Reviewing and reforming a traditional engineering course

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Abstract

This paper outlines how academic staff have used the ten Generic Graduate Attributes prescribed by Engineers Australia to map the Civil and Construction Engineering degree at Curtin University of Technology. The paper describes and provides illustrative materials about the way in which the degree was mapped, the way staff engaged in the design and evaluation process and the way in which the degree now meets the competing demands made by a range of stakeholders. The contribution this curriculum work makes to engineering education lies in the curriculum design and evaluation processes that were used by the staff in the Civil Engineering Department at Curtin.

Introduction

At Curtin University of Technology an Outcomes Focused Education (OFE) approach is being rolled out which requires staff to re-conceptualise curriculum design from the broad course level to the more specific level in units. Statements of generic graduate attributes and learning outcomes at these different levels must be in terms of the range of student learning and not only the content knowledge and skills they will acquire. Furthermore, a Common First Year of study for all engineering disciplines was implemented at Curtin 2004. A developmental and sequential way of curriculum design within an outcome-focused approach, together with a major revision of the course, has not been a straightforward process for staff as they attempt to make statements for student learning in the knowledge-age of the 21st century. The design process becomes even more confronting when the implications for teaching, learning and assessment in an outcomes framework are considered within the broad program structure of an engineering degree suggested by Engineers Australia. Thus the purpose of this paper is to describe how academic staff have used the Generic Graduate Attributes, prescribed by Engineers Australia, have mapped these into the Civil and Construction engineering degree at Curtin.

Over the past 20 years at Curtin several influences have impacted on the civil engineering degree and it has evolved, perhaps haphazardly, based on gradual but significant changes. One major change was the amalgamation of two degrees, civil and construction, into a single degree making it by default a double degree. Another policy change at Curtin, the Consolidated Teaching Policy, demanded that units be re-sized into 25 or 12.5 credits from 30 credit size units. Naturally, like all academic staff across the University, civil engineering staff were reluctant to "let go" of the unit content and change the units for which they were responsible. As a consequence, students seasonally complained about the workload in their studies. The introduction of the Common First Year for all engineering disciplines created further change. While the program was designed around the Generic Graduate Attributes (Engineers Australia), it still remained to be confirmed that the subsequent years of the degree were cohesively linked as a sound curriculum design. These pressures, together with the demands from industry and institutional resource constraints faced by all Australian universities, has highlighted a growing need to review and evaluate the design of the civil and construction degree. When the opportunity arose to apply for internal University funding to address the recently introduced outcome-focused education (OFE) approach at Curtin, the authors (Head of Department, Civil Engineering and the Teaching Fellow for the Division of Engineering, Science and Computing) applied and gained funds to conduct a project titled *Workload and Learning Outcomes in the Civil and Construction Engineering Degree*.

The purpose for the project was multifaceted and encompassed:

1. mapping the Civil and Construction Engineering degree to demonstrate how the Generic Graduate Attributes were embedded into the design of the degree;
2. defining Course Learning Outcomes (CLOs), as required by Curtin, for the degree; and
3. ascertaining where the workload was too heavy for students by examining the Unit Learning Outcomes (ULOs) for each unit in relation to the set assessments tasks.

Rationale for the Curriculum Work

For over a decade now, Curtin University, like all Australian universities has been developing statements of generic graduate attributes based on the Higher Education Council report *Achieving Quality*[1]. According to Barrie[2]

> [b]roadly speaking, generic graduate attributes in Australia have come to be accepted as being the skills, knowledge and abilities of university graduates, beyond disciplinary content knowledge, which are applicable to a range of contexts. It is intended that university students acquire these qualities as one of the outcomes of successfully completing any undergraduate degree at university. (p. 262)

Moreover, the major review of the accreditation of engineering programs in Australia reported in *Changing the Culture: Engineering Education into the Future*[3] generated a focus on outcomes based engineering curricula. Subsequently, ten Generic Graduate Attributes were identified for all engineering graduates to acquire (see Figure 1).

The essential principles underpinning outcome-based education (OBE) are:

- identifying the clarity of focus for curriculum design;
- designing downwards from broad statements about significant outcomes;

- setting high expectations for students to achieve; and
- expanding the opportunities for students to engage in worthwhile learning experiences[4-7].

