Educational purposes of final year engineering projects and their assessment

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Structured Abstract

BACKGROUND
Final Year Engineering Projects (FYEP) present students, project supervisors and assessors, professional accreditation bodies and industry project sponsors with many challenges. Interest in the supervision and assessment of FYEPs led to a successful CQUniversity Learning and Teaching Grant and subsequent report to investigate teaching practices in sixteen Australian and New Zealand Universities.

PURPOSE
This paper presents key issues raised by the pilot investigation, and outlines plans for follow-up research by a team of scholars from seven universities. This research is funded by a successful Australian Government grant, "Assessing Final Year Engineering Projects (FYEPs): Ensuring Learning and Teaching Standards and AQF8 Outcomes".

DESIGN/METHOD
The 2009 pilot study surveyed practices associated with final year engineering projects designed to comply with accreditation requirements that were current at that time. The study found no clear articulation of what FYEPs sought to achieve in the context of the associated program of study. It appeared that universities had over the years developed diverse practices while seeking to improve the quality of FYEP learning and teaching experiences and learning outcomes, but improvement focused on problems and details and not on the overall purposes of FYEPs.

RESULTS/OUTCOMES
The follow up project proposes to develop tools and processes to support systematic improvement of FYEPs. These include

- a best practice guideline for assessment of FYEPs based on the Threshold Learning Outcomes for Engineering;
- a clear definition of educational purposes and expectations of FYEP, particularly in the key area of research skills (AQF8);
- benchmarking of these outcomes based assessment practices with industry partners and with the Stage 1 Competency Standards of Engineers Australia.

CONCLUSIONS
Project course coordinators and project supervisors work in difficult contexts, under time pressures, and in isolation from practice at other universities. This constrains scholarship and systematic improvement of practices surrounding final year engineering projects. At the same time, FYEPs are important vehicles for assessing the capabilities of graduating students and for evaluating program standards, it is critical that teaching and assessment practices are efficient, fair, reliable and valid. To address the issues identified, the authors seek to promote scholarship in this area, to build a community of FYEP practice while surveying, sharing and reviewing current practices. This paper is intended to stimulate interest in the issues already identified, and to inform the engineering education community of the developments.

KEYWORDS
Final Year Engineering Projects, learning and teaching standards, AQF8 outcomes

Background to the study

Final Year Engineering Projects (FYEP) present students, project supervisors and assessors, professional accreditation bodies and industry project sponsors with many challenges. Experience with coordinating FYEPs and discussions with colleagues at the Australian Association for Engineering Education conferences in 2007 and 2008 indicated that many engineering educators had concerns about supervision and assessment of FYEPs. This led to a successful CQUniversity Learning and Teaching Grant for a pilot investigation and subsequent report on teaching practices in sixteen Australian and New Zealand Universities (Rasul, Nouwens, Swift, Martin & Greensill, 2009). This paper presents key issues raised by this report, and outlines plans for follow-up research by a team of scholars from seven universities. This research is funded by a successful Australian Government grant, "Assessing Final Year Engineering Projects (FYEPs): Ensuring Learning and Teaching Standards and AQF8 Outcomes". This research is to be conducted in 2013 and 2014.

What are FYEPs?

Students undertaking an engineering degree are required to undertake a major project at the end of their program of study to show that they are capable of personally conducting a major engineering project to achieve a substantial outcome that meets standards expected of prospective graduates. Graduates are expected to use the project to demonstrate (to supervisors, moderators, prospective employers, program evaluators and accreditation panels (Engineers Australia, PO5, 2006)) that they can apply the knowledge, skills and attributes developed during their program of study at a professional standard. The project often involves one semester in which students scope and prepare a project proposal, conduct a literature review and plan implementation. During the following semester students implement their project plan and prepare a formal project report or thesis.
Students are supported by a project supervisor. The initial research showed use of a variety of assessment instruments and assessment methods, but most assessment regimes involved formative assessment based on regular meetings and feedback during term and at the end of the planning semester, and formal final moderated assessment based on the project thesis.

