Full Paper

Abstract

Final Year Engineering Projects (FYEPs) present students, academic staff (project supervisors) and assessors (review panel), professional accreditation bodies and industry project sponsors with many challenges. Experience with coordinating and examining FYEPs and discussions with colleagues at past few AAEE conferences indicated that many engineering educators have concerns about learning and teaching approaches of FYEPs. Development of good practice guidelines which meet Australian Qualifications Framework (AQF) Level 8 outcomes was therefore required. This led to a successful Australian Government grant on "Assessing Final Year Engineering Projects (FYEPs): Ensuring Learning and Teaching Standards and AQF8 Outcomes" funded by Office for Learning and Teaching. This paper presents the guidelines developed for good practice in learning and teaching of FYEPs as an outcome of the above mentioned grant.

Introduction

FYEPs are important vehicles for assessing the capabilities of graduating students and for evaluating program standards, it is critical that learning and teaching practices are efficient, fair, reliable and valid. Students should be able to demonstrate that they can integrate knowledge, skills and professional graduate attributes developed during the program and perform at a standard expected of graduates. Students should be capable of 'personally conducting and managing an engineering project to achieve a substantial outcome to professional standards' (Engineers Australia, 2011). Such requirements emerges from international engineering accreditation agreements (Washington Accord, International Engineering Alliance (2009)) to which the Australian accreditation body is a party. Accreditation Board for Engineering and Technology (ABET) of United States of America has promoted and monitored development of capstone project to assess individual students and to provide evidence for assessing standards in their study programs (McKenzie et al., 2004; Howe, 2008).The main purpose of this study (OLT grant mentioned in abstract) was to develop good practice guidelines to assist students, supervisors and coordinators, and to make these available to the community of FYEPs.

It was found that the principles of constructive alignment in *curriculum design* are still recognised as best practice in Australia (Biggs, 1996). However, there are significant variations in *assessment and supervision practices* (Boud, 2003; Gardner & Willey, 2012; Hattie, 2008; Rasul et.al. 2009; Sambell, McDowell & Montgomery, 2013). To reflect current thinking in the practice of supervision, the term *advisor* has been considered in this study. It is believed that whilst the term *Advisor* is accepted the term *supervisor* might be more commonly used worldwide. Authors believe that the activity of an effective supervisor who adopts more of a mentor and facilitator role (learner centred) than an authoritative and directive one (teacher centred) is better captured through the use of the term *Advisor*. This reinforces the AQF requirement for students to complete projects *with some independence*. Such curriculum, assessment and advisor principles are assumed to be already embedded within local institutional practices. Therefore, these guidelines will not address basic educational principles; rather will address how these practices can facilitate students in meeting AQF8 learning outcomes. *Scaffolding* is another term used in a number of places in the document which is best described as the guided support for students. Under this circumstance, the advisor can model and demonstrate a concept/task then work together with a student so that student becomes increasingly capable of doing the task independently. Scaffolding both within a final year course and throughout the curriculum is important for all students across all aspects of learning and teaching.

This suggests a need for the explicit and appropriate teaching and support for FYEPs students throughout their program of study. The three discrete sets of guidelines developed in this study (i.e. curriculum, advisor and assessment) 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, advisor and assessment decision making. The middle circle captures those local contextual influences which acknowledge the uniqueness of each university's FYEP courses.

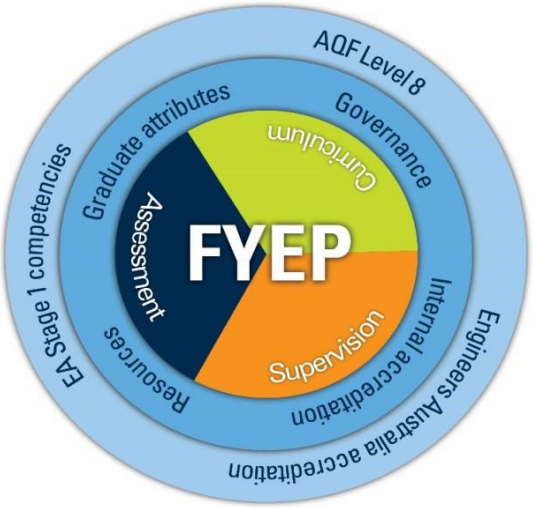

Figure 1: Schematic representation of guidelines

Understanding of FYEPs at AQF8 Level

The project team investigated further to understand the definition of AQF of research. The AQF (2013, p. 100) defines research as "(comprising) systematic experimental and theoretical work, application and/or development that results in an increase in the dimensions of knowledge". The authors believed that this definition did not fully capture the work of research practised by graduate engineers; rather it reflects more of a scientific paradigm. The team based on the feedback from workshop participants across Australia, and Accreditation Division of Engineers Australia, generated a contextualised understanding of what is involved in FYEPs which may apply regardless of the discipline and/or the project type (Rasul et al, 2015; Lawson, Hadgraft & Jarman, 2014; Rasul et al., 2014). The team believed that the definition of FYEPs at AQF8 level can be elaborated as follows;

- Defining and identifying the open ended problem, 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 and understanding the local context.
- Determining appropriate methodology and what constitutes evidence.
- Conducting systematic investigation and application to the engineering problem.
- Undertaking experimentation, design, modelling, problem solving, 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.

