Identifying teaching approaches that develop engineering students' graduate attributes

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Abstract*: In Australia, undergraduate engineering programs are accredited, in part, on their demonstrated success in teaching and assessing students' graduate attributes. These graduate attributes are encapsulated in the Engineers Australia Stage 1 Competency Standard which lists seven professional attributes (dubbed 'the PE3s). In this paper we report some interesting findings from a conversational process for qualitatively and quantitatively mapping the teaching of the PE3s in the School of Engineering at the University of Tasmania. We conclude that the quantitative findings allowed gaps to be seen in the teaching of PE3s across years, but also raised questions about when and how much teaching effort should be devoted to graduate attribute development. The qualitative findings suggested a diverse range of approaches to teaching where in use that were judged by academic staff to preferentially develop particular PE3s. The contribution of diverse approaches to teaching to PE3 development, however, was often under-acknowledged and was largely undocumented.*

Introduction

Australian engineering schools are expected to develop undergraduate students' graduate attributes (GA). In the field of engineering, the need for GA learning has been expressed in numerous documents (Henley Report, 2006; King Report, 2008; EA, 2006) and several groups are working on metrics to formally evaluate graduating engineering students' generic skills (Graduate Skills Assessment; AHELO). The teaching, learning and assessment of GAs in Australian undergraduate engineering is mandated by the professional body, Engineers Australia (EA) and the GAs are described in EA's Stage 1 Competency Standard (EA, 2006). Further, EA formally reviews and (re)accredits undergraduate courses in Australia every five years, and part of the review is on the capacity to deliver GA-competent graduates. EA says (2006: 4):

> *The accreditation criteria provide a platform for judging the potential of an individual program to deliver graduates satisfying the Engineers Australia Stage 1 Generic Competency Standards*

Reorienting engineering curriculum and courses to develop students' GAs - while continuing to maintain technical competence at a high level and within limited time - has proved challenging. A series of regional forums in 2007 identified a range of hurdles to the teaching and assessment of GAs including (Carew and Therese, 2007): engineering academics lacking time, motivation, resources or skills to re-orient teaching and assessment approaches; conflict/confusion over definitions of GAs and the appropriate balance with technical learning and skills development; means to stimulate deep student learning; and authentic, efficient means to assess student GA learning. Various researchers have suggested much student GA learning occurs incidentally, accidentally or outside of formal classroom settings (Kuh, 1995; Smith and Bath, 2006; Walther and Radcliffe, 2007). Australian engineering faculties cannot, however, rest on the idea that GAs are developing somehow, somewhere during students' undergraduate tenure – EA require evidence that students are being taught GAs within undergraduate courses, and that student competence is being assessed prior to graduation (EA, 2006).

Method

In this paper, we report on some interesting outcomes from the 2008 audit of GA teaching and assessment for re-accreditation of the University of Tasmania's (UTas) undergraduate engineering courses. The authors developed and used a conversational process to actively engage groups of engineering academics in auditing their teaching and assessment of the Professional Attributes (PE3s) specified in the Stage 1 Competency Standard (EA, 2006) (Box 1). We describe relevant aspect of the conversational process here but further details on design and execution of the wider study are available in Carew and others (2008). As part of the conversational process, groups of 8 academics who taught undergraduate engineering met together to audit their teaching and assessment of the PE3s. During the meeting, each academic was tasked to audit one of the units they taught (an undergraduate degree in engineering at UTas requires successful completion of 32 taught units in addition to a period of professional experience). First the academic rated the teaching of each PE3 in their unit. The rating scale for teaching asked the academic to allocate a numerical value on the extent of focus and coverage each PE3 enjoyed in their unit. The scale encompassed 0 (not covered), 1 (covered to some extent), 2 (a component of learning and assessment), or 3 (attribute is directly assessed). Next, each academic was asked to note down (qualitative) examples of teaching or assessment practices that they used to develop each of the PE3s. Following this, the group of 8 academics debated the numerical rating each of them had allocated to teaching of each PE3 in their unit. During the debate, consensus was reached over what the group considered a 'reasonable' teach rating to allocate based on the qualitative examples described by the academic auditing the unit. The process of academics conversing and debating over teach ratings provided a form of 'calibration' for the teach rating. During the discussion and debate, one of the authors acted as a 'synthesizer' and noted the range of different approaches to teaching and assessment nominated by the groups of participating engineering academics as effective for developing each PE3 under discussion.

