

Improving outcomes-based engineering education in Australia *

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SUMMARY: Graduate attributes are now a ubiquitous feature of higher education in Australia and internationally, and have been part of engineering education for more than a decade. The idea of graduate attributes is an apparently simple concept, focusing on educational outcomes, rather than inputs and process. While there is evidence of some benefits in engineering education arising from the introduction of outcomes-based accreditation, there is also evidence of many short-comings of the graduate attributes approach. There would be significant value in Engineers Australia providing additional, discipline-specific guidance on attribute development. There would be significant value in Engineers Australia simplifying and consolidating the current multi-document accreditation system. A genuinely outcomes-based accreditation system would be based (only) on the demonstrated individual student attainment of appropriate graduate attributes, which might be delivered/gained by a range of means, including distance education. To fully meet the letter and spirit of the law for accreditation, programs will need to adopt some method of certification of individual student attainment of graduate attributes – one such method would be the use of student portfolios.

1 INTRODUCTION

Graduate attributes are now a ubiquitous feature of higher education in Australia and internationally, and have been part of engineering education for more than a decade. The idea of graduate attributes is an apparently simple concept, focusing on educational outcomes, rather than inputs and process. However, research has revealed limited understanding of graduate attributes among educators and an often superficial response to graduate attributes by institutions. While there is evidence of some benefits in engineering education arising from the introduction of outcomes-based accreditation, there is also evidence of many short-comings of the graduate attributes approach. This paper seeks to explore the issues and problems associated with the graduate attributes approach to engineering education and to propose some options for improving the system.

2 GRADUATE ATTRIBUTES

Arising from the push in higher education for quality assurance, accountability for outcomes and capability

of graduates (Leathwood & Phillips, 2000), specifying a list of qualities or capabilities that graduates will attain provides a benchmark against which the performance of a higher education institution can be measured. As required by the Department of Education, Science and Training since 1998, most Australian higher education institutions identify a list of expected graduate attributes or outcomes, though, for many universities, statements of graduate attributes have historically been more rhetorical than real (Lister & Nouwens, 2004). Graduate attributes are typically expressed in terms of: a) discipline-specific attributes that relate to the particular program(s) the student is studying; and b) generic attributes that are common to all or most graduates. It has been suggested that it is the generic attributes that are the most important (Hager et al, 2002), perhaps because the discipline-specific body of knowledge is prone to obsolescence and will require continual renewal, and in the longer term, as graduates progress in their careers, they will become less involved in the details of their discipline and more reliant on their generic skills.

Although an apparently logical and natural response to a shift in higher education thinking and policy in the early 1990s, which saw a move away from inputs to a focus more on outcomes (Clanchy & Ballard, 1995), because of their important role in higher education, graduate attributes, particularly “generic attributes”, warrant a closer inspection. Graduate attributes form a component of an on-going evolution

* Paper D08-033 submitted 7/03/08; accepted for publication after review and revision 20/08/08.

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of competency-based education and training that can be viewed as five separate phases commencing in the late 19th century (Lloyd et al, 2001). In fact, graduate attributes, particularly generic attributes, are not underpinned by a strong conceptual framework, and the efforts of universities to describe them, and university staff to teach them are characterised by a wide range of differing terminology, viewpoints and approaches (Barrie, 2004). Australian academics do not share a common understanding of the nature of generic attributes and how such outcomes might be achieved (Barrie, 2006). Despite a pervasive influence on recent policy developments in higher education, the evidence from the literature indicates that graduate attributes have generally been implemented only in limited ways, and viewed by many staff as a primarily managerially-driven curriculum reform agenda (Moore & Hough, 2005). The fact that the stated graduate attributes of many universities, and even many different professional program accrediting bodies, appear to be remarkably similar can lead many staff to cynically view these lists as rhetorical organisational posturing, rather than anything of substantive educational value (Moore & Hough, 2005). Another criticism of many identified graduate attributes is that they purport to imbue students with a range of knowledge, skills and attitudes that are not directly observable in the course of a program of study, or cannot be determined to be in evidence until some future period in the student's personal and/or professional life, leaving the university with a certification task that is logically and/or practically impossible (Chanock, 2003). Attributes relating to objective knowledge and specific observable skills are more readily visible and assessable, leading some to be concerned that the practicalities of what can actually be measured have led to graduate attribute lists emphasising skills and contributing to the "vocalisation" of higher education (Moore & Hough, 2005).

