Contextualising Research in AQF8 for Engineering Education

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CONTEXT
Engineering education historically has been shaped by professional accreditation and internal university imperatives. The recent strengthening of the Australian Qualifications Framework (AQF) adds a new layer of thinking and has required many universities to re-examine how embedded honours degrees are awarded and the degree to which undergraduate programs reflect the level 8 requirements. The AQF is necessarily broad as it applies to all disciplines and fields of education. What is needed is a way of contextualising AQF requirements for engineering education and a means for understanding how these are similar to, or differ from, Engineers Australia's Stage One Competencies. This paper represents a work in progress that is designed to ignite thinking about AQF8 implications – particularly those around research in the final year engineering project.

PURPOSE
An Office for Learning and Teaching (OLT) project set out to map practices in relation to final year engineering projects and to consider the implications for compliance with AQF8 outcomes. One aspect of the study looked specifically at how AQF8 outcomes are understood by coordinators and the team came to examine the nature and role of research in final year projects. From here, the team sought to generate a contextualised definition for AQF8 outcomes as they might apply to engineering education. Although there are other points of differentiation between AQF7 and AQF8, the team sought, in particular, to develop a broadly accepted definition for research.

APPROACH
This paper reports on one part of the larger project. The wider project methodology was largely qualitative, adopting a case study approach. Data was gathered from 16 universities across Australia (from all states and territories) and included university documentation such as subject outlines, rubrics and student guidelines. Additionally, interviews were conducted with coordinators of final year project courses. It was within these interviews that participants were asked specifically about AQF8 outcomes. Additional data was gathered from participants during a conference workshop designed to explore understanding of AQF8 outcomes. The notion of a contextualised definition of research is derived from this data together in collaboration with Engineers Australia.

RESULTS
The data revealed that universities are at different stages of AQF compliance. Further, there is mixed understanding in relation to AQF8 with degrees of uncertainty about some terms used in the document, particularly around what comprises research. There is some sense that some engineering programs are already meeting the higher order requirements of AQF8 outcomes and that compliance is merely procedural. Beyond this, however, is the revelation that there is a great deal of contention around research and autonomy as defined by AQF. It was in this context that the OLT team sought to develop a definition of research as applied to the final year or capstone project. The definition delineates specific engineering knowledge, skills and application as would be seen in the final year project.

CONCLUSIONS
This paper proposes a nationally supported definition of what research means within the undergraduate engineering education context and in doing so assists linking AQF8 directly to final year projects specifically, but to embedded honours programs more generally.

KEYWORDS
Research, Australian Qualifications Framework

Introduction

Engineering education historically has been shaped by professional accreditation and internal university imperatives. The recent strengthening of the Australian Qualifications Framework (AQF, 2013) adds a new layer of compliance and has required many universities to re-examine how embedded honours degrees are awarded and the degree to which undergraduate programs reflect the level 8 requirements. The AQF is necessarily broad as it applies to all disciplines and fields of education. What is needed is a way of contextualising AQF requirements for engineering education. This paper represents a work in progress that is designed to ignite thinking about AQF8 implications – particularly those around *research* in the final year engineering project.

The paper is presented in four parts. First, it locates research as a critical (though not single) point of difference between AQF level 7 and level 8. Second, it describes the process undertaken by the project team in defining research in an engineering context. Third, it considers the curriculum implications if such a definition is adopted and fourth, it offers a framework by which all institutions might undertake to develop a research definition at a local level. That is, we do not purport to have all the answers here, but rather, present a framework within which our assertions may be challenged and localised, including key questions to be asked.

An Office for Learning and Teaching (OLT) project: *Assessing Final Year Engineering Projects (FYEPs): Ensuring Learning and Teaching Standards and Australian Qualification Framework (AQF8) Outcomes* set out to map practices in relation to final year engineering projects and to consider the implications for compliance with AQF8 outcomes. One aspect of the study looked specifically at how AQF8 outcomes are understood by coordinators and the team came to examine the points of difference between levels 7 and 8 within the framework. Table 1 identifies these differences in bold and whilst there are other points of differentiation, there has been a great deal of focus on and interest in the element of *research* and this was the starting point for the team focus on generating a contextualised definition.