Approach and Methodology

This work was done by a team of 7 universities, namely Central Queensland University (the lead), the University of Technology Sydney, Deakin, RMIT University, University of Tasmania, University of Adelaide and Curtin University. The guidelines was developed for four year undergraduate engineering degrees with embedded Honours and support achievement of the level 8 learning outcomes of the AQF (2013). The guidelines were developed through literature, survey and data gathered from 16 Australian universities from all states and territories. Data included documentary material such as subject outlines, student handbooks, supervisor guides, rubrics and teaching materials as well as 16 interviews with course coordinators and a workshop conducted with a range of supervisors and coordinators. This final iteration was derived after dissemination workshop evaluations and testing across Australia which involved over 100 participants from a total of 26 universities. All projects (design, research, experimental etc.), at AQF8 level, should develop similar skills of definition (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 & Jarman, 2014). The Graduates at AQF8 level should have coherent and advanced knowledge of the underlying principles and concepts of research principles and methods. The guidelines were developed against the following skills and AQF8 descriptors which graduate should have gained from their study program.

1. Cognitive skills to review, analyse, consolidate and synthesise knowledge to identify and provide solutions to complex problems with intellectual independence.
2. Cognitive and technical skills to demonstrate a broad understanding of a body of knowledge and theoretical concepts with advanced understanding in some areas.
3. Cognitive skills to exercise critical thinking and judgement in developing new understanding.
4. Technical skills to design and use research in a project.

5. Communication skills to present a clear and coherent exposition of knowledge and ideas to a variety of audiences.
6. Graduates should demonstrate the application of knowledge and skills to plan and execute project work and/or a piece of research and scholarship with some independence.

Result and Discussion

The guidelines begin with some general principles followed by more specific and instructional guidelines which are aligned with each of the AQF8 learning outcome descriptors. General principles for curriculum, advisor and assessment are presented below (Rasul et. al, 2015).

Curriculum:

Learning outcomes must be clearly articulated, explicitly assessed, and should be demonstrable and should reflect AQF level 8 and EA Stage 1 Competencies. These are;

- Consider where the target skills in AQF8 are being taught in your course/program,
- Identify which AQF8 descriptors you expect your course/program to have demonstrated in FYEP.
- Ensure both professional and technical outcomes are included (though technical outcomes may vary for individual students).
- Support the skills, knowledge and application of skills and knowledge expected in the FYEP course, including teamwork and intercultural skills, prior to as well as within the subject. This might include project management and research methodologies.
- Provide exemplar annotated projects for student use.
- Require students to write regularly and frequently in preparation for final report/thesis/journal paper writing.

Advisor:

Primarily good mentoring of student projects is about strong interpersonal skills. Strong interpersonal skills will also enable you (advisor) to facilitate projects that are outside your area of expertise. These are;

- If you want to improve your advisory skills then further develop your interpersonal skills, not technical skills.
- Familiarize yourself with whole of course curriculum to gauge student prior knowledge and skill.
- Ensure that you monitor and document student progress throughout all phases of the project.
- Read, review and comment on clarity of communication (e.g. reflective writing, draft submissions).
- Scaffold student learning rather than provide answers.
- Organize group project meetings and consider enabling meetings between groups/individuals.

Assessment:

Assessment practices must reflect general principles of validity, equity and rigor. There should be a clear focus on the features of the project that separate it from previously demonstrated coursework. These are;

- Develop and apply criteria (tools/methodology/moderation) in rubrics or standards statements (and this might be in conjunction with students) that address each of the AQF outcomes

- Provide formative assessment that is focused on enhancing student learning and reflection
- Look for clear and coherent written exposition of knowledge
- Look for evidence of learning in both process and product or artefact
- Provide regular and timely opportunities to assess project progression and milestones
  - consider outcomes and process with appropriate weightings
- Actively involve students in self and peer assessment throughout all phases of the project and encourage students to write and reflect regularly.

The specific guidelines developed against all the skills listed in approach and methodology guidelines for curriculum, advisor and assessment are presented in Table 1 (Rasul et. al, 2015).