It is easy to become confused with the terminology surrounding outcomes-based education and graduate attributes. Universities may identify their institutional graduate attributes as composed of both generic attributes (applying to all students) and discipline-specific attributes (applying to, or needing to be contextualised into, particular programs of study). When professional bodies identify required graduate attributes, by definition, they are listing discipline-specific graduate attributes, but, may refer to some attributes as "generic". In this context, "generic" means required by the discipline, but not necessarily specific to the discipline.

3 GRADUATE ATTRIBUTES IN AUSTRALIAN ENGINEERING EDUCATION

Outcomes-based education, implemented via graduate attributes, has had a strong influence on engineering

education in many countries. As engineering was one of the professions to embrace graduate attributes early on, many of the initial case studies relating to graduate attributes documented in the literature were cases from engineering education. In engineering, the idea of specifying required student outcomes in terms of graduate attributes has been embraced internationally for some years (Jolly, 2001; Lister & Nouwens, 2004), including Australia (Engineers Australia, 2006a), the USA (Engineering Accreditation Commission, 2007) and the UK (Engineering Council UK, 2004).

In Australia, in parallel to and initially pre-dating the movement to outcomes-based accreditation of engineering education, there was a developing agenda for the competency-based definition of professional engineering practice. Through the 1980s, there was a push to "correct" what was seen by some as an anomaly in the Australian labour market where a distinction was made between "professional" and "other" engineers, and to remove this "restraint" imposed by the profession against the free substitution of labour by employers (Bureau of Labour Market Research, 1985; Scherer, 1982). By the end of the 1980s, this push had manifested itself in a proposal by unions to remove the education qualification requirements for entry to the engineering profession and replace them with a competency-based assessment avenue for unqualified people to gain membership of the profession (Lloyd et al, 2001). This attempt to uncouple the knowledge-based requirements from the workplace competency requirement was a threat to the genuine professional status of engineering in Australia, and was countered by the Institution of Engineers Australia (now Engineers Australia) developing, with government support, the National Competency Standards for Professional Engineers (Institution of Engineers Australia, 1993), which defined competency requirements for two stages of professional engineering development – stage 1 being equivalent to the graduate engineer, and stage 2 being experienced engineers having professional autonomy for their normal engineering work. The competency standard restated that a four-year undergraduate degree was the normal route for the development of the knowledge and skills required for professional formation and stage 1 competency. The competency standard defined 11 "units of competency", which were further divided into "elements of competency", which were further divided into "performance criteria".

In 1996 a major review of engineering education in Australia (sponsored by Engineers Australia, the Australian Academy of Technological Sciences and Engineering (ATSE), the Australian Council of Engineering Deans (ACED) and the Department of Employment, Education, Training and Youth Affairs (DEETYA)) was published (Johnson, 1996). It made wide ranging recommendations that sought to revolutionise engineering undergraduate education in Australia. The review also proposed more freedom for,

and scope for innovation by, individual engineering schools in determining their program content and modes of delivery, moving from a prescriptive system of accreditation to one focusing more on demonstrated outcomes and graduate attributes. In response to the recommendations of the review, Engineers Australia issued a revised framework for the accreditation of undergraduate programs in 1997 (Institution of Engineers Australia, 1997). It became apparent in 1998 that, while the objectives of the post-Johnson review program accreditation regime were widely supported, both the engineering schools and Engineers Australia were experiencing difficulty in implementing the operational requirements of the system. In June 1999 a task force comprising members of Engineers Australia and ACED was formed to review the accreditation process, and devise a workable policy and process for accreditation of undergraduate engineering programs. In October 1999 a revised version of the *Accreditation Manual* was approved and issued (Institution of Engineers Australia, 1999a).