Clear definition of educational purposes of FYEPs

The 2009 pilot study surveyed practices associated with final year engineering projects designed to comply with accreditation requirements that were current at that time. All engineering Bachelor programs surveyed included FYEPs because the Engineers Australia accreditation documents require students to demonstrate achievement of the Unit of Competency - PE2.5 Ability to conduct an engineering project - which included the following elements;

> *… (a) graduate should have undertaken and completed two or more construction projects, at least one investigative project and at least one major design project. At least one substantial project should be conducted individually, and at least one as part of a team. Accredited degree programs should provide and require such project work for all students. (Engineers Australia, 2006, p.8)*

Students must also show that they can conduct and manage a substantial engineering project to professional standards, apply project management principles, produce at least one major report demonstrating mastery of subject matter, and demonstrate that they can communicate complex material to technical and lay readers.

These project accreditation requirements had to be read in the context of the whole suite Engineers Australia Stage 1 Competencies (Engineers Australia, 2006) which defined 79 indicators of competency. Each university was required to prepare a curriculum design, including the design of an FYEP, to prepare graduates for identified segments of the

engineering profession. The intention of the accreditation guidelines was to afford universities scope for diverse responses to meet the broad needs of the profession. However the detailed exposition of 79 competency indicators made it difficult to focus the curriculum design of FYEPs on key aspects of professional engineering practice. In response to accreditation requirements, one university in the study asked students to assess their project proposal against all 79 competency indicators. Such a detailed assessment risks a focus by students and staff on the details and may fail to develop a holistic understanding of the role and responsibility of a professional engineer and the nature of professional projects. Development of such an understanding should be a key outcome of the program of study and the FYEP in particular.

Related to development of a clear understanding of the role of professional engineers is the nature of research in engineering and what standards of research should be applied to engineering projects. Some universities surveyed described FYEPs as design projects, whereas others required students to undertake research projects, not design projects. It was often not clear whether design projects required significant investigation of design problems or whether the design could be completed simply by applying relevant manuals, codes and standards.

The 2009 pilot study found no clear articulation of what FYEPs sought to achieve in the context of the associated program of study. It appeared that universities had over the years developed diverse practices while seeking to improve the quality of FYEP learning and teaching experiences and learning outcomes, but improvement focused on problems and details and not on the overall purposes of FYEPs.

Two recent developments in engineering education in Australia and New Zealand, developments that can assist clarification of educational purposes and thus affect curriculum design, teaching and assessment of FYEPs are:

- Development of Threshold Learning Outcomes (TLO) for engineering degree programs (Wright, Hadgraft and Cameron, 2010),
- Refinement of the Australian Qualifications Framework (AQF) for Bachelor Degrees and Bachelor Honours Degrees (Australian Qualifications Framework Council, 2013).

These developments promise to be of assistance in clarifying the educational purposes of FYEPs.

Development of Threshold Learning Outcomes for Engineering and ICT was a project funded by the Australian Learning and Teaching Council to develop an academic standards statement for learning and teaching for professional engineering and ICT courses. The project involved academics, industry professionals, professional and accrediting bodies, recent graduates and senior students throughout Australia to reconceptualise the numerous accreditation competency indicators developed by Engineers Australia and learning outcomes developed for the ICT professions to develop “a set of five overarching learning outcomes that is considered more useful and meaningful to all stakeholders” (Wright, Hadgraft and Cameron, 2010, p. 1) and align with outcomes specified by the International Engineering Alliance – a body established to facilitate and oversee mutual recognition of engineering qualifications at international level. The aim of the project was to develop a clear, short description of what engineering and ICT professionals do. This standards statement then provides:

- Support for integrated program design: Year 1 to FYEP
- A basis for evaluating the design of the whole program curriculum and program level outcomes, and identifying gaps in the program design
- A framework accepted by academic staff as the basis for assessing students’ progress towards graduate professional competence.
- A five-point framework for student self-assessment that is easier to grasp

The TLOs define five major domains of professional engineering capability at a program level, to give coherence to the list of discrete learning outcomes and competency indicators

associated with individual courses (subjects) in the program. These five major domains provide a useful framework for learning, teaching and assessment in FYEPs. The five domain areas are:

TLO1: Needs, context and systems
TLO2: Problem-solving and design
TLO3: Abstraction and modelling
TLO4: Coordination and communication
TLO5: Self-management

The Learning and Teaching Academic Standards Project report explicitly advocates the use of TLOs as a self-management tool that students (and project supervisors and assessment moderators) can use to clarify the educational purposes of FYEPs.