Willis and Kissane believe that the curriculum approach should encompass restructuring the curriculum, assessments and reporting processes to allow students to demonstrate their achievement of higher order learning and mastery[8]. Further, in the outcomes approach there is a shift in emphasis from teaching to learning and how students' demonstration of their learning might be assessed.

Curtin University, in order to distance itself from the various interpretations of OBE, has adopted the term outcome-focused education (OFE) to drive the planning of all courses to ensure graduates achieve the Curtin identified attributes. Barrie[2], however, noted that academics have differing conceptions about generic graduate attributes and how these outcomes might be realised through the teaching, learning and assessment processes as universities attempt to implement systematic curriculum reform. In particular, assessment practices in higher education have been challenged which is partly due to the importance given to students' development of generic graduate attributes [9]. These issues are relevant to Curtin. It was important that academic staff in the Civil Engineering Department developed some shared understanding of these issues to ensure that the course they taught met the outcomes expected by various stakeholders.

Stages in the Project

The initial step taken in the project was when academic staff examined both the Generic Graduate Attributes (Engineers Australia) and the Graduate Attributes (Curtin University) to ascertain that these sets of statements were closely inter-related. The links between these two sets of attributes were explicated to ensure that civil and construction graduates from Curtin were characterised by both the expectations set by the University and the engineering profession. Once staff were satisfied that mapping the Generic Graduate Attributes (Engineers Australia) would serve both "masters", the mapping process to embed the attributes into the degree followed several stages.

The First Stage of the process involved mapping each unit using a template which is illustrated in Figure 1 where Fluid Mechanics 230, a 25 credit unit, is shown as an example unit.
An external consultant, a civil engineer by profession and knowledgeable in the area of outcome-based education, was employed to initially map the second, third and fourth years of the civil and construction degree using the mapping template shown. (Please note for the purpose of this paper not all of the syllabus details have been included in the example.)

The process was a both a qualitative and quantitative one, although subjective, with the consultant making professional judgements about the proportion of credit points allocated to each of the Generic Graduate Attributes being fostered in each specific unit. However, the strength of these judgements was that they were made external to those intimately involved with the design of the units. In Figure 1 there are notes to justify way in which evidence was provided for the judgements made. To complete the mapping of the whole degree, the consultant then mapped the Common First Year because it was important to ascertain how this year contributed to the overall degree. (It also will be useful information for the other engineering disciplines at Curtin.).

Fluid Mechanics 230	Credits: 25	
Learning Outcomes	Successful students in this unit will be able to: 1. Recognise fluid phenomena and understand their causes, especially with regard to viscous and inviscid flows; 2. Characterise fluid behaviour and its effects using non-dimensional groups; 3. Apply basic conservation principles in Fluid Mechanics; 4. Model simple flow situations to make estimates of fluid forces; and 5. Perform design calculations for engineering applications that involve fluid flow.	
Generic Graduate Attributes	**Credit Proportion and Evidence** **NB. Not all GGAs will be addressed in each unit.**	
Apply Knowledge	5/25 Application of Engineering principles to fluid networks	
Communication	3/25 participation in group laboratory and class exercises	
Technical Competence	5/25 development of civil engineering skills as related to fluid mechanics	
Problem Solving	6/25 solution of fluid mechanics problems	
Systems Approach to Design	4/25 perform design calculations for engineering applications involving fluid flow	
Team Work	2/25 participation in laboratory and class projects	
Professional Responsibilities	Not addressed	
Sustainable Development	Not addressed	
Ethical Responsibilities	Not addressed	
Lifelong Learning	Not addressed	
Syllabus:	**Part 1: Ideal Fluid Flow** **Part 2: Viscous Effects in Fluid flow** ***Note****: Weekly detail of content to be taught was included in this mapping template.*	
Methods of Assessment:	**Assessment Method**	**Value**
	Two-hour examination	60%
	Assessed Laboratory	10%
	Assessed Group Exercise	10%
	Class test	20%

Figure 1. Template for Mapping Generic Graduate Attributes in a Unit

The Second Stage of the process was commenced after the independent mapping process was completed. The authors aggregated the units in the manner shown in Table 1 for each year level. Year 2 units in the degree are shown to illustrate how each year level of the degree was mapped to this point. Fluid Mechanics 230, the example use as an illustration in Figure 1, can be viewed in Table 1 within the framework of the other second year units. The ten Generic Graduate Attributes (Engineers Australia) are listed for reference.