In early 1998, Engineers Australia commenced a review of its national generic competency standards, the second edition being published in April 1999, and with stage 1 and stage 2 competencies presented in separate volumes. The new edition was more comprehensive than its predecessor, with the competency standards for professional engineer, engineering technologist and engineering associate (now engineering officer), for a particular stage, included in a single volume (Institution of Engineers Australia, 1999b). The national generic competency standards for stage 1 were revised and re-released again in 2004, in draft form, as an appendix to the *Guide to Assessment of Eligibility for Membership (Stage 1 Competency) for Candidates not holding an Accredited or Recognised Qualification* (Engineers Australia, 2004).

Responding to experiences with the new accreditation regime, on-going international developments in engineering program accreditation, the recommendations of a 2002 Washington Accord review of the Engineers Australia accreditation system and input from a range of national stakeholders, in 2005 the entire undergraduate engineering accreditation documentation system was revised and re-released as a package of approximately 20 individual documents including context, guidelines and policy. Minor amendments were made to most elements of the accreditation documentation system again in 2006. The required generic graduate attributes remained essentially the same as previously identified.

Graduates from an accredited program should have the following attributes:

- a) ability to apply knowledge of basic science and engineering fundamentals
- b) ability to communicate effectively, not only with engineers but also with the community at large

- 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 multidisciplinary and multicultural 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 development
- h) understanding of the principles of sustainable design and development
- i) understanding of professional and ethical responsibilities and commitment to them
- j) expectation of the need to undertake lifelong learning and capacity to do so (Engineers Australia, 2006a, pp. 7).

It is important to note that in this context, Engineers Australia uses the term "generic attributes" to identify attributes that are common to all engineering graduates, rather than all graduates in any discipline. And within this list of "generic attributes", some are clearly discipline-specific to engineering graduates, while others could well be viewed as generically valuable to graduates from a wide range of disciplines. In the following, references to Engineers Australia's "generic attributes of a graduate" will identify them simply as "attributes".

While the accreditation documentation system is the current principal reference point for program accreditation, it also refers to (and includes) the current (dated 2006) version of the stage 1 competency standards. Prior versions of the national generic competency standards have also included in their stated objectives: "To provide an aid to the design of undergraduate and postgraduate engineering courses intended to prepare candidates for membership of The Institution of Engineers Australia." (Institution of Engineers Australia, 1999b, pp. v).

The Johnson review of engineering education recommended a major change in the culture of engineering education, with the goal that this change would ultimately propagate through the wider profession. The recommended culture change included a broadened and more outward looking education that appealed to a wider range of entrants, so that the profession might one day be more representative of wider society. The review also identified the need for more diversity in modes of education, to reflect the wide diversity in professional engineering practice. Specific recommendations from the review included:

- Recommendation 1 – Engineers must receive a broader education and be drawn from a wider range of backgrounds.
- Recommendation 4 – Professional accreditation systems must encourage innovation in course content and delivery (Johnson, 1996, pp. 78-80).

The review also made some recommendations dealing with technical aspects of the program accreditation process, which were generally fully implemented in the new accreditation system. The review offered the promise of a more open, inclusive, innovative and flexible education for engineers. Some trace of these aspects of this review can be found in the new accreditation system, with the system "Overview" document acknowledging: "*Changing the Culture: Engineering Education into the Future ...* As the title implies, the report advocated fundamental changes in the culture and processes of engineering education." (Engineers Australia, 2006c, pp. 5).