It is interesting to note the italicised bold in level 7 indicating something not addressed in level 8, which suggest some added detail or clarification compared to level 8. Of course, an engineering degree is the sum total of the AQF7 component, the first three years say, and the final year, which delivers the AQF8 outcomes.

Similarly, Engineers Australia (2011) requires both broad knowledge (outcomes 1.1 and 1.2) as well as specialised knowledge in the discipline (1.3) as well as research capability (1.4).

Table 1: Points of Difference between AQF levels 7 & 8 (AQF, 2013, p.16)

	Bachelor Degree (level 7)	**Bachelor Honours Degree (level 8)**
Purpose	The Bachelor Degree qualifies individuals who apply ***a broad and coherent*** body of knowledge in a range of contexts to undertake professional work and as a pathway for further learning	The Bachelor Honours Degree qualifies individuals who apply a body of knowledge **in a specific context** to undertake professional work and as a pathway **for research** and further learning
Knowledge	Graduates of a Bachelor Degree will have a broad and coherent body of knowledge, with depth in the underlying principles and concepts in one or more disciplines as a basis for independent lifelong learning	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**
Skills	Graduates of a Bachelor Degree will have:	Graduates of a Bachelor Honours Degree will have:

	• cognitive skills to review ***critically***, analyse, consolidate and synthesise knowledge	• cognitive skills to review, analyse, consolidate and synthesise knowledge **to identify and provide solutions to complex problems with intellectual independence**
	• cognitive and technical skills to demonstrate a broad understanding of knowledge with depth in some areas	• cognitive and **technical skills** to demonstrate a broad understanding of a body of knowledge and **theoretical concepts with advanced** understanding in some areas
	• cognitive ***and creative skills*** to exercise critical thinking and judgement ***in identifying and solving problems with intellectual independence***	• cognitive skills to exercise critical thinking and judgement **in developing new understanding**
		• **technical skills to design and use research in a project**
	• communication skills to present a clear, coherent and independent exposition of knowledge and ideas	• communication skills to present a clear and coherent exposition of knowledge and ideas **to a variety of audiences**
Application of knowledge and skills	Graduates of a Bachelor Degree will demonstrate the application of knowledge and skills: • with initiative and judgement ***in planning, problem solving and decision making*** in professional practice and/or scholarship	Graduates of a Bachelor Honours Degree will demonstrate the application of knowledge and skills: • with initiative and judgement in professional practice and/or scholarship
	• to adapt knowledge and skills in diverse contexts	• to adapt knowledge and skills in diverse contexts
	• with responsibility and accountability for own learning and professional practice and in collaboration with others within broad parameters	• with responsibility and accountability for own learning and practice and in collaboration with others within broad parameters
		• **to plan and execute project work and/or a piece of research and scholarship with some independence**

Given that research is a significant, though not the only point of difference between levels 7 and 8, the team sought to unpack the AQF definition of research and began to contemplate what it might mean for engineering education. 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”. It was felt that this definition reflected more of a scientific paradigm and that whilst experimental work might indeed feature in engineering education, it didn’t fully capture the work of research in the field. In some ways the New Zealand Qualification Framework (NZQF) is clearer about what it expects for graduates at level 8 to demonstrate in research (2013, p. 15):

> *Research in the context of a Bachelor Honours Degree develops an individual’s ability to design and undertake a project under supervision, and to report on this in an appropriate way. It sharpens the individual's analytical and communication skills and provides a supported introduction to planning, conducting and reporting on the type of independent research that may be undertaken at higher levels.*

Both the Australian and New Zealand Qualification Frameworks award Bachelor Honours degrees at level 8. Both expect graduates to have advanced understandings, work in independent and self-directed ways and engage in research activity. In New Zealand, however, the Honours Degree is awarded by merit, whereas in Australia, all students who enrol in an accredited level 8 degree will graduate with Honours. Contextualising research for engineering as discussed in this paper will be useful for both New Zealand and Australia given the expectation of both qualification frameworks that graduates will conduct research.

Initially, the team, in collaboration with Engineers Australia, generated some ideas about what research at an undergraduate Honours level might look like. Table 2 shows these ideas. Of particular note is the way in which 'local context' is used to delineate the precise nature of knowledge contribution. From here, as part of phase two of the OLT project, which included a series of dissemination workshops, the team invited workshop participants to contribute their ideas about what constituted research at an undergraduate Honours level and, more specifically, to think about the type of research students might typically engage in as part of their final year project. Some of their ideas are captured in Table 3.

