lack of clarity about supervision and assessment requirements among teaching staff within and across institutions.
- Conflict exists between supervisor assessment and moderation assessment.

Academic supervisors and others involved in teaching and facilitating FYEPs have not yet managed to develop productive dialogue relating to assessment and learning and teaching methodologies within the universities at national and international level. There is some consensus about the place and purpose of a FYEP as a means for students to demonstrate technical and professional knowledge and skills, and its place as an integrated and authentic learning opportunity that encourages independent, self-directed and higher order learning. However, there remains a need for further collaboration around consolidating the paradigm of capstone projects and the ways in which they might be assessed. The need for this consolidation is highlighted by Rasul et al., (2012) who note the ill-defined paradigm of capstone engineering projects means that students are often uncertain of their academic expectations, leading to confusion and miscommunication.

The literature shows a broad range of practices and a lack of consensus about what constitutes a legitimate assessment task, what assessment criteria are appropriate or what level of formative assessment and support is legitimate (Ma & Zhou, 2000; Armstrong et al., 2005; Oehlers, 2006; Blicblau, 2006; Seidel et al., 2006; Kuisma, 2007; Mills, 2007; Beckerleg & Collins, 2007; Rasul et al., 2009; Cochrane *et al.,* 2009; Valderrama et al., 2009; Rasul et al., 2010; Ku and Goh, 2010; Fraile et al., 2010**;** Rasul et al., 2012; Dong, 2012). Much of the variation appears to result from insufficient preparation of and academic isolation of academic supervisors, a lack of general discussion about project expectations among faculty and lack of agreement about issues of educational task design and assessment.

This paper summarizes the findings from different studies and attempts to convey a portrait of the role and nature of the development and assessment in capstone design courses.

Development of FYEPs

Significance of the FYEPs

The literature shows that undergraduate students in engineering need to carry out a FYEP as part of the final year, and in partial fulfilment of their graduation requirements. The FYEP is a significant part of work that will involve with the creative activity and original thinking. A good engineering project starts with the formulation of a problem, suggests alternative solutions, and then implements one of them. In general, students can achieve some of the core features through completing FYEPs (Rasul et al., 2010, 2012; AUB, 2010) which are:

- Students are allowed to demonstrate a wide range of the skills learned at the FYEP during their course of study.
- Students are often asked to deliver a product that has passed through the design, analysis, testing, and evaluation stages.
- Students are encouraged to do multidisciplinary research through the integration of material learned in a number of courses.
- Students are allowed to develop problem solving, analysis, synthesis and evaluation skills.
- Students are encouraged to work as a team and to collaborate with the academics and other researcher and students.
- Students can improve their communication skills through the generation of the professional reports (thesis) and oral and poster professional poster presentations at the end of the Term.

Quality Assurance of the FYEP

In recent years, particularly, FYEPs require an extensive quality assurance process at every educational institution and this must be assessed by an appropriate accreditation agency. In the case of a professional qualification, quality assurance procedures have traditionally been conducted by a professional body such as the Engineering Council of South Africa (ECSA) in South Africa. ECSA recently employed an outcomes-based accreditation process in association with several international engineering accreditation agencies in a move to standardise procedures across national boundaries (Jawitz et al., 2002). Engineers Australia, a professional body in Australia has been monitoring the quality of engineering education and expects that graduating engineers will, for example, be able to demonstrate various skills and knowledge; that they will be able to coordinate their work with others and be able to communicate at every stage. Therefore, accreditation guidelines require engineering programs to show that students are capable of 'personally conducting and managing an engineering project to achieve a substantial outcome to professional standards' (Engineers Australia, PO5, 2005). These capabilities are also required from international engineering accreditation agreements (Washington Accord, International Engineering Alliance, 2009) to which Engineers Australia are a founding signatory. There are two new requirements for Final Year Projects as follows:

1. An Australian Qualification Framework (AQF8) requirement that it demonstrates research capability: Graduates of a Bachelor Honours Degree will have coherent and advanced knowledge of the underlying principles and concepts in one or more disciplines and knowledge of research principles and methods (AQF, 2011).
2. A requirement to satisfy the Threshold Learning Outcomes that will be used by Tertiary Education Quality Standards Agency (TEQSA). Graduates must demonstrate an ability to: Identify needs, context and systems of problems; Apply problem solving, design and decision making methodologies; Apply abstraction and modelling skills; Communicate and coordinate proficiently; and Manage Self in the short and long term.