> *It is expected that graduates will be able to demonstrate a broad and coherent assimilation of the identified TLOs across the various knowledge, skills and attitudinal domains. For example, as part of a final year project, a student, in approaching a complex problem that requires the design of an artifact or system, will use the full range of outcomes. They will engage with the problem using systems thinking (TLO1). They will use a design or problem-solving process (TLO2) and complex analysis and modeling skills (TLO3). They will coordinate their work with others and communicate it effectively at various stages (TLO4). Throughout the process, students will be planning their work and self-monitoring to ensure that what is delivered matches the original requirements (TLO5) (Wright, Hadgraft and Cameron, 2010, p.7).*

The second recent development that will affect FYEPs is the recent refinement of the Australian Qualifications Framework (AQF) for Bachelor Degrees and Bachelor Honours Degrees (Australian Qualifications Framework Council, 2011). The pilot survey identified differences between universities regarding the standard and type of research that students should demonstrate in final year projects. A related issue is the award of Bachelor Honours degrees and the standard and type of research required for Honours.

The AQF guidelines specify different requirements for Bachelor Degrees (AQF Level 7 Qualification) and Bachelor Honours Degree (AQF Level 8 Qualification). The guidelines are to be implemented in all university courses by the beginning of 2015. The specification for AQF8 (Honours) allows an Honours Degree to be embedded as an extra year in a three-year Bachelor Degree. Professional engineering degrees are designed as four year degrees to meet accreditation requirements, so the Honours Degree can be embedded, however a Bachelor Degree can also have a four-year duration without Honours.

The AQF7 (Bachelor) specification does not require project work, while the AQF8 (Honours) specification requires students to “plan and execute project work and/or a piece of research and scholarship with some independence” (AQF 2013, p. 51). In addition, AQF8 specifies that Honours study should qualify students to undertake professional work AND provide a pathway for research. AQF8 also requires development of “technical skills to design and use research in a project” (p.51). This clearly indicates that Bachelor Honours projects must incorporate research while Bachelor Degree projects need not involve formal research.

Because the AQF8 (Honours) specification refers specifically to projects and research, choice and scope of project topic and student performance in the project will determine whether students are eligible for Honours. It will no longer be possible to award Honours on grade point averages for subjects completed.

Some clarification is required about what standards of research are required for FYEP projects, and how students should be prepared for honours work if such projects are to be used as the basis for awarding honours. Some current practices found in the Pilot Study may need to be reviewed. Not all universities surveyed provided explicit instruction in research design and methods. Some institutions indicated that they award honours to students who obtain Distinctions and High Distinctions for their FYEP. Project supervisors must guide students in selection and scoping of project topics to allow students to demonstrate their capabilities. There will also be a need to consult widely with teaching staff

to develop consensus about the standard of research that students must demonstrate for both Bachelor and Honours awards so students can obtain fair advice when selecting projects. Project investigations indicate that some academics feel that the research standard of most FYEPs do not justify award of honours. It will be necessary to establish what kind of research would need to be associated with engineering design projects to qualify a student for an honours award.

Clear understanding of the purposes of project assessment

The Pilot Study indicated conflicting understandings about the purposes of assessment and about the methods appropriate for various purposes. For some, assessment focused on what the student produced. Others sought to determine what students had learned in the course of the project.

Fourteen universities responded in the Pilot Study, and ten of these required students to complete the FYEP mainly as individual projects. The FYEPs are not like other courses in the program because they rely on students to take the initiative from the start. With other courses in the program, the lecturer imposes a great deal of structure on content, timing, resources and assessment. Consequently for many students, the FYEP is an unfamiliar experience, where students are learning to undertake unstructured and complex tasks associated with professional practice. While the project may involve research, the purpose of the project is to develop the student's professional capabilities, and not to produce new knowledge for the discipline. Establishing a clear purpose for FYEPs will assist in designing effective assessment.

