What should we teach?
Defining your discipline to drive curriculum renewal: an environmental engineering case study

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INTRODUCTION

In Australia, the federal government, employers, and accrediting bodies, such as Engineers Australia, are calling for more clearly defined *program outcomes* or *exit standards* for engineering programs [1-3]. Engineering Schools are therefore under increasing pressure to more clearly define what graduates from four or five year engineering programs should *know* and be able to *do*.

This paper describes a simple, but elegant stakeholder process that can be used to define the capabilities of a graduate who could claim in-depth technical competence in their discipline. The Defining Your Discipline (DYD) Process [4] may be used by educational institutions and industry organisations to develop practitioner-authenticated sets of *graduate capabilities* for their discipline.

During 2010 and 2011, the DYD team worked with the members of Engineers Australia's Environmental College to produce a set of graduate capabilities for environmental engineering programs. This work resulted in the publication of a Guide [5] that defines the profession's expectations of the capabilities of graduates during their first two or three years of practice. These graduate capabilities are described, including the Environmental Engineering Capability Cube, a somewhat unexpected result.

1 THE BACKGROUND

The aim of defining exit standards for engineering programs is to improve:

- Graduate employability skills;
- The quality of educational programs;

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- The international transferability of graduates and qualifications; and
- The marketability of Australia as a provider of high quality tertiary education.

In the Vocational Education and Training (VET) sector, these generic attributes and skills are referred to as *employability skills*. In the higher education sector they are normally referred to as *graduate attributes* or *graduate capabilities*.

This interest in graduate outcomes means that tertiary education providers face increasing pressure to more clearly define what graduates from their programs should *know* and be *able to do*. This is not an easy task for individual institutions, schools or departments because of tight timelines, competing priorities and limited resources. The result is that the definition of program objectives may be undertaken in a rush, often after limited consultation with stakeholders, such as employers and other industry organisations.

Most Australian universities have defined and published a set of graduate attributes that they expect all undergraduate students to acquire in their programs. Barrie [6] suggests that '*... 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.'*

However, these attributes tend to be bland and generic as they must be suitable for graduates from the many different programs offered by a university. They do, however, normally include an attribute that recognises the need for graduates to acquire discipline specific knowledge and skills (**Table 1**).

Table 1 – A comparison of graduate attributes

RMIT graduate attributes are [7]:	USQ graduate attributes are [8]:
• Work-ready • Global in outlook & competence • Environmentally aware & responsive • Culturally & socially aware • Innovative • Active & lifelong learners	• Discipline Expertise • Professionalism • Global Citizenship • Scholarship • Lifelong Learning

Many professional organisations have defined a set of graduate attributes for their discipline, for example, Engineers Australia's Stage 1 Competency Standard [2]. However, as with university graduate attributes, many of these sets of attributes are bland and lack the detail required for them to be useful as the driver of curriculum renewal, or for assessing graduate outcomes.

Likewise, the proposed national learning and teaching standards for Australia in Engineering and ICT [9] are also a general framework and are not intended to provide a detailed set of disciplinary requirements.

There is, therefore, a need for the establishment of clear, detailed and agreed national standards in the form of discipline-specific graduate capabilities which would provide a sure footing for discipline leaders who must reorient their undergraduate programs to meet current and emerging trends in their discipline.

The DYD project was funded by the Australian Learning and Teaching Council (ALTC) with the intent to develop an efficient, effective, and inclusive consultation process that can be used by discipline stakeholders to define graduate capabilities for their discipline. The method has been tested in the environmental engineering discipline and in three other disciplines.

2 THE SIMPLIFIED PROCESS

At the heart of the DYD process is the definition of *tasks*, in this case the tasks which a graduate from a program should be able to do in their first two or three years after graduation. Stakeholders are given a set of large sticky notes on which they are asked to write, on each note, one task that they would expect a recent graduate to be able to perform in their company. This may be an imaginary task for academics, particularly for those with no industry experience, while it is more authentic for industry representatives, who usually have considerable experience in supervising young graduates, as they know the sorts of tasks that a recent graduate should be able to complete.

