Embedding graduate attribute development into the engineering curriculum: less is more?

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***Abstract**: 'Graduate Attributes' is a term which all too frequently sends shivers down the spines of engineering academics. The idea of having to instil a diverse set of professional behaviours and attitudes in youthful engineering students, while still ensuring a level of technical competence, can be intimidating for many. With high stakes associated with accreditation, high level university policy, and external government auditing, there can be perception that addressing as many different attributes as possible in a subject is desirable. Recent research at the University of Wollongong suggests that the idea of tackling several different Graduate attributes may be ineffective. This paper describes a review of six different engineering subjects which investigated what was being done in each subject to address Graduate Attributes, and how these efforts were perceived by students. The findings indicate that subjects addressing just a few graduate attributes in an explicit and in-depth manner may have more effective learning outcomes than subjects attempting to address numerous attributes. Also discussed are issues surrounding academics perceptions of Graduate attributes statements, and how these impact on teaching approaches and student perceptions.*

Introduction

The embodiment of graduate attributes in the university teaching and learning experience has stood out as a major challenge for the higher education sector in the UK, US and Australasia (Adams & Felder, 2008; S. C. Barrie, Hughes, & Smith, 2009; Bradley, 2006; Harpe et al., 2009; Rugarcia, Felder, Woods, & Stice, 2000). These graduate attributes are generally understood as generic outcomes of university educational experiences, which can also be referred to as graduate capabilities or qualities. In Australia, the significance of graduate attribute development has been clearly stated in policy documents and strategic plans for teaching and learning at many universities (S. C. Barrie, 2007; Chanock, Clereban, Moore, & Prince, 2004; Hadgraft & Muir, 2003). Many universities have also identified ways to support the development of graduate attributes at the institutional, course, and to a lesser extent, subject level (Nghiem & Bell, 2008). Indeed, there has been an increased emphasis on research to facilitate the development of generic capabilities of graduates as an integrated outcome of a university training process.

Graduate attributes can be seen as an orientating statement of education outcomes used to inform curriculum design and engagement with teaching and learning experiences at a university (S. C. Barrie, 2009; S. C. Barrie et al., 2009). Graduate attributes describe the core abilities and values a university community agrees all its graduates should attain as a result of successfully completing their university studies. However, while all Australian universities claim such outcomes in policy, few can

provide convincing evidence of success in translating such institutional policy to tangible student learning outcomes (Harpe et al., 2009). In fact, many universities still seem to struggle with comprehensively and systematically embedding graduate attributes in their curricula (S. C. Barrie et al., 2009). This slow progress is despite an acknowledgement by all stakeholders that graduate attributes are important. Acknowledging the challenge of curriculum renewal to achieve graduate attribute development within universities and across the sector, several dedicated research projects have recently been funded by the ALTC to disentangle the many complex issues involved (see for example the National GAP project or the *B* Factor project (S. C. Barrie et al., 2009; Harpe et al., 2009)). According to Barrie et al., (2009) there needs to be a strategy for developing a shared, complex understanding of the many facets of the embodiment of graduate attributes in university teaching and learning. Such shared understanding reflects the multi-dimension and multi-viewpoint of a typical educational process which is the hallmark of a scholarly community. Overall, Barrie et al., (2009) suggest a fundamental focus on students and teaching staff, along with the development of an institutional framework that can support university staff in engaging with graduate attributes curriculum renewal in an intellectual and scholarly way. In another ALTC project (known as the *B* Factor project) conducted by Harpe et al., (2009) the beliefs of academic staff about graduate attributes were systematically examined. The *B* Factor project clearly highlights the considerable gap between teaching staff believing in graduate attributes and having the confidence and willingness to teach and assess them in their courses. Harpe et al., (2009) also raise questions about the efficiency and wisdom of traditional change approaches used by universities to further the graduate attribute agenda.

This small sample of the literature on graduate attributes points toward staff development as, perhaps, the most significant challenge in the quest to successfully and meaningfully embed graduate attribute development in university curricula. This study aims to identify key learning and teaching strategies that teaching staff can readily implement in a typical engineering classroom environment. The research seeks to elucidate the distinction between indiscriminately targeting a long list of graduate attributes simultaneously within a single subject versus a strategic and in-depth development of a limited number of graduate attributes suitable to the nature of the particular subject.