The conversational process of debating teach ratings using qualitative evidence had multiple goals: the gathering of evidence to support application for reaccreditation by EA, building the participating academics' confidence in the veracity of the audit/data, and catalysing the sharing of teaching and assessment practices amongst colleagues. Due to the multiple goals, a mixed method research approach was developed to generate rich quantitative and qualitative findings. The process blended methodologies: facilitation and running order from semi-structured group interview technique (Kvale, 1996), and consensus building based in the practices of community consultation (Dick, 1997). The process was also influenced by the intent of appreciative inquiry (Hammond, 1996) which invites individuals and groups to honour, share and explore that which is working well, and by a desire to strengthen the community of (teaching) practice (Lave and Wenger, 1991) within the School for the purpose of academic development.

The primary aim of this research was solving a teaching and learning problem through the 'context specific negotiation of knowledge' (Lawrence and Despres, 2004; Wickson *et al.*, 2006). This definition is drawn from the literature on 'transdisciplinary' or 'Mode 2' (Gibbons, Limoges *et al.*, 1994) research which argues for and supports research designed with the primary intent of making change. As such, the Mode 2 aim of this research was:

1. Engaging engineering academics in research focussed on their graduate attribute (GA) teaching and assessment practices as a preparation for them deciding and enacting change in their (shared) curriculum.

A more traditional conceptualisation of research (Mode 1) would see the aims of this research described differently:

1. Are GAs being taught and assessed throughout the engineering degrees offered at the University of Tasmania (UTas)?
2. How much are GAs being taught and assessed in engineering at UTas?
3. Do UTas engineering academics associate particular approaches to teaching with development of particular GAs?

Results & Discussion

Totalled PE3 teach ratings for Civil Engineering 2nd and 4th year, and Electrical Power Engineering 2nd and 4th year are shown in Box 1. We present totals (rather than means and standard errors) because 100% of the 'population' of units was captured during the auditing process thereby negating the need for statistical analysis. The only legitimate form of 'error' in the research lays in the method which was fundamentally interpretation and debate (subjective), and hence is not claimed as objective. Ratings are 'out of' different totals due to different proportions of service subjects in the 2nd and 4th years of the undergraduate degrees. We present percentages in brackets to represent the actual teach performance as a function of the total teach rating that was possible for each PE3 at each year level/discipline.

Box 1. PE3s average teach rating - two engineering disciplines and two year levels

PE3 Professional Attributes	Total teach rating			
	Civil 2	Civil 4	Elec 2	Elec 4
PE3.1 Ability to communicate effectively, with the engg team and with the community at large	9.5/18 (53%)	8.5/15 (57%)	9.5/15 (63%)	7.0/12 (58%)
PE3.2 Ability to manage information and documentation	10.5 (58%)	8.5 (57%)	10.5 (70%)	7.0 (58%)
PE3.3 Capacity for creativity and innovation	6.5 (36%)	4.5 (30%)	6.5 (43%)	5.0 (42%)
PE3.4 Understanding of, and commitment to, professional and ethical responsibilities	5.0 (28%)	4.0 (27%)	3.0 (20%)	0 (0%)
PE3.5 Ability to function as an individual, in multidisciplinary and multicultural teams, and as team leader, manager, member	8.0 (44%)	5.0 (33%)	7.0 (47%)	4.0 (33%)
PE3.6 Capacity for lifelong learning and professional development	6.5 (36%)	5.0 (33%)	8.5 (57%)	6.0 (50%)
PE3.7 Professional attitudes	7.5 (42%)	7.5 (50%)	7.5 (50%)	2.0 (17%)

The results in Box 1 show that PE3.1 and PE3.2 were the most taught of the professional attributes for these two years in these two degrees. It was heartening to see that participating academics continued to teach teamwork (PE3.5) despite perennial/perceived difficulties with managing student group dynamics, allocation of workload and fair assessment. The two professional attributes which were reported as least taught were creativity and innovation (PE3.3) and professional and ethical responsibilities (PE3.4). Life long learning and PD (PE3.6) gained a low total teach rating in the Civil discipline. The teaching of the PE3s appears to consistently fall away in 4th year in the Electrical Power degree, compared with 2nd year. The results in Box 1 could be interpreted as a need for greater balance in effort and emphasis directed at teaching PEs, particularly PE3s 3.3, 3.4 and 3.6. Or perhaps the findings simply raise useful points for debate: Should each PE3 or GA enjoy equal emphasis, or are some more or less important? Should each PE3 be afforded equal teaching time or effort in all four years of the undergraduate degree? Who should decide which PEs are more or less important (EA, academics, students, industry)? Are some of the PE3s easy or impossible/impractical to teach?