4 ISSUES WITH GRADUATE ATTRIBUTES IN AUSTRALIAN ENGINEERING EDUCATION

Engineering as a profession is becoming increasingly diverse, with disciplines, roles and career paths expanding over time (Lloyd et al, 2001). Engineers Australia is the professional body for all Australian engineers regardless of discipline, hence the single list of attributes provided in the accreditation system is necessarily loosely defined to fit all disciplines (Ferguson, 2006). It is intended that individual engineering schools then flesh out the details of their program through reference to the Stage 1 National Generic Competency Standards, Academic Advisory Boards, industry consultations, their own institutional missions and other sources. However, there is wide variation in the purpose, membership and function of engineering advisory boards, and they are often observed to take a passive role – convening infrequently and primarily responding to requests from the engineering school (Coe, 2008). In addition, the membership of advisory groups is finite, and their views are subjectively influenced by their own engineering education and range of industrial experiences (Ferguson, 2006).

Supplementing these sources of program advice, the accreditation process involves assessment of the program by an "independent evaluation panel comprising senior academic and industry practitioners" (Engineers Australia, 2006c) who provide recommendations for the improvement of the program. However, this group is also small in number, and likewise constrained by their own professional formation and experiences. It is the experience of the authors that the recommendations of accreditation panels often overtly show the personal preferences of their members, and that the recommendations of successive accreditation

panels (generally comprised of different experts) can contradict each other. In a recent review of a decade of experience with outcomes-based accreditation of engineering programs in the USA, ABET Inc reported that the apparent inconsistencies of program evaluation (accreditation) outcomes was the most recurring concern expressed by all constituencies (ABET Inc, 2004). The specification of only a single set of attribute outcomes, common to all discipline areas, which then rely on the advice of a comparatively small group of experienced discipline experts for fuller expression in the context of the discipline has the potential to lead to a limited and conventional view of the body of knowledge, skills and attitudes that graduates of a particular engineering discipline should possess (Cook, 2000).

Walther & Radcliffe (2007) observed that, even though Engineers Australia's attributes were derived from the perceived needs of stakeholders, including industry, and that even though industry input is used at the individual program level for the development of desired program outcomes, and even though much effort has been devoted in engineering programs toward the development of these identified attributes, there is still a range of recent evidence that indicates that industry believes that engineering graduates continue to have deficiencies with respect crucial non-technical job skills. They note that the use of "expert panels" to determine the competency requirements has been found to have only moderate agreement with competencies shown to be important from behavioural event interviews of successful incumbents (Walther & Radcliffe, 2007). They suggest that this "competency dilemma" is, in part, caused by:

- the fundamental and practical limitations of what can be taught in a university education context
- the necessarily general nature of undergraduate education as preparation for the full spectrum of possible engineering careers versus the very specific job tasks that are the reality of a particular engineering role
- that the accreditation attributes, as currently expressed, do not capture the full complexity of engineering practice, nor reflect the complex nature of competency development (Walther & Radcliffe, 2007).

While other engineering education accrediting bodies internationally have also gone down the outcomes-focused path based on a set of graduate attributes, some national accreditation systems supplement their common graduate attributes with additional guidance on program characteristics for individual engineering disciplines. For example, the program accreditation criteria for ABET Inc, the accrediting body in the USA, not only specifies 11 common program outcomes that all undergraduate engineering programs must demonstrate that their students attain, but it also provides additional

program criteria for 24 identified major (and similarly named) engineering discipline areas (Engineering Accreditation Commission, 2007). Most Australian universities already specify their own institutional list of graduate attributes, which typically cover much the same ground as the Engineers Australia attributes, and for which faculties, schools or programs are required to translate into details appropriate for their discipline area. In this regard, the Engineers Australia approach of specifying only a common set of attributes adds little value (Carew & Therese, 2007). Some other professional bodies in Australia that have the task of undergraduate program accreditation provide both generic and discipline-specific curriculum requirements. For example, in accounting, the accreditation guidelines for universities address both "core curriculum" discipline content requirements as well as generic skills development across the program (The Institute of Chartered Accountants in Australia & CPA Australia, 2008).