After about 20-30 minutes, most participants come to a stop. They can't think of any more tasks. Sometimes, it is helpful for them to talk to people around them for more ideas. This might last another 10-15 minutes.

So, within 40-50 minutes the participants are ready for the next stage, which is to *cluster* the tasks into meaningful groups. This takes another 20-30 minutes. There is usually quite a bit of discussion about the names of the clusters, and also when negotiating the cluster into which an individual task belongs. Examples of tasks and clusters are shown in **Table 2** and **Table 3** [10].

Table 2 – Tasks performed by recent environmental enginering graduates

Process	Examples of identified tasks
Investigation	• Executes simple sampling plans for collection of air, water and soil samples. • Collect, evaluate and interpret water quality data and prepare a report on the results and recommended solutions to improve the water quality.
Audit and compliance	• Audit the environmental compliance of a small, low complexity project against its environmental approval or management plan. • Undertake audits of specific sites or parts of an organisation to identify adequacy of current practice against significant environmental aspects of the operation.
Design	• Contribute to contaminated site remediation design/strategy. • Design a catchment management plan for both groundwater and surface water catchments.
Modelling	• Develop inventories of emissions including the physical, chemical and spatial characteristics of the sources. • Manipulate and combine data to arrive at assessment of aggregate effects. • Calculate mass balances and identify flux paths e.g. water or nutrient.

Table 3 – The adopted Clusters from five of the workshops

Event	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6		Other clusters
1	Design	Environmental management and plan	Auditing	Modelling	Environmental impact assessment	Investigation		Risk assessment
2	Design	Environmental management and plans	Auditing	Modelling	Environmental impact assessment			Data collection & analysis; Communication Project management
3	Design	Environmental management and reporting	Auditing	Modelling				Data collection, Implementation, Evaluation
4	Design solutions	Site management options	Auditing	Conceptual model	Environmental impacts	Site history plus Site investigation		Communication, Data mining /analysis, Project management
5	Design	Management plans and programs	Situational reporting & monitoring		Impact assessment			Stakeholder engagement and communication

3 ENVIRONMENTAL ENGINEERING CLUSTERS

The graduate capabilities are defined by these clusters of tasks that together define what an environmental engineering graduate should be able to do in their first two or three years after graduation, with supervision, of course. The tasks were developed from the information provided by the 111 people (61 academics, 42 practitioners and eight recent graduates) who attended at least one of the 22 DYD stakeholder workshops that were held in all mainland states during 2010 and 2011.

The clustering process undertaken by the participants at each workshop yielded quite unexpected results. The project team had expected that clusters would form around the specialisations in environmental engineering, such as soil, water, energy, noise, and air pollution, with the resulting capability statements forming a more detailed layer in the graduate outcomes hierarchy, one step below, and expanding on, Engineers Australia's Stage 1 Competency Standard [2].

Instead, clusters consistently formed around six major work processes: *Investigation; Modelling and analysis; Integrated design and implementation; Assessment of impact, risk and sustainability; Environmental planning and management; and Audit, compliance and review*. Of these, half of them are quite generic skills (Investigation; Integrated design and implementation; and Modelling and analysis) while the remaining three have a distinctly environmental feel (Assessment of impact, risk and sustainability; Environmental planning and management; and Audit, compliance and review).

The information provided by the participants (more than 1000 task descriptions and comments) was synthesised by the members of the Project Team and then refined by the members of the Environmental Engineering Reference Group. Their role in this process was critical. They also ensured that the focus was on the skills graduates may need in 10 or 20 years as well as current requirements.