Research methodology

This study consisted of three major components: (1) a comprehensive literature review; (2) student survey; and (3) interview of teaching staff. The literature review aimed to define a set of criteria to evaluate the feasibility of a range of teaching and learning activities which could be implemented in a typical engineering classroom to engage students in graduate attribute development. The student survey and staff interview aimed to map and calibrate the graduate attribute targets stated in the subject outline and actual learning/teaching activities. The student survey was conducted at the end of the spring semester (week 10 or 11) in the 2009 academic year. Six engineering subjects (Table 1) were selected for this study and the students were invited to complete the questionnaire form on a voluntary basis. These subjects were selected to present a wide spectrum of engineering teaching at the University of Wollongong. The survey was administered at the beginning of the class by a staff member who was not involved in the teaching of the selected subjects. At least one member of teaching staff involved in the delivery of each of the above subjects was interviewed shortly after the completion of the semester. The interview was conducted in a semi-structured format. It was recorded and fully transcribed for subsequent analysis.

Table 1: Selected subjects for the survey

Subject name	Code name	Level	No of students	Student Response rate	No of teaching staff
Physics for engineers	PHYS142	1st yr	240	78% (50% invited)	6
Air & noise pollution eng.	ENVE221	2nd yr	38	58%	2
Construction materials	CVIL245	2nd yr	85	75%	4
Ceramics, glass & refractories	MATE303	3rd yr	11	91%	1
Applied Finite Element Analysis	CVIL491	4th yr	31	68%	2
Mining economics	MINE412	4th yr	35	57%	1

Results and Discussion

Criteria for useful instructional methods

There is an apparent lack of focus on the support in graduate attribute development available to teaching staff (Harpe et al., 2009). Many Australian universities have not developed a formal training program to assist their staff with the teaching of graduate attributes. Although good teaching practices that can facilitate graduate attribute development do exist, they are not well documented and widely articulated to teaching staff. Recognizing the enormity of this issue, we first scanned the literature to define a set of criteria against which teaching staff would like to use when considering new or different teaching methods. A brief synthesis of our literature review is presented here. A collection of six papers reported by Felder and co-worker represents one of the most significant volumes of work in this area (Rugarcia et al., 2000). Although these authors did not specifically address the issue of graduate attributes (or generic skills), the essence of their work is readily transferable to formulate a set of criteria for useful instructional methods that can facilitate graduate attributes development.

According to our literature review, the instructional methods to be widely adapted by academic staff should meet the following criteria (Felder, Woods, Stice, & Rugarcia, 2000):

- ***Relevant to engineering education:*** Involvement of students is critical for effective classroom learning. However, as Felder et al., (2000) correctly pointed out, much of the basic content of engineering courses is not a matter of opinion. Graduate attribute development must not be done at the expense of discipline specific technical content. It is essential that the relevance of the selected teaching activity to engineering education must be made explicit and must be appreciable by both teaching staff and the students.
- ***Suitable for a typical engineering classroom:*** Recent years have seen numerous novel applications of technologies, particularly information technologies, to advance university teaching and learning. These technological based applications have an enormous potential and may have been well proven in a specific context. However, academic staff are likely to only adapt teaching techniques that can be implemented in regular classrooms and laboratories with equipment routinely available to all engineering teaching staff. This criterion should not be taken as technophobia. It is rather a hard look at the reality.
- ***Matching teaching techniques to staff expertise:*** It is conceivable that teaching staff can often achieve the best outcome when they can operate within their comfort zone. Diversity has been the hallmark of the academic community in Australian and in many other countries. While techniques like role-play have been recognized as an excellent approach to foster graduate attributes development, many staff may not have the required level of comfort in social and interpersonal interaction to adapt this technique. On the other hand, those staff would most likely have a unique ability that made them hirable by their institution at the first place.
- ***Consistent with modern theories of learning and have been tried and proven effective:*** It is intuitive that successful teaching techniques that can foster the development of graduate attributes in engineering curriculum must have a pedagogical basis and must be well proven. Given the number of novel teaching techniques reported in the literature, one would naturally be reluctant to implement them until evidence of consistency and successful implementation in engineering class by independent investigators or their peers. Again, this should not be seen as anti innovation, but rather a frank consideration of the time budget and resources available to a typical teaching staff.

Student survey and staff interview

On average, it took a student approximately 10 minutes to complete the survey. It is noted that PHYS142 was a large subject and approximately 50% of the students of this class were invited to participate in the survey. At least two interesting implications can be interpreted from this survey. In good agreement with a previous study (Nghiem and Bell, 2008), the results suggest that the development of some graduate attributes can occur as a consequence of the learning process, even if the teaching staff have not specifically intended to target those graduate attributes. Student survey results obtained from the ENVE221 subject are presented in Figure 2 and Table 2 as an example.

Attributes 3 and 6 were perceived as developed by students (shown in Figure 2) while not integrated into the subject (as in Table 2).