Table 2: Project team's definition of research in engineering

"to search intensely"
• Typically, in the context of design or problem solving relevant to the practice of engineering
• Discovering the state of the art globally or broadly.
• Knowledge management, publication and contribution to good practice in local context.
• Systematic investigation, distillation and application to an engineering problem
• Generation of new knowledge in the local context (or limited context)
• Creation and innovation – makes a contribution of knowledge
• Open ended problems
• Synthesising with judgement – unique interpretation
• Learning and meta-learning
• Investigation – literature, practices, data collection, etc. qualitative research (scaffolded)

Table 3: Definitions of research from workshop participants

• Producing **new knowledge**
• Solving **new problems**
• Requires **new methodologies**
• Creative/**innovative solutions (**in practising engineer context)
• Understand the **context**
• What is **existing practice**? (relevance to practising engineers)
• Asks the right **questions**, e.g. What is the problem?
• Research skills of **investigation**; decisions about what constitutes **evidence**
• Demonstration of ability to **self-learn** i.e. there is no-one to give you an answer
• Sometimes product doesn't matter but **process** does
• **Integration** of knowledge, context, views
• **Synthesis** of solutions and procedures
• Ability to **critically evaluate**
• Identify **problems/gaps** versus take a gap or a problem and investigate
• Ability to describe/solve/articulate a gap to form a coherent **research question**
• Investigating in a **lab setting**
• Apply existing natural laws, materials and technologies to **deliver 'novel' goods**
• Research versus design? Overlap between research and design is considerable
• **Producing versus doing** research (e.g. techniques)/investigation/analysis
• Research is about **generalising** – design is about solving a specific problem

• Small ‘r’ (r)esearch and capital ‘D’ (D)evelopment
• Extends **beyond normal coursework**
• **International** significance?
• **Boundary pushing**; beyond area

Typical research activity in final year projects

Final year projects typically vary across a wide range, from design projects to scientific research projects. This variation can be observed within a single discipline at a university and also between disciplines and, of course, between universities. Some disciplines, for example, chemical engineering, insist on both design projects (application of known techniques to interesting problems) and research projects (exploring a problem without a well-tried solution). This is sometimes an accreditation requirement, for example, in IChemE, though civil engineering also usually follows this approach at many or most universities, without a strict accreditation requirement.

Some disciplines use one project to achieve both aims – development of research skills plus design. In many cases, one semester is used for the research or investigation component, which is the ‘understand the problem’ phase of the design process, which leads to conceptual design. This includes reading the literature and talking to experts to find the ‘state of the art’ as mentioned in Table 2. It can also include data gathering to contextualise the problem. This can include sourcing data from elsewhere, e.g. traffic data, meteorological data, internet data, as well as collection of primary data, such as new traffic surveys, laboratory testing of materials, etc.

In this first semester, the students are also discovering and documenting potential solutions to the problem. This can include algorithms and other computer models as well as hardware solutions, e.g. chipsets and communication protocols. The students complete an interim report and, often, a presentation, which sets out their conceptual design of the artefact.

In the second semester, students proceed to detailed design, which usually includes careful modelling of the componentry and calculation and prediction of performance. Students deliver a significant report plus presentation, that builds on the interim report (the investigation/research phase) and also delivers the key detailed design calculations. In some disciplines, e.g. electronic engineering, mechanical engineering, software engineering, students may also deliver a prototype of the final product, which can be tested under realistic conditions.

In traditional, scientific research projects, students might investigate new technologies or materials, e.g. which concrete mix design should be used for a particular purpose or which alloy is best suited to repeated loading under certain conditions? These projects generally fit a scientific method approach, where the outcome is framed as a research hypothesis, which may be disproved through data collection.

It is possible to see engineering design in a similar way. The hypothesis becomes the problem to be solved, e.g., what is the optimal design for a bridge across river X at this location? The investigation phase is used to shape and articulate the hypothesis, because many design problems present as a set of symptoms (e.g. traffic congestion) rather as a neat problem to be solved (build a bridge). Likewise, many research projects begin as the exploration of a set of issues, before the candidate has identified a component of the problem that is amenable to some careful data collection and resolution.