The final stage in the stakeholder consultation process was undertaken in February 2012 when all of the members of the Environmental Engineering College and the Heads of the relevant Engineering Schools were invited to comment on a draft of the Guide. The Project Team then considered all of the comments received during this process and refined the guide. This draft was then considered by the College Board and the Environmental Engineering Reference Group. The final draft of the Guide is currently being reviewed prior to publication in November 2012.

4 THE ENVIRONMENTAL ENGINEERING GRADUATE CAPABILITIES

The Stage 1 Competency Standard for Professional Engineers [2] defines the expectations for all engineering graduates, including Environmental Engineering graduates. The major outcome from the DYD Project was the development of a set of *graduate capabilities* that define the Environmental College's requirements for a graduate to be able to claim in-depth technical competence in the environmental engineering discipline.

It is important to note that the graduate capabilities *do not replace* the Stage 1 Competency Standard. The graduate capabilities are to be used in conjunction with the Stage 1 Competency Standard during accreditation visits as they provide an insight into how Stage 1 Competency may be assessed in the Environmental Engineering discipline.

The Graduate Capabilities have been grouped into *three* sets of capabilities and these are accompanied by a *set of contexts* (item 4 below).

1. **Technical Capabilities:** Environmental Engineering graduates are expected to have a sound knowledge of the engineering and science fundamentals that underpin the following eight environmental engineering Technical Domains, and in-depth knowledge and skills

in at least *three* of the Domains: Water resources and supply; Stormwater management and reuse; Water and wastewater treatment; Waste management and reuse; Soils and geology; Air and noise; Energy systems and management; Sustainable communities.

2. **Process Capabilities:** Environmental Engineering graduates are expected to have a sound understanding of *all* six of the environmental engineering processes defined in the DYD process: Investigation; Modelling and analysis; Integrated design and implementation; Assessment of impact, risk and sustainability; Environmental planning and management; and Audit, compliance and review.
3. **Generic Capabilities:** Environmental Engineering graduates are expected to have acquired an appropriate level of knowledge and skills in all seven generic domains: Project management; Ethics; Communication; Innovation; Information; Self-management; and Teamwork [2].
4. **Environmental Engineering Contexts:** Environmental engineering graduates should have an understanding of the Contexts in which they may practice. Seven contexts were defined: Natural environments and systems; Agricultural environments and systems; Industrial environments, processes and systems; Built environments and systems; Natural resources and extraction systems; Utility infrastructure and systems; Transport infrastructure and systems.

The three sets of capabilities are shown as three dimensions in the Capability Cube below (**Figure 1**). This is intended to help visualise learning activities for the purpose of curriculum design. The shaded inner cube is a *design* activity in the area of *waste management and reuse* where *information skills* are being used to gather data and information for the design. It may also address other generic skills such as teamwork and self-management (not shown explicitly). Thus, the many tasks undertaken during the life of a project could be represented by a number of cells in the Capability Cube.