Conclusions

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 guidelines developed are intended for use by final year engineering project subject coordinators whose primary responsibilities may include both operational and governance matters. Subject coordinators may pass these guidelines directly onto others with vested interest such as advisors, or may use these guidelines in the preparation of local materials including subject outlines, assessment activities and criteria. These guidelines will act to assist the coordination of FYEP subjects as it is acknowledged that the role can be more demanding because of the potentially large groups of advisors that may need to be managed.

References

Australian Qualifications Framework Council (2013). *Australian Qualifications Framework, 2nd Ed*, January 2013. Retrieved July 2013, from http://www.aqf.edu.au/wp-content/uploads/2013/05/AQF- 2nd-Edition-January-2013.pdf

Biggs, J. (1996). Enhancing teaching through constructive alignment. Higher Education, 32 1-18.

Boud, D. (2003). Enhancing Learning through Self Assessment. New York: Routledge.

Engineers Australia. (2011). Stage 1 Competency Standard for Professional Engineer. Retrieved July 2012, from http://www.engineersaustralia.org.au/sites/default/files/shado/Education/Program Accreditation/110318 Stage 1 Professional Engineer.pdf

Howe, S. (2008, 22-25 June), Focussed Follow-up to 2005 national capstone survey, Paper presented at the *American Society for Engineering Education (ASEE) Annual Conference and Exposition*, Pittsburg PA.

International Engineering Alliance (2009), Washington Accord, International Engineering Alliance, http://www.ieagreements.org/Washington-Accord/ Accessed 23June 2009

International Engineering Alliance (2009), Graduate Attributes and Professional Competencies, Version 2-18June 2009, *International Engineering Alliance*, http://www.ieagreements.org/GradProfiles.cfm Accessed 23June 2009

Gardner, A. & Willey, K. (2012), Student participation in and perceptions of regular formative assessment activities. Paper presented at the annual *Australasian Association for Engineering Education*, Melbourne, Australia, December 3-5, 2012.

Hattie, J. (2008). Visible learning: A synthesis of over 800 meta-analyses relating to achievement. New York: Routledge.

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

McKenzie, L. J., Trevisan, M. S., Davis, D. C., & Beyerlein, S. W. (2004, 20-23 June), Capstone Design Courses and Assessment: A National Study. Paper presented at the *American Society for Engineering Education (ASEE) Annual Conference and Exposition*: Engineering Education Reaches New Heights, Salt Lake City.

Rasul, M.G, Nouwens, F., Martin, F., Greensill, C., Singh, D., Kestell, C. and Hadgraft, R. (2009), Good Practice Guidelines for Managing, Supervising and Assessing Final Year Engineering

Projects, Proceedings of the 2009 *Australasian Association for Engineering Education* (AaeE 2009) Conference, Paper ID 108, University of Adelaide, 7-9 December 2009

Rasul, M.G., Lawson, J., Howard, P. and Martin, F. (2014), Learning and Teaching of Capstone Final Year Engineering Projects: An Australian Study, Presented in *Capstone Design Conference*, Paper ID 31, 2-4 June 2014, Columbus, Ohio, USA.

Rasul, M.G., Lawson, J., Jarman, R., Hadgraft, R., Howard, P., Martin, F., Kestell, C., Anwar, F., Stojcevski, A., Henderson A. and Kootsookos, A. (2015), Good Practice Guidelines for Curriculum, Supervission and Assessment of Final Year Engineering Projects and AQF8 Outcomes, *OLT 2015 final report on Project ID12-2495*.

Sambell, K., McDowell, L. & Montgomery, C. (2013), Assessment for learning in higher education, New York: Routledge

Table 1: Guidelines developed on curriculum, advisor and assessment

AQF8 learning outcome descriptors	**Curriculum** Teaching/learning activities that support student opportunity to reach AQF8 might include:	**Advisor** Advisor action that supports AQF8 might include:	**Assessment** Assessment activity that support student opportunity to demonstrate AQF8 might include:
1. Graduates will have cognitive skills to review, analyse, consolidate and synthesise knowledge to identify and provide solutions to complex problems with intellectual independence	• Include scoping statements in unit outline that articulate boundaries of complexity – provide examples of projects that are 'too thick' or 'too thin' • Allow for complexity to apply to process and not just deliverables • Reduce the risk that students complete a simple project done well or a difficult project done poorly • Support students' production of proposals, final reports/journal papers, posters etc. by modelling, jointly constructing, annotating examples of these • Provide extensive formative feedback on individual or group proposals	• Ask open ended questions that challenge the student to consider project complexity, establish stakeholder needs, define context and determine the nature of the problem rather than rush to solutions • Maintain scaffolding of learning but also enable student to take increased control of the project and to do the work themselves • Provide critical feedback so that the student works towards greater complexity and intellectual independence • Where students are engaged in group projects, ensure there is a means for determining individual student contribution. This might be in written submission or oral defence	• Look for complexity as defined by AQF in the project question, scope of works and outcomes • Provide feedback so that the project topic and scope affords the opportunity for the student to demonstrate complexity and intellectual independence in the project itself • Look for independence as evidenced by individual capacity to articulate their contribution to the project and their understanding of the project complexity. This might be in written or oral form
2. Graduates will have cognitive and technical skills to demonstrate a broad understanding of a body of knowledge and theoretical concepts with advanced understanding in some areas	• Facilitate group discussion that explores theoretical concepts • Require library resource activities • Facilitate discussions with external bodies and other experts	• Advise students to locate a range of appropriate sources within the body of knowledge • Advise students to engage in and articulate advanced engineering activity (e.g. calculations, modelling, designs) • Ask open ended questions that probe concepts and advanced understanding	• Look for breadth and diversity of sources (not just a literature review but also industry IP, interviews with stakeholders etc.) • Look for student development and testing of theoretical concepts