Although superficially simple, the current Australian undergraduate engineering program accreditation system contains a confusing array of reference points for fleshing out the full meaning of engineering graduate attributes (Carew & Therese, 2007). These include:

- the Engineers Australia accreditation documentation (which is presented in approximately 20 separate parts, including policy, guidelines and summaries)
- the Engineers Australia Stage 1 Competency Standards, which is presented with a structure that overlaps, but is different to, that of the rest of the accreditation system, and which requires a separate document to explain the relationship between it and the rest of the accreditation system (Engineers Australia, 2006d)
- whatever local university institutional requirements for graduate attributes apply to a particular engineering program
- any other requirements arising from input from the program's academic advisory board.

To assist in the compilation of the required accreditation submission, the accreditation documentation system does contain detailed directions on the preparation of the required documentation (Engineers Australia, 2006b).

Within the *Accreditation Criteria Guidelines* documentation, the "specification of educational outcomes" is presented as a list of "generic attributes" (really attributes common to all engineering graduates), the majority (six-to-eight out of 10) of which would be considered as primarily "non-technical". Yet, barely three pages later, the "program structure and implementation framework" provides a list of "expected elements" of a program with "indicative proportions" that indicate that the

technical content is expected to be 80-90% of the program (Engineers Australia, 2006a). While we do not suggest that a simple proportion by number of the stated attributes is meant to be interpreted as a measure of relative importance or weighting of curriculum content, nor that this multiple representation is inconsistent, we do contend that this presentation of attributes versus program structural elements is potentially confusing. Documentation prepared as part of a submission for course (re-) accreditation would typically present essentially the same information in at least three different formats, in an attempt to demonstrate that the program satisfies the attributes requirements, the stage 1 competency standard requirements and the program structure requirements.

Accrediting bodies, and others, see graduate attributes as a technology for influencing and controlling undergraduate engineering education (Jolly & Humphries, 2003). However, a restricted focus primarily on the strictly "technical" aspects of a new technology and a lack of acknowledgement, or even lack of awareness, of the closely related cultural and organisational aspects of a technology can lead to its limited diffusion and adoption (Pacey, 1983). There is evidence that graduate attributes, as a tool for the structuring and improvement of engineering education in Australia, has run into cultural and organisational impediments. The elevation of non-technical generic skills to the same level of importance as technical skills has met with resistance from some engineering educators, and the overlay of a complex and poorly understood educational concept on to an already overloaded engineering curriculum and overworked academic staff has, not surprisingly, failed to gain universal acceptance and adoption (Carew & Therese, 2007; Jolly & Humphries, 2003).

Perversely, there is some evidence that the recent focus on non-technical generic graduate attributes may have indeed improved employer's perceptions of graduates' abilities in many areas traditionally seen as deficient, but that this improvement may have been achieved at the expense of discipline technical knowledge; an area that has traditionally been acknowledged as a strength of Australian engineering graduates (Bates et al, 1992; Johnson, 1996; Williams, 1988). A recent survey of Australian employers of mechanical engineers asked them (among other things) to rate the ability of new graduates across a wide range of technical and generic abilities. The ratings for many of the mechanical engineering graduate abilities previously assessed as deficient, such as effective communication skills, lifelong learning, team skills and time management, were found to be rated substantially better than moderate or significant; graduate abilities in other attributes previously assessed as deficient, eg. critical thinking, intellectual curiosity, independent thought and problem solving, appear also to have improved;

however, the graduate ability of the mechanical engineering knowledge base was generally rated as moderate or less (Ferguson, 2006; Ferguson & Palmer, 2007).

Australian engineering schools have had great difficulty effectively implementing graduate attributes at all levels – embedding of graduate attributes systematically into the curriculum, effective teaching of graduate attributes, effective assessment of graduate attributes (if they are assessed at all), and in developing rational and objective measures of the effectiveness of programs in developing these stated/desired attributes in their graduates. Where developments have been undertaken, they are often at the unit/subject level, isolated from any more systematic effort across a school or program, and even these developments are rarely evaluated for their effectiveness in any rigorous manner (Carew & Therese, 2007). Perhaps prompted by an impending accreditation visit, a common response to the need to document the coverage of attributes in a program is to conduct a post hoc "attribute audit" of the curriculum – of which a range of approaches can be seen in the literature (Atrens et al, 2004; Bullen et al, 2004; Chanock, 2003; Chapman, 2004; Yeo, 2004). Such attribute audit exercises may be followed by "brown fields" adjustments to the existing syllabus and/or assessment conducted in units to improve the coverage of attributes – few engineering educators have the luxury of commencing program design with a blank sheet of paper; for most, the recent focus on attributes has been a post facto overlay onto existing program structures.