Thus 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 Jenkins' (2012) idea that student critical reflection of their developing professional competencies is an integral part of quality assessment. The Pilot Study identified many processes and artefacts used by various universities to obtain evidence of student learning from projects (see Table 1).

Table 1 University processes and artefacts

Processes	Artefacts
• Regular meetings with supervisor • Team meetings (for team based projects) • Criteria for assessing project • Moderation feedback on project plan • Peer assessment • Self-assessment (based on student's criteria) • Presentations	• Literature review • Project proposal • Project scope • Project plan • Project files/design workbooks • Reflective Journal • Work Breakdown Structure and Gantt Charts • Posters • Project technical paper • Project final report/Thesis

Often students were given the means to compile a rich description of learning from their project, and the project supervisor could obtain a reliable indication of the developing capability of the student.

However it is difficult to convey what the supervisor knows to assessment moderators. Typically three or more moderators are involved in assessment. Moderation adds to the cost of assessment and to staff workloads, so moderators focus on the assessment artefacts produced by the student, primarily on the final report or thesis. There is insufficient time for moderators to review all the assessment artefacts in detail, and to discuss what was learned

with the student and supervisor, to obtain a valid perspective of what the student has done and what was learned. The thesis itself can only be a summary. The Pilot Survey (p. 21) indicated that supervisors typically looked after between 2 and 14 students, with three moderators per project, so moderators could be expected to assess 20 to 30 project theses per year.

There is then a recognised complexity around assessment. It seems there is a need to distinguish the moderated thesis mark that is an assessment of the project as 'product' from the assessment of the professional capability of the student based on all the evidence available. A number of authors point to the need for assessment of projects to focus on the full range of technical and professional skills and include both formative and summative instruments (Garner & Willey, 2012; Littlefair & Gossman, 2007; Mills, 2007). Formative assessment has been shown to both enhance learning and reduce failure rates in courses (Gardner & Willey, 2012; Jiao & Brown, 2012). Furthermore, the design of the assessment task (e.g. a portfolio) might serve multiple purposes. It could be for example, a source of formal assessment for academics, but it might also offer a means for employers to evaluate prospective employees as well encourage student learning and self-management through self and peer assessment, or support career long reflection and aid future performance review (Aziz, 2011; Blicblau, 2006; Bramhall, Short & Lad, 2012). Synthesising and disseminating best practice in the area of project assessment is the focus of the follow up project described below.

Follow up project

The Pilot Survey of FYEP practices has been a scoping exercise for the follow-up grant "Assessing Final Year Engineering Projects (FYEPs): Ensuring Learning and Teaching Standards and AQF8 Outcomes".

In addition to identifying the issues mentioned above, the Pilot identified a number of other common issues at the institutions surveyed.

- Student support
- Supervisor support
- Assessment criteria
- Issues with assessment of individuals in team projects
- Over-dependent students
- Conflict between industry and academic expectations of student work
- Availability of staff members
- Intellectual property/ confidentiality issues (student, industry, university)

The follow up project during 2013 and 2014 proposes to develop tools and processes to support systematic improvement of FYEPs. These include

- tools to evaluate how well students can apply much of the knowledge gained during their university studies in solving a real life problem (i.e. a best practice guideline for assessment of FYEPs based on the Threshold Learning Outcomes for Engineering);
- a clear definition of educational purposes and expectations of FYEP, particularly in the key area of research skills (AQF8);
- benchmarking of these outcomes based assessment practices with industry partners and with the Stage 1 Competency Standards of Engineers Australia.

The project will be undertaken over a two-year period in two phases as outlined below:

Phase 1: Survey and critically review coordination, supervision and assessment practices of FYEPs in universities and disciplines of engineering.