The results in Box 1 were an attempt to quantify the teaching inputs associated with developing students' GAs. During the conversational process, we also captured qualitative evidence of GA teaching in each unit. The qualitative approaches to teaching and assessment nominated by participating academics and collected by the synthesizer for PEs 3.2 (ability to manage information and documentation), 3.3 (capacity for creativity and innovation), and 3.4 (professional and ethical responsibilities) are presented in Box 2. Space precludes presentation of full results. In viewing the exemplars presented in Box 2, it is important to recall that these exemplars were nominated and explained by engineering academics as their interpretation of which of their current teaching practices developed or rewarded development of each of the PE3 professional attributes specified by EA.

Box 2. Teaching and Assessment Exemplars for PE3 Development

3.2 Ability to manage information and documentation

- Library and web research and retrieval
- Citation of references in written work
- Literature reviews
- Pert/Gantt charts (project planning)
- Working with spreadsheets
- Lab reports, assignments, preliminary reports
- Familiarity with diagrams, CAD, circuit schematics, PSpice, Matlab, Labview.

3.3 Capacity for creativity and innovation

- Lectures across streams (disciplines)
- Open-ended problems
- Field trips
- Problem solving in design
- Debates/challenges
- Cross-stream and cross-disciplinary tasks
- Honours projects
- Requirement to read technical papers

3.4 Understanding of professional and ethical responsibilities, and commitment to them

- Exposure to engineering standards
- Use of codes of practice and ethics
- Occupational Health and Safety (OH&S)
- Wiring rules
- External lectures in environmental engineering
- Statutory requirements
- Ethical and social consequences of engineering failures

These findings have multiple significances. It is notable that over a dozen distinct teaching or assessment activities are associated with just three of the PE3s (Box 2). This demonstrates a diversity of approaches to teaching, and diverse interpretation of how students might best be supported and encouraged to develop the PE3s. While the links between some approaches to teaching and development of a PE3 are self evident (eg. creativity and innovation – open-ended problems; managing information and documentation – citation of references; spreadsheets), other exemplars are less obvious and the claim likely depends on how the particular teaching approach is executed or the learning assessed (eg. creativity and innovation – field trips, debates; professionalism and ethics – OH&S, external lectures). Interestingly, while problem-based and project-based learning are generally recognized as high return in terms of GA learning (Dym et al, 2005; de Graff and Kolmos, 2007), they are not the only approaches nominated by participating academics. Some viewed project and design-based learning as better suited to high achieving students, with returns more marginal for 'students without the ability to see linkages between different (sometimes cross-disciplinary) concepts, or lacking the skill or creativity to investigate them unaided'. Prominent Australian educator, Professor Allen Luke, has advocated 'pedagogical pluralism' and the diversity of approaches listed in Box 2 suggest his position is well supported in this particular engineering school.

Part of the motivation for conversational mapping was our observations of discrepancies and omissions in the formal documentation which described learning, teaching and assessment in the School's units (eg. unit outlines, assessment schedules etc…). It was apparent that the 'paper universe' had failed to capture and describe the richness and complexity of teaching and assessment practices in sufficient detail to claim or show how students' PE3s were being developed. This was unsurprising as delivery of technical content has been the traditional focus of teaching in engineering, and unit documentation is still skewed in that direction. Also, academics have previously had little motivation to 'claim' the incidental or accidental PE learning that resulted from use of teaching approaches which were selected for their effectiveness for technical learning (eg. literature review on a technical topics, use of spreadsheets for data sorting and analysis, field trips for exposure to professional practice, technical analysis of engineering failures). The teach ratings shown in Box 1 and the range of different teaching approaches (Box 2) provided evidence that PE3 teaching was an integral part of the existing curriculum. That PE3 teaching was not well represented in the course documentation supports the notion that academics underplay or undervalue the incidental GA learning that likely eventuates from some of their teaching. In other words, some teaching approaches likely provide unrecognised 'bang (technical **and** GA learning) for the buck'.

Conclusion

Perhaps the most salient point from the findings presented is that they shift our focus away from *what* is taught (eg. content, concepts, facts) and towards *how* students are taught. This is particularly salient for the teaching and learning of GAs because part of the intention is to shift students' attitudes and shape behaviours (eg. professionalism, respect for diversity, ethics). We foreshadowed in the introduction to the paper that the need to develop students' attitudes and change behaviour places greater onus on engineering teachers to create learning experiences, as opposed to imbuing students with content, concepts, facts. Walther and Radcliffe (2007) temper this position with a call for greater consideration of the role of behavioural conditioning, accidental competency formation and individual affective learning which may result from creation of learning experiences for students. The findings presented here show the diverse kinds of learning experiences engineering academics at our university are crafting and delivering for students and that those experiences differentially develop GAs. Further research along similar lines could provide a basis for better aligning teaching approach with desired attitudinal and behavioural change in our current and future undergraduate students.

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