The Third Stage in the process was to test the reliability of the mapping. Each year level was sorted into the program components recommended by Engineers

Australia (mathematics, science and engineering fundamentals; design and projects; discipline specialisation; professional practice; and other) as illustrated in Table 2. It is important to note that the authors made an arbitrary decision [but one based on professional and academic experience] at this stage of the mapping process.

Table 1. Contribution of Second Year Units to the Generic Graduate Attributes

S/Yr	Unit	Teaching school/dept	Contribution of Units to the Graduate Generic Attributes										
			a	b	c	d	e	f	g	h	i	j	Evidence for unit contribution
S1/Y2	Fluid Mechanics 230 **25 Credits**		16% 4	12% 3	20% 5	24% 6	16% 4	8% 2	0%	4% 1	0%	0%	Applications of engineering principles to fluid networks. Development of civil engineering skills as related to fluid mechanics. Solution of fluid mechanics problems. Group participation in laboratory and project work.
	Structural Analysis 267 **25 Credits**		28% 7	8% 2	28% 7	28% 7	0%	8% 2	0%	0%	0%	0%	Application of engineering statics to structural problems. Participation in group exercises and lab work. Development of competence in structural/civil engineering. Solution of structural engineering problems.
	Civil Engineering Materials 267 **25 Credits**		28% 7	8% 2	28% 7	28% 7	0%	8% 2	0%	0%	0%	0%	Application of engineering knowledge in the use of engineering materials. Participation in lab work. Development of competence in the selection of engineering materials. (civil). Solution of combined stress problems.
	Civil Engineering Methods 267 **25 Credits**		20% 5	8% 2	20% 5	20% 5	20% 5	8% 2	0%	4% 1	0%	0%	Apply the limit design process. Communicate effectively with lecturer and peers. Technical competence in structural design. Provide solutions to a design brief. Familiarity with the design process. Some introduction to a team approach to design. Some appreciation of the sustainable design concept.

(Table 1 continues)

a) Ability to apply knowledge of basic science and engineering fundamentals;

b) Ability to communicate effectively,

c) In-depth technical competence in at least one engineering discipline;

d) Ability to undertake problem identification, formulation, and solution;

e) Ability to utilise a systems approach to design and operational performance;

f) Ability to function effectively as an individual and in multi-disciplinary and multi-cultural teams, with the capacity to be a leader or manager as well as an effective team member;

g) Understanding of the social, cultural, global and environmental responsibilities of the professional engineer, and the need for sustainable design and development;

h) Understanding of the principles of sustainable design and development;

i) Understanding of professional and ethical responsibilities and commitment to them; and

j) Expectation of the need to undertake lifelong learning, and capacity to do so.

(Table 1 continued)

S/Yr	Unit	Teaching school/dept	Contribution of Units to the Graduate Generic Attributes										
			a	b	c	d	e	f	g	h	i	j	**Evidence for unit contribution**
S2/Y2	Structural Design 266 **25 Credits**		16% 4	8% 2	20% 5	20% 5	20% 5	8% 2	0%	4% 1	0%	4% 1	Apply the limit design process. Technical competence in structural design. Familiarity with the design brief. Provisions of solutions to a design brief. Introduce the team approach to design appreciation of the sustainable design concept. Communicate and work in a design team
	Geotechnical Engineering 268 **25 Credits**		32% 8	0%	32% 8	32% 8	0%	0%	0%	4% 1	0%	0%	Application of engineering principles to soil related behaviour. Development of skill in civil engineering as related to soil mechanics. Solution of soil mechanics problems. Treatment of sustainable development through soil related problems such as drainage and stability of soils.
	Structural Analysis 268 **25 Credits**		28% 7	8% 2	28% 7	28% 7	0%	8% 2	0%	0%	0%	0%	Application of engineering statics to structural problems. Participation in group exercises and lab work. Development of competence in structural/civil engineering. Solution of structural engineering problems.
	Civil Engineering Analysis 262 **25 Credits**		16% 4	8% 2	32% 8	36% 9	0%	8% 2	0%	0%	0%	0%	Apply statistics and principles of stress analysis to assess risk and design structural elements. Technical competence in stress analysis and structural analysis. Involvement in group work and projects.
		Total Credit Points = 200	46	15	52	54	14	14	0	4	0	1	
		Average % second year units	23 %	8%	26 %	27 %	7%	7%	0%	2%	0%	1%	% Av Contribution to credits