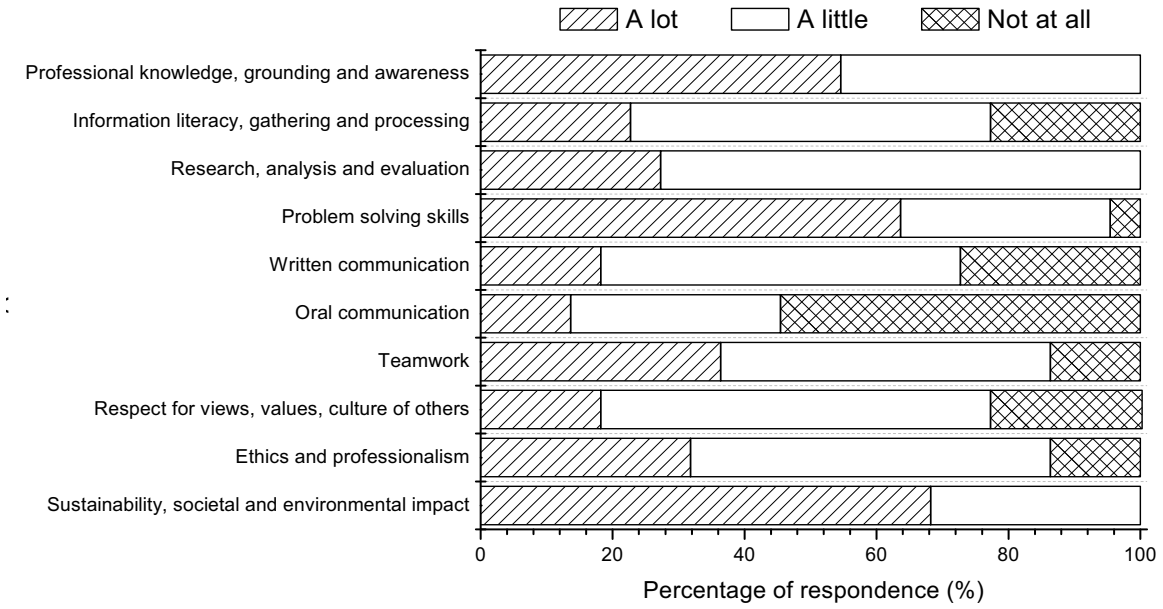

Figure 2: Results of the student survey of the ENVE221 subject (n=22; Respondent rate = 58%).

Table 2: Targeted graduate attributes to be developed in the teaching and learning of ENVE221

No	Learning Outcomes	UoW Engineering Graduate Capabilities in this subject
(i)	Understand the basic principles of air & noise pollution	1, 2, 4, 5, 7, 10
(ii)	Identify the significant factors affecting air & noise pollution	1, 2, 4, 5, 7
(iii)	Become proficient in laboratory procedures to measure air & noise pollution	1, 2, 4, 5, 7, 10
(iv)	Apply analytical techniques to solve problems in air & noise pollution measurement & control	1, 2, 4, 5, 7, 10

UOW Graduate Quality	UoW Engineering Graduate Capabilities
Informed	1. Professional knowledge, grounding and awareness
Independent learners	2. Information literacy, gathering and processing 3. Research, analysis and evaluation
Problem solvers	4. Problem solving skills
Effective communicators	5. Written communication 6. Oral communication 7. Teamwork
Responsible	8. Respect for views, values, culture of others 9. Ethics and professionalism 10. Sustainability, societal and environmental impact

In all six subjects surveyed in this study, professional knowledge and problem solving are the two most frequently mentioned graduate attributes students indicate that they have had opportunities to develop. This is perhaps not a surprise in the context of engineering education which is in general technically driven. The results also highlight the level of subjective judgement involved in evaluating the development of graduate attributes by both students and teaching staff. This presents a major challenge to the process of mapping and calibrating graduate attribute development of a complete program. Without a structure and measurable approach, graduate attribute development may only occur at the surface. Secondly, it is notable from the obtained results that when teaching staff specifically target only one or two graduate attributes, there is strong indication that students can identify and focus on these specified graduate attributes. Staff interviews also confirm that teaching

staff tend to have a clear and systematic teaching approach to foster the development of graduate attributes when they only target two or three.

Several simple, effective teaching methods have been documented as a result of the interview with teaching staff. For example, the writing of a conference style paper was used to facilitate the development of research, information literacy, and written communication skills among students of the MATE303 subject. Given the specific focus on these three graduate attributes, the educator involved was able to assist the students with their specific needs, and make clear the requirement for students to develop these attributes. Results from the student survey of this subject clearly highlight that "Research, analysis and evaluation", "Information literacy, gathering and processing", and "written communication" were the three dominant graduate attributes students thought were being developed (Figure 3).