Designing a program curriculum to expose students to a range of graduate attributes is a necessary step, but in itself it does not ensure that students have actually developed the desired attributes. One element of such an assurance is including assessment tasks that seek to measure the student's attainment of the desired attribute(s). Of course, it is often possible for a student to complete a unit of study by attaining the minimum pass mark, but not actually cover a particular attribute. A "pass student" may progress through their entire program and successfully graduate having avoided a range of graduate attributes that were designed into the curriculum and dutifully assessed (Ferguson, 2001). It is important to make the distinction between processes that ensure that a program will contain opportunities for student to learn and practice desired attributes, and processes that seek to certify *actual student attainment of graduate attributes* – this subtle but crucial distinction is acknowledged by Engineers Australia (Business Industry and Higher Education Collaboration Council, 2007).

The Johnson review of engineering education in Australia that recommended a move to an outcomes-based accreditation system saw this as one element of increasing access to engineering education, of

increasing the diversity of students undertaking engineering education, and of increasing the number of engineering graduates. A decade on from the review, there has been minimal, if any, progress made in the headline diversity issue in engineering education – the participation of female students. Engineering continues to have the lowest rate (by far) of female participation of all broad study areas in Australian universities (Gill et al, 2005). While it would be unfair to blame the introduction of outcomes/attribute-based accreditation for the continuing low numbers of female students in engineering, there is another group of potential engineering students who have the right to feel disappointed by the unfulfilled promise of outcomes-based engineering education. Mature-age students predominately study in off-campus/distance mode to meet their concurrent commitments to family, work and study (Palmer & Bray, 2005). The move to outcomes/attributes-based accreditation offered a hope for distance education students in engineering that program accreditation might focus on equality of outcomes rather than prescribing the educational process. However, at the time when the profession is in clear need of mature, motivated and experienced students, the current accreditation system creates barriers to participation by these students by insisting on mandatory minimum on-campus attendance periods that deter many otherwise qualified and competent students.

In 2004, prior to the introduction of mandatory minimum on-campus attendance periods for off-campus engineering students at Deakin University, the authors undertook a survey of all currently enrolled engineering students to gauge the impact of the changes. The full results of this research are presented elsewhere (Palmer & Bray, 2005), but are summarised here. Respondents were asked to rate on a scale of 1 to 5 (1 = no impact; 5 = extreme impact) what impact would the introduction of mandatory two-week residential attendance for each year of full-time study have had on their decision to enrol in their course – the mean rating for on-campus students was 3.0; the mean rating for off-campus students was 4.1; the median rating for off-campus students was 5. Respondents were asked to indicate (Yes or No) whether they would have been able to attend full-time, on-campus for a two-week residential session for each year of their study – 79.4% of on-campus students reported that they would be able to attend residential sessions; 31.3% of off-campus students reported that they would be able to attend residential sessions. Respondents were asked to rate on a scale of 1 to 5 (1 = not difficult; 3 = difficult; 5 = impossible) the difficulty to them in getting time off work to attend a two-week residential session – the mean rating for on-campus students was 2.3; the mean rating for off-campus students was 3.7; the median rating for off-campus students was 4 (and the maximum value was 6 out 5!).

There is a certain irony that while mandatory attendance requirements are placed on off-campus enrolled students, there is no acknowledgement that many "full-time on-campus" enrolled students spend little time on-campus between lectures, or at all (Palmer et al, 2008a). This irony is compounded when it is observed that there are significant benefits to be gained in the professional formation of undergraduates by sending them into the engineering workforce for periods of experience (Jorgensen & Howard, 2005), and, yet, mature age off-campus students, who are normally already members of the engineering workforce, are compelled to attend on-campus for arbitrary periods. The imposition of additional requirements on off-campus students, over and above those for on-campus students, suggests that even the program accreditors do not fully believe that specification of program outcomes alone is a complete and adequate basis on which to award a degree.