a) Ability to apply knowledge of basic science and engineering fundamentals;

b) Ability to communicate effectively,

c) In-depth technical competence in at least one engineering discipline;

d) Ability to undertake problem identification, formulation, and solution;

f) Ability to function effectively as an individual and in multi-disciplinary and multi-cultural teams, with the capacity to be a leader or manager as well as an effective team member;

g) Understanding of the social, cultural, global and environmental responsibilities of the professional engineer, and the need for sustainable design and development;

h) Understanding of the principles of sustainable design and development;

e) Ability to utilise a systems approach to design and operational performance;

i) Understanding of professional and ethical responsibilities and commitment to them; and

j) Expectation of the need to undertake lifelong learning, and capacity to do so.

The conflation of the Generic Graduate Attributes into the program components was conducted to analyse the way the design of the degree met expected requirements. The Generic Graduate Attributes were coalesced into the program components in the following way.

mathematics, science and engineering fundamentals

a) Ability to apply knowledge of basic science and engineering fundamentals
d) Ability to undertake problem identification, formulation, and solution

design and projects

b) Ability to communicate effectively,
e) Ability to utilise a systems approach to design and operational performance
h) Understanding of the principles of sustainable design and development

discipline specialisation

c) In-depth technical competence in at least one engineering discipline

professional practice

f) Ability to function effectively as an individual and in multi-disciplinary and multi-cultural teams, with the capacity to be a leader or manager as well as an effective team member
g) Understanding of the social, cultural, global and environmental responsibilities of the professional engineer, and the need for sustainable design and development
i) Understanding of professional and ethical responsibilities and commitment to them

other

j) Expectation of the need to undertake lifelong learning, and capacity to do so

Table 2. Generic Graduate Attributes and Program Components – Year 2

	MSE	Des+proj	Special	Prof & mngt	Other	Credits
Fluid Mechanics 230	40%	32%	20%	8%	0%	
	10	8	5	2	0	25
Structural Analysis 267	56%	8%	28%	8%	0%	
	14	2	7	2	0	25
Civil Engineering Materials 267	56%	8%	28%	8%	0%	
	14	2	7	2	0	25
Civil Engineering Methods 267	40%	32%	20%	8%	0%	
	10	8	5	2	0	25
Structural Design 266	36%	32%	20%	8%	4%	
	9	8	5	2	1	25
Geotechnical Engineering 268	64%	4%	32%	0%	0%	
	16	1	8	0	0	25
Structural Analysis 268	56%	8%	28%	8%	0%	
	14	2	7	2	0	25
Civil Engineering Analysis 262	52%	8%	32%	8%	0%	
	13	2	8	2	0	25
	MSE	**Des+proj**	**Special**	**Prof & mngt**	**Other**	**Credits**
2nd year totals	50%	17%	26%	7%	1%	
	100	33	52	14	1	200

MSE= mathematics, science, engineering principles, skills and tools appropriate to the discipline of study (Engineers Australia guideline >40%)
Des+proj= engineering design and projects (Engineers Australia guideline ~20%)
Special= engineering discipline specialisation (Engineers Australia guideline ~20%)
Prof & mgt= integrated exposure to professional engineering practice, including management and professional ethics (Engineers Australia guideline ~10%)
Other= more of any of the above or other elective studies (Engineers Australia guideline ~10%)

The Fourth* Stage** of the process included each year level of the program being mapped and the year levels aggregated into an overview of the civil and construction engineering program according to the process described in ***Stage Three. The result is shown in Table 3.

Table 3. Proportions of the Degree in Relation to the Program Components

	MSE	Des+proj	Special	Prof & mngt	Other	
CFY	113	19	39	24	6	200
Year 2	100	33	52	14	1	200
Year 3	92	33	48.5	20	6.5	200
Year 4	41.5	40	25.5	25.5	5	137.5
	MSE	**Des+proj**	**Special**	**Prof & mngt**	**Other**	
Total no options	347	125	165	83	19	738
	47%	17%	22%	11%	3%	
	MSE	**Des+proj**	**Special**	**Prof & mngt**	**Other**	
Total with final	366.5	129.5	190	93	21	800
year options	**46%**	**16%**	**24%**	**12%**	**3%**	

The structure of the program for civil and construction engineering meets the requirements specified by Engineers Australia.