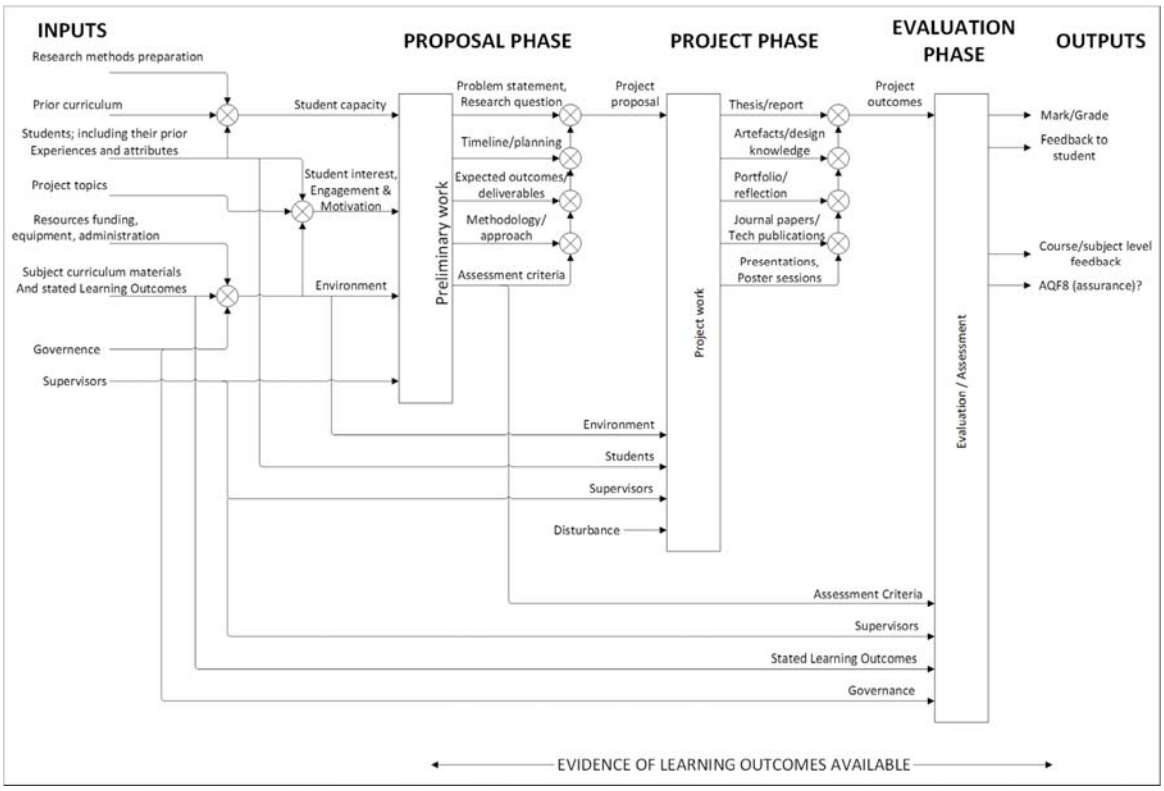
- Prepare a report summarising current practices, issues and concerns and presenting findings from the literature to inform the FYEP.
- Run workshops with stakeholders to critically review current practices.
- Prepare a report with recommendations for good practice.

Phase 2: Develop and promote an FYEP assessment model and benchmarking guidelines to assist engineering disciplines to improve FYEP assessment

- Establish a FYEP website to support dissemination and debate about good practice.
- Trial and evaluate guidelines with students, supervisors, coordinators and industry.
- Refine guidelines with feedback from the evaluation.
- Develop an online community of practice to promote further development of good practice, and extend good practice to other professional fields (such as sciences, health, business).

The data gathered from university documents and pilot interviews in phase one of the follow up study suggests that one way the FYEP might be conceptualised is as a series of activities and inputs culminating in outputs including AQF8 assurance. These activities might be clustered broadly into proposal, project, implementation and evaluation phases and include multiple internal feedback loops to account for the degree to which a project is 'worked through' and 'worked out' (see Figure 1).

Figure 1: Conceptualising the FYEP Process



Such a depiction identifies the areas worthy of attention for improvement in FYEP courses. It shows how FYEPs typically move through phases for academics and students with each phase having accompanying activity. Whilst the phases are temporal (proposal, implementation and evaluation), they are also reflexive and are shaped by factors such as student experience and capacity, supervisors and governance. The figure particularly highlights the importance of the evaluation or assessment phase. Rigour and validity in assessment in this area is thus paramount.

As the project continues, ways in which some of these activities and inputs might be enhanced will be identified together with deeper consideration of the specific actions that might be adopted by academics and students to ensure smooth processes and high quality outcomes.

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