What is important in both contexts is to thoroughly explore the problem and to identify that part of the problem to be solved. This requires reading the literature and speaking with experts, because not all knowledge is available explicitly in written form. Design must be seen, then, as an exploration exercise rather than as the application of a known theory to a familiar problem, which is sufficient at AQF7 level (‘planning, problem solving and decision making in professional practice', Table 2). At final year level, students need to be able to demonstrate 'cognitive skills to exercise critical thinking and judgement in developing new understanding', Table 2.

So, a routine design is adequate at third year level (AQF7). This might include applying known techniques to the sizing of components, such as a power supply for an electronic device. In final year, the project must be sufficiently open-ended to allow exploration of a range of solutions (hypotheses) to the problem. An example might be the design of a Bluetooth-enabled tracking device for pets, keys, etc.

In summary, at AQF8 level, both design projects and research projects should build upon and develop similar skills of investigation (what is the problem?), literature and practice review (how has this problem be solved or addressed in the past?), identification of feasible solutions (hypotheses), testing of the hypotheses (e.g., in the laboratory or through model simulations) and the production of recommendations, e.g. confirmation of the preferred hypothesis and the rejection of alternative hypotheses (e.g. alternative designs). Students are learning to 'boldly go' beyond the packaged solutions they've learned at AQF7 level.

Developing a research definition at the local level

The OLT project as a whole has sought to recognise that, whilst universities might face similar accreditation imperatives at a national level, there is local variation attributable to factors such as student numbers, resourcing and governance. This means that curriculum, supervision and assessment of FYEPs will vary amongst universities even though there is common purpose to meet EA Stage One Competencies and (usually) AQF level 8 outcomes. The project team has found great value in trying to contextualise the 'research' dimension of AQF8 for engineering and considering how such a definition can assist in evaluating the quality of FYEP students engage in. The final part of this paper urges that all universities undertake such an exercise as a way of gaining meaningful experience and commitment at a local level and offers a schema for a workshop to explore and extend what we have presented here.

The following ideas are based on the dissemination workshops conducted as part of Phase Two of the wider project. It should be noted that whilst there is a focus on the outcome of defining and understanding undergraduate Honours research for each university, our observations of the workshops we have conducted to date suggest that there is much value in the lived experience of the workshop itself. That is, whilst participants might grapple with, debate and question various definitions of research and maybe not reach a definitive outcome, there is value simply in this opportunity to grapple, debate and question. Key to this is for the facilitator/s not to offer commentary or feedback on the ensuing discussion, but rather, keep communication open and focused on participant contributions.

Table 4: Schema for workshop

Mapping the local known	Participants are invited to individually note what aspects of their projects might constitute 'research'. One idea noted on each post-it note. Participants also note what aspects of the project worry or trouble them.
Sense making	Ask participants to stick their notes in clusters according to common ideas/themes (affinity diagram).
Analysing	Show group Tables 2 and 3 (above). In groups, participants take one or more of the clustered ideas and see if they can be mapped to the ideas in the tables. If they cannot, circle or place to one side.
Creating	For the post-it notes not represented in the definitions provided, groups write this aspect of project research as another dot point.

Discussing	Ask the question: what matters to you in research that you think should be retained in the FYEP? Record on whiteboard. Where and how do we support this is in our project subjects?
Synthesising	Based on the earlier analysis, creation and discussion activities, what is 'research' in our FYEPs? What do we need to do from here to ensure that all projects embody this? What are we already doing?

Conclusions

Final Year Engineering Projects are rightly positioned as capstone because they enable students to demonstrate both the culmination of their learning and to extend their technical and professional skills in new territory. For compliance with the Australian Qualifications Framework Level 8 outcomes, demonstrated learning must also include research activity. Generating a definition of research as contextualised for engineering education has been useful in defining the types of activities students can engage in across a full range of engineering projects at undergraduate Honours level. Such a definition has pointed to the ways in which students' projects, either design or research focussed, can afford AQF8 level learning outcomes and contribute to new understanding and knowledge at a local level. It is suggested that in understanding how projects can embody research activity, each institution should undertake to examine what research means to them and in their context. A schema for generating this dialogue presents one means for achieving this.

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