The Fifth Stage of the project was to distil the Generic Graduate Attributes into broad learning outcome statements for the program. To meet Curtin's OFE requirements, Course Learning Outcomes (CLOs) must be stated for all courses. Staff identified these Course Learning Outcomes based on the key areas of capability that a graduate should demonstrate. These Course Learning Outcomes are shown in Figure 2.

Engineering Knowledge	Engineering Application	Professional Attributes
Students are able to: 1. Design and construct civil works to a level commensurate with a junior engineer with full understanding of the design and construction requirements of the design and construction process. 2. Manage and make significant contributions to the feasibility of the design and construction process. 3. Work with the inter-relationship between different engineering disciplines and the sub-disciplines of civil engineering: • structures; • materials; • geomechanics; • water; and • construction.	**Students are able to:** 4. Apply their knowledge and experience to solve engineering problems. 5. Integrate their learning with client requirements to produce feasible, practical, and economic solutions to civil engineering problems. 6. As lifelong learners, work within the limitations of their own knowledge and continually extend their professional understandings and skills. 7. Deal with and take due account of the positive and negative aspects of their contributions to civil engineering works in relation to the aesthetic, environmental, economic, social and political impacts.	**Students are able to:** 8. Acquit themselves in their work as junior civil engineers according to the extent, breadth, and depth of the work expected of civil engineers. 9. Make a contribution to the civil engineering profession at a junior level. 10. Continue and quickly improve their knowledge and skills base, building on their undergraduate learning. 11. Integrate the implications of civil works with environmental, social, economic and political matters.

Figure 2. CLOs for the Civil and Construction Engineering Degree

The Sixth Stage of the project remains as work in progress. Now that the structure of the program has been reviewed, staff need to examine how to embed the Course Learning Outcomes into each unit as Unit Learning Outcome. These must be statements which are clearly and cohesively expressed within and across units in the different year levels of the program. Moreover, it will be imperative to consider these Unit Learning Outcome statements as ones that will capture the dynamic nature of students' working futures in the profession. At the same time, assessment tasks for each unit which authentically assess students' achievement in a developmental, progressive and culminating way will be audited for fairness and appropriateness with due consideration to the workload of students' undergraduate work.

Findings

From the mapping to date, two clear findings have been established. First, the degrees, despite the ongoing changes over the past 20 years has retained a reasonable balance in terms of the broad goals intended for student achievement. It seems that content experts in the ongoing curriculum development of the degree, the academic civil engineers in this case, have used their professional judgement wisely to make informed decisions about making any changes to the academic structure of the degree. Second, the Generic Graduate Attribute, *lifelong learning*, emerged as problematic when this attribute was used as an identifier and isolated in the mapping process. It was, as it were, in a different dimension from the other attributes and could not be easily assessed as a percentage of the overall learning quotient. The attribute is not transparent in the design of the program and will need closer attention when Unit Learning Outcomes are defined for different units. This attribute, as with the others, must be made patently obvious to students. Students need to be clear about what they are learning and how this learning leads to their desirable qualities as a civil and construction engineer.

Conclusion

When engineering educators grapple with the intricacies of reform in the curriculum design of a traditional degree course such as civil engineering, patterns of professional thinking and inquiry are challenged. Many of the confronting issues are associated with the considerable and rapid changes occurring in industry and the world of work. The professional inquiry process continues as a challenge for all staff who, more often than not, only work with their own immediate teaching and research interests. The process of inquiry in a systematic and planned manner about the holistic nature of an academic program is eventually about arriving at a negotiated curriculum design.

The contribution this curriculum work makes to engineering education lies in the curriculum design and evaluation processes that were used, and will continue to be used, by the staff in the Civil Engineering Department at Curtin. The curriculum work demonstrates a straightforward way to work with the complexity of review and reform of a degree for a university's internal purposes and for external accreditation by Engineers Australia.

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