The literature shows in order to maintain excellent quality and high standards, the FYEPs should (AUB, 2010);

- Be a practical problem-solving project that involves an engineering design approach.
- Engage at least 200 hours or more of individual student effort.
- Put the problem in context and review the relevant literature.
- Involve the generation of professional reports on the process, including problem definition and formulation, literature review, design specifications and alternatives, justification of the chosen design, relationship to previous research on the project, analysis, and critical evaluation.

Stages in the FYEPs Process

The selection of an FYEP is significant and should be done methodically. Figure 1 shows the steps that could be used as guidelines to help students to choose their project. Students usually select their FYEPs according to one of the following ways:

- Suggested by an academic
- Something based on students' interests
- A university-based problem (e.g. related to the school's teaching or research)
- Suggested by a prospective industry partner
- Something that responds to the needs of the society
- An extension of a previous project

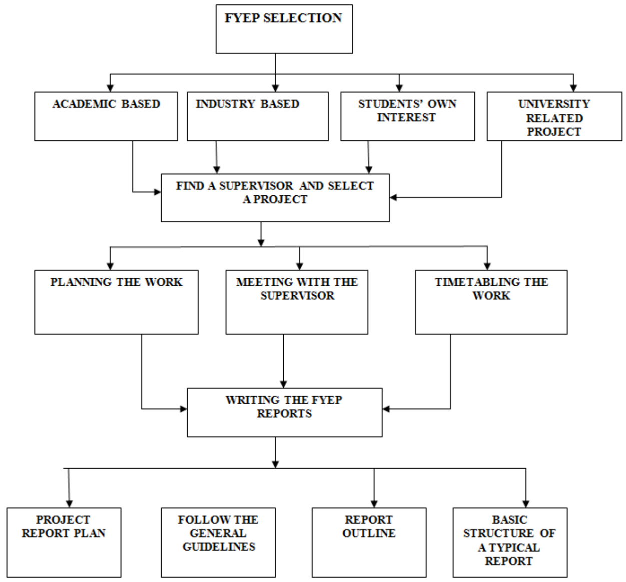

Figure 1: Steps of the FYEPS

Assessment of the FYEPS

Assessment of final year projects in engineering 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 (ECSA, 2000). Some studies of higher education assessment practice reported that academic staff generally adopted different approaches to assess their task (Tribe & Tribe, 1988; Yorke et al., 2000). But it is revealed from the literature that assessment process should be coherent and consistent in the light of good education practices. A pilot investigation of Rasul et al., (2010) indicated the assessment practices must have some common features: Self-assessment, assessment moderation, assessment criteria, and an assessment component matrix. In another study, Valderrama et al., (2009) presented an efficient and objective procedure for the outcome-based assessment of FYPs (See Figure 2). This study introduced a User Guide, consisting of 6 steps, and can easily be implemented for different engineering curricula to help institutions create their own FYEP assessment system. The literature stipulates that assessment criteria should be robust and able to withstand the appeals process if any students claimed that he or she had not been correctly judged. Explicit and well-written assessment criteria should allow academics to make assessment decisions benchmarking against standards rather than absolute marking resulting in improved efficiency and greater consistency (Littlefair & Gossman, 2007). Seymour (2005) highlighted the six stages assessment criteria with a clear benchmark standard. The assessment criteria are given in Table 1.

Table 1: Assessment criteria "Research processes in Engineering" (Seymour, 2005)

Assessment Criteria

Development -Strength of argument. -Use of information to sustain argument. -Awareness of strengths and weakness and of approach.	Applied research problem, including -Formulation -Focus -Rationale	Use and application of theory -Critical awareness of relevant theory. -Analysis and evaluation of the state-of-art. -Grounding in theory	Literature review, including -Range and depth of the reading. -Relation of research question -Independent research	Methodology including -Appreciation of methodological issues. -Explanation of information gathering and analysis. -Articulation of the limitations of the research approach.	Presentation and expression, including -Accuracy of referencing. -Standard of presentation. -Appropriate and accurate use of language.

There are also some features which are important aspects to be considered in FYEPs for successful completion. Supervisors of FYEPs should be involved in the assessment process. The supervisor should be aware of the students' progress and to encourage and support the students' technical and project management development. Supervisors are to help answer questions that students have and to challenge students with more difficult concepts that can be incorporated into the project (ELEC4840A&B, 2008). Therefore, it is recommended that the supervisor should have extensive expertise in the area of the field of the project. It is also recommended to make peer evaluations in initial stage of the project and include external experts in the assessment for the final milestones of the project. The supervisor is to act as an 'Engineering Manager' on the project.