3. Graduates will have cognitive skills to exercise critical thinking and judgement in	• Include requirement for clearly articulating the local known, probably early in the project (e.g. literature review but not annotated bibliography)	• Direct students to synthesise literature and local known	• Look for synthesis in the literature review – links between and across sources – not sequential description

developing new understanding	• Provide opportunity for students to demonstrate their contribution to the local known (articulating the gap in the local known) • Encourage students to argue the logic of how their contribution addresses the gap	• Enable students to articulate their understanding of the local known compared with their contribution • Scaffold and monitor student work – reduce risk student work is less than AQF8 or well beyond AQF8 • Discourage students simply describing what they have done	• Ask if the project shows new understanding – how is it differentiated from previous work in the field and from previous coursework? Look for creative contribution
4. Graduates will have technical skills to design and use research in a project	• Include development of technical skills to the extent that student can demonstrate these in design work in their project • Consolidate and or review student understanding of research methodologies (this might include a parallel subject in research skills, one-off workshops, library skills workshops etc.) • * Include requirement for application/demonstration of research skills/methodology (e.g. in project proposal)	• Direct students to relevant technical experts (e.g. lab access, industry experts) • Scaffold the student's understanding and design of their project research methodology/approach (e.g. experimental lab work, modelling, design) • Monitor the outcomes and documentation and provide formative feedback • Resist giving answers	• Look for evidence of engineering discipline technical skills applied in the students' design work – may have focus on outcomes and process/methodology • Look for evidence of use of research outcomes – focus on research process/methodology (selecting appropriate models and theories, drawing logical and justifiable conclusions) • Focus on evidence of student's learning in technical skills demonstrated during project work
5. Graduates will have communication skills to present a clear and coherent exposition of knowledge and ideas to a variety of audiences	• Include requirement for formal oral and written presentation/exhibition/ seminar/ where students defend their project to an audience that includes students, academics and where possible, industry and public representatives • Provide opportunity for student rehearsal of presentation in front of peers and others	• Meet regularly with all project students concurrently • Facilitate peer group discussion through modelling asking open-ended questions of each other • Help students arrange an external or independent audience for review of written material and oral presentation • Help student to consider the different needs of diverse audiences	• Look for clear and coherent exposition of knowledge in oral and written presentation • Focus on the dialogue not the monologue • Look for appropriateness of responses to questions from a diverse audience • Ensure students are exposed to a range of higher/lower order questions • Collate feedback and peer and self-assessment of rehearsal and presentation

6. Graduates will demonstrate the application of knowledge and skills to plan and execute project work and/or a piece of research and scholarship with some independence	• Include opportunity to teach and develop engineering project management skills (this might be done as a parallel subject, addressed through guest/industry visitor lectures or workshops) • Include requirement for project proposal which would include planning documentation • Set clear deadlines for expected progress as well as assessment submissions. Given the nature of any project, have clear procedures in place to manage when things that are beyond the control of the student go wrong	• Scaffold, mentor and monitor student progression through well-organised planning and implementation phases of their project • Encourage student to investigate 'state of the art' by asking questions • Guide the student to think about similar problems in related domains • Provide regular formative feedback and question students to determine where they are in relation to the project's progress. • Help students identify barriers and ways to address • Where students are engaged in group projects, ensure appropriate guidance and instruction in group work is provided, as well as ensuring there is a means for determining individual student contribution. • Be more directive early in a project and gradually encourage students to assume more responsibility	• Look for application of project management skills such as: o Project planning o Timelines/Gantt charts o Keeping notes of meetings o Action lists o Milestones o Response to disruptions to plan o Communication with stakeholders • Focus on the process not the deliverable/outcome • Provide regular formative feedback

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