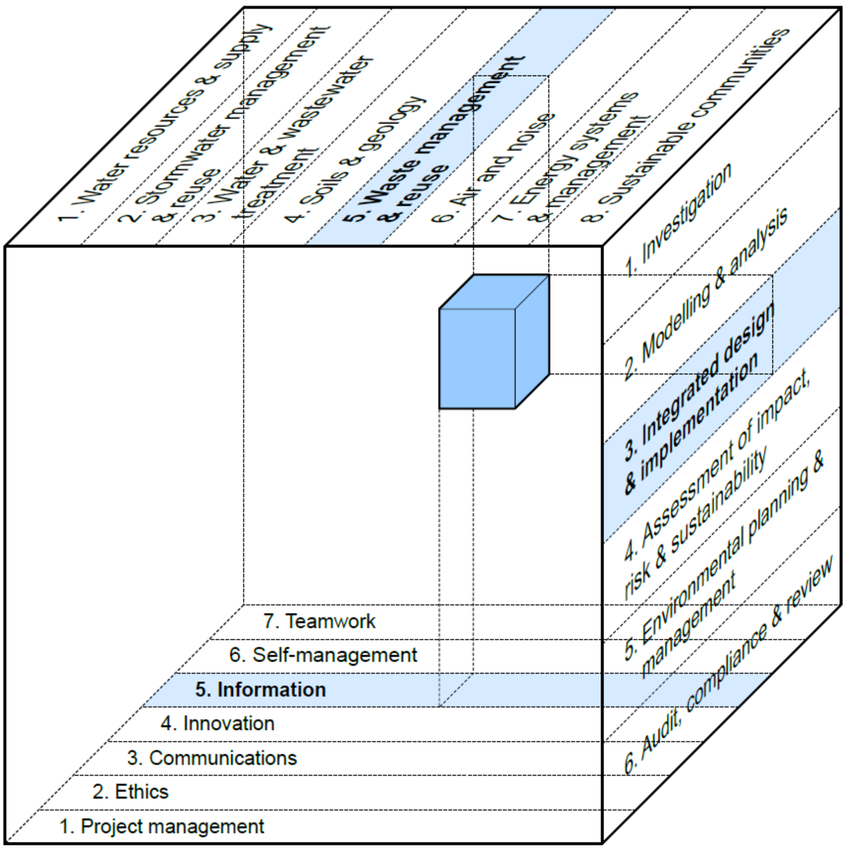

Figure 1 – The Environmental Engineering Capability Cube

5 THE DYD STAKEHOLDER CONSULTATION PROCESS IN MORE DETAIL

The phases of the DYD Stakeholder Consultation Process are shown in more detail in the schematic reproduced below (**Figure 2**). A brief description of each phase in the process, including tips and techniques, is given in the following sections.