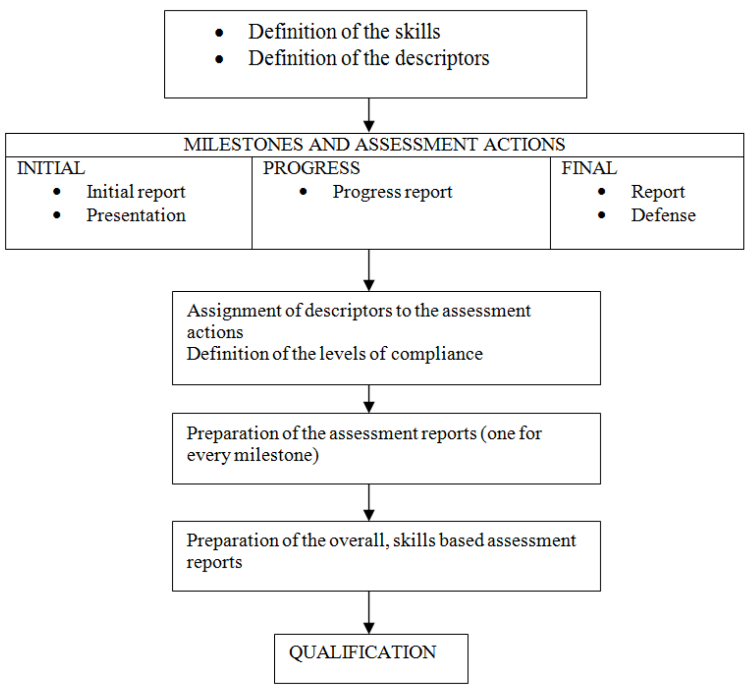

Figure 2: Procedure proposed for the definition of the FYEPs process (Valderrama *et al.*, 2009)

The development of guidelines and resources should be highlighted on the following areas:

- Support for students
- Preparation for academic staff
- Preparation of industry clients and supervisors
- Selection of Projects
- Project Assessment
- Standard of Project Reports
- Curriculum Integration

- Coordination and supervision of projects

Conclusions

Effective use of FYEPs should be the holistic and integrating learning experience that engages students in the strength of professional practice, enabling them to demonstrate achievement of Threshold Learning Outcomes for Engineering. Good practice guidelines should ensure that students are better prepared to undertake projects, have clearer expectations about what is required of them within the project, and what to expect of academic supervisors. In other words it can be seen that the effective use of FYEPs is the vehicle for assessing student proficiency across the full range of Threshold Learning Outcomes. Students should be better, more consistently prepared to articulate what they have learned from their project. Efficient use of FYEPs is the indicator of program standards in accreditation and curriculum design. This study promotes shared understandings of requirements of good projects and standards of project work that final year students are expected to demonstrate in their assessment. It is recommended that staff capacity should be increased to provide students with advice, supervision and assessment of FYEPs. Academic staff needs to develop a clear, more consistent understanding of how to supervise, assess and moderate undergraduate projects and understand how projects prepare students for professional practice.

This study has provided an insight into the purpose of development and assessment of the undergraduate Final Year Engineering Projects. Extensive literature has been reviewed at national and international levels. The paper outlines a variety of information regarding the final year projects' structure and key elements of its assessment criteria. The assessment criteria reviewed in this study will help increase the general quality of the process of assessing FYEPs. The wider Office for Learning and Teaching (OLT) commissioned study is designed to increase awareness of the standards agenda and promotion of dialogue, collaboration and scholarship across institutions and industry for refining and improving the standards of professional engineering education.

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Acknowledgements

The authors wish to acknowledge the wider project team and participating universities in the project *Assessing Final Year Engineering Projects (FYEPs): Ensuring Learning and Teaching Standards and AQF8 Outcomes.* They have contributed to the ideas represented in this paper: Roger Hadgraft (RMIT), Alex Stojcevski and Guy Littlefair (Deakin), Colin Kestell (University of Adelaide), Faisal Anwar (Curtin), Alan Henderson (University of Tasmania) and Rob Jarman (University of Technology, Sydney).

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