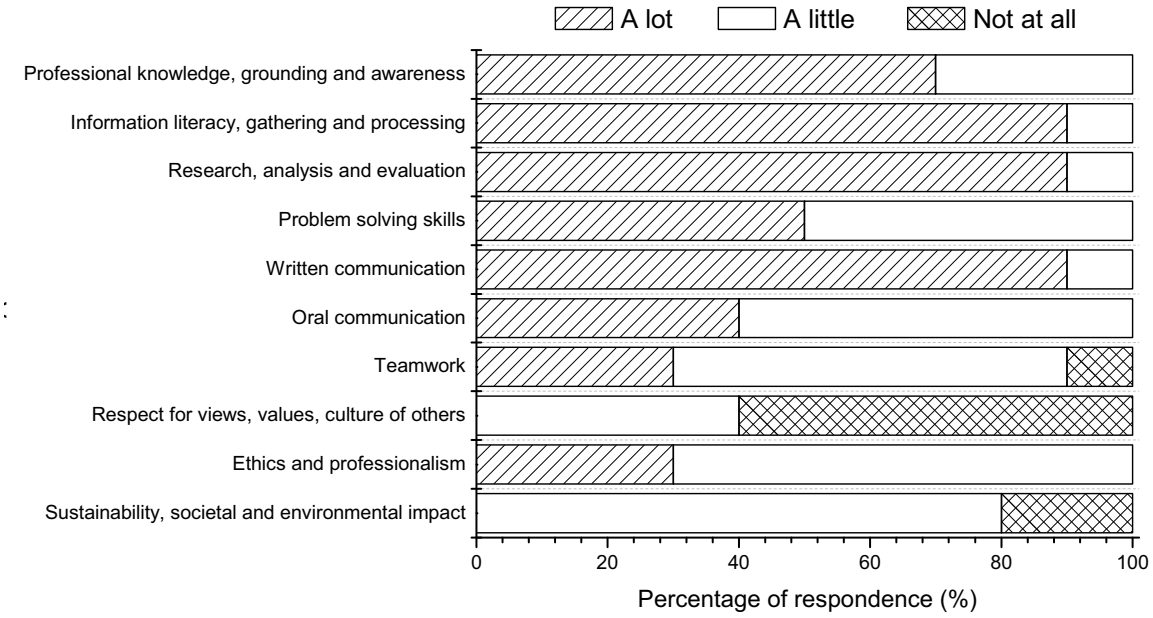

Figure 3 MATE303 student perceptions of learning opportunities (n=10, response rate=90%)

Information gathered from staff interviews also revealed several areas for further improvement with respect to the issue of graduate attribute development. The faculty has a clear policy that graduate attributes to be developed during the course of the subject are to be clearly stated in the subject outline. All academic staff involved in the interviews complied with this requirement. The targeted graduate attributes were briefly discussed and the connection between these attributes and assessment tasks was highlighted to the students in week one. However, there is evidence of inconsistency in the approach toward graduate attribute developments when more than one academic staff involved in the teaching of a subject. Teaching staff who took over the subject after week one often did not have the opportunity to discuss what graduate attributes would be assessed in their part and how. In addition to the number of teaching staff involved, the number of students per class can also be a significant factor limiting the development of graduate attributes that require hands-on practice such as oral presentation. Comprehensive statistical analysis is being conducted to further delineate this relationship between opportunities to embed graduation attribute development to in class teaching/learning activities, the number of students/teaching staff in the subject, and students perceptions of learning opportunities.

Based in the preliminary results of this study, there are indications that when it comes to graduate attributes education, less is indeed more. It has been observed that academics who set out with the intention of teaching just two or three interlinked attributes tend to create learning opportunities that are readily perceived by the students. Where broader approach is used, that is, a wider range of attributes are addressed, students perceptions of these learning opportunities are less consistent. This

inevitably has implications of students awareness of learning, where they appear to be more focused on just getting the assignment done and are missing the opportunities for developing graduate attributes that are available.

Conclusion

This study aimed to develop a body of practical knowledge relevant to the embodiment of graduate attribute development in the context of every day teaching and learning. Information gathered from the staff interviews suggest that the involvement of several academic staff in the delivery of a subject may reduce the consistency in the approach toward graduate attribute development. In addition, there appears to be a relationship between opportunities for graduate attributes development in the context of a subject and the number of students as well as teaching staff involved in that particular subject. Results reported here suggest that the embodiment of graduate attribute development may be more effective if teaching staff focus on only two or three graduate attributes at a time. It is also recommended to establish a more explicit approach in year one for graduate attribute training to allow students to acquire basic knowledge with regard to graduate attribute development at an early stage.

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