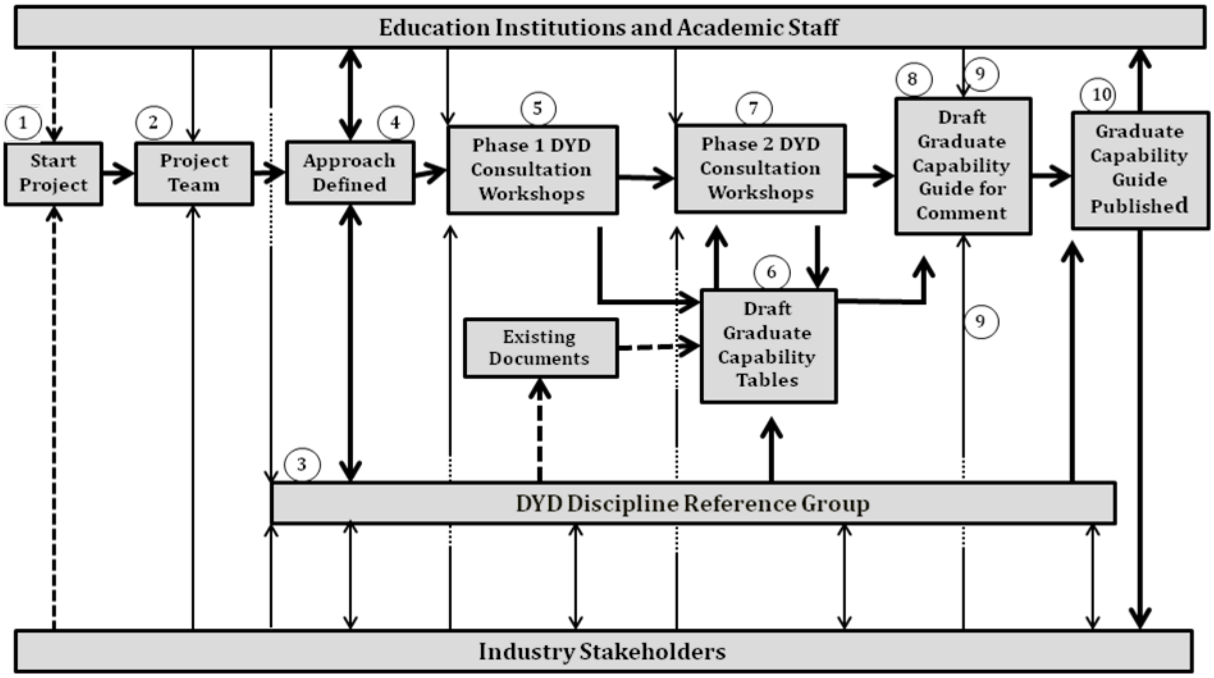

Figure 2 – A schematic showing the steps in the DYD Stakeholder Consultation Process

Step 1: Project initiation: The Project ***Client*** decides to use the DYD Stakeholder Consultation Process to develop a set of Graduate Capabilities for a program. The Client may be an industry organisation, a discipline group from one or more educational institutions, or a combination of these.

Step 2: Appointment of the Project Team: The Client appoints a ***Project Team*** to lead the project and facilitate the development of the Graduate Capabilities for the discipline. Reporting guidelines and funding arrangements are agreed at this stage.

Step 3: Formation of the DYD Discipline Reference Group: The Client appoints a ***Reference Group*** to advise the Project Team and oversee their work.

Step 4: Approach selected: The Project Team consults with the key stakeholders and then decides on the approach to be used to develop the graduate capabilities. This includes the decision to start with a clean slate or to base the graduate capabilities on existing documents.

Step 5: Phase 1 Stakeholder Consultation Workshops: The Project Team organises a series of Stakeholder Consultation Workshops to gather information about the tasks that graduates undertake in their first few years of employment in the industry. The project team works with the Client and the reference group to identify and recruit participants for the workshops, which should include practitioners, recent graduates and teaching staff.

Step 6: Preparation of a draft of the Graduate Capability Tables: A draft set of Graduate Capability tables is developed from the information gathered from the workshops and/or existing documents.

Step 7: Phase 2 Stakeholder Consultation Workshops: The Project Team organises a second series of Stakeholder Consultation Workshops to receive feedback on the draft set of Graduate Capability tables. The Project Team works with the Client and the reference group to identify and recruit participants for the these workshops, including, people who attended the Phase 1 Workshops, teaching staff from relevant educational institutions, and additional people from the stakeholder groups.

Step 8: Preparation of draft Graduate Capability Guide: The Project Team liaises with the Reference Group to review the Phase 2 Workshop responses and finalise the Graduate Capability tables. These are then integrated into the Draft Guide.

Step 9: Stakeholder review of the draft Graduate Capability Guide: The Draft Guide is circulated to all stakeholders for comment.

Step 10: Publication and dissemination of the Graduate Capability Guide: The Project Team liaises with the Reference Group to review the responses from the stakeholder consultation and then finalises the Graduate Capability tables. The Guide is then published and disseminated to stakeholders.

6 CONCLUSIONS

The paper demonstrates an efficient process for determining the graduate outcomes for an engineering degree. The same process is also being tested on non-engineering programs. The process is efficient in terms of stakeholder time, taking about one and a half hours to collect 100-200 tasks to be accomplished by a young graduate, depending on the attendance. The participants categorise these tasks into clusters and these can then be synthesised with the results from other workshops.

The project team believes that it is advisable for a discipline to undertake this work at a national level rather than at the single institution level. The resulting set of graduate capabilities can then be used to inform the curriculum, for example, as a starting point for curriculum renewal. A national approach would also overcome the risk that a School could face if its local stakeholder-defined graduate outcomes were not aligned with the views of the current executive members of the relevant accreditation body.

The interesting result for environmental engineering is the separation of graduate outcomes into technical, process and generic capabilities. A three dimensional view of these capabilities is proposed to demonstrate their inter-relationship.

7 ACKNOWLEDGMENTS

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