5 DISCUSSION – A WAY FORWARD

While many concerns about the application of graduate attributes in higher education can be found in the literature, it is acknowledged that the observed problems do not necessarily represent a fundamental deficiency in the concept of graduate attributes itself, rather they signify short-comings in the implementation of graduate attributes at the institutional level (Moore & Hough, 2005). It is not unreasonable that a university, or other institution, should be able to explicitly define what its intended student learning outcomes are (Clanchy & Ballard, 1995). The shifting of the Australian undergraduate engineering education system, and the associated program accreditation system, from one primarily focused on inputs and processes to one focused on outcomes defined by graduate attributes was conceptually a major breakthrough, offering encouragement for diversity and innovation in discipline and delivery. It is clear that this change has brought benefits. Many of those involved in the design and administration of engineering programs have had cause to (re-)consider the goals/learning outcomes of their programs, the content and structure of their program's curriculum, and the modes of assessment employed in their programs. There have been many innovations in engineering education directly inspired by efforts to teach, assess and/or develop attributes in students. And there is evidence of a general improvement in graduate capacities in "non-technical" areas – the missing "soft skills" that engineering graduates have been criticised for lacking in the past.

However, in the move from a focus on prescribing process and technical content to one based on describing general graduate outcomes, we contend that the pendulum has swung too far, creating a vacuum of guidance, requiring too much interpretation,

and leaving Australian engineering educators to wade through a complex accreditation system and to second-guess the often differing requirements of successive accreditation panels. For the benefits of outcomes-based education and accreditation systems to be fully realised in engineering, Engineers Australia needs to be more active in the promotion of the conceptual understanding of graduate attributes among engineering educators, and more active in disseminating examples of good practice in curriculum design and assessment processes embodying the effective development of graduate attributes. There would be significant value in Engineers Australia providing additional, discipline-specific guidance on attribute requirements (such as that provided by ABET Inc in the USA) that was independent of, and in addition to, the sources currently used that are potentially subject to individual preferences and wide variation. There would be significant value in Engineers Australia simplifying and consolidating the current multi-document accreditation system that requires engineering educators to design, document and report their program curricula against three overlapping sets of criteria – attributes, program structure element proportions and stage 1 competency standards. In addition to providing clearer guidance to those involved in the provision of engineering education, these changes would also provide firmer guidelines for accreditation panels in their role as auditors of the Australian engineering education system.

While the accreditation system suggests that its "emphasis is on encouraging innovation and diversity in the education design, delivery and quality process" (Engineers Australia, 2006a, pp. 3), our experience is that the accreditation process is conservative and reinforces time-honoured conceptions of engineering education. The accreditation system espouses an outcomes-based philosophy, but prescribes minimum on-campus attendance periods for off-campus students. The modern study-plus-work arrangement of the typical on-campus student is moving closer to the work-plus-study pattern of the typical off-campus student. The "on-campus experience" is not what it used to be, especially when compared to the time that most of the current institutional (education and professional) administrators might have completed their undergraduate studies. A genuinely outcomes-based accreditation system would be based (only) on the demonstrated individual student attainment of appropriate graduate attributes, which might be delivered/gained by a range of means, including distance education.

While the current accreditation system "requires that all programs ensure that their engineering graduates develop *to a substantial degree* (Engineers Australia's emphasis) the generic attributes listed" (Engineers Australia, 2006a, pp. 7), in practice, what is actually certified is that the accredited program is designed to include opportunities for students to

learn and practise a range of knowledge, skills and attitudes, not that any given student will have fully or even adequately engaged with any particular graduate attribute by the point of graduation. Ultimately, to fully meet the letter and spirit of the law for accreditation, programs will need to adopt some method of certification of individual student attainment of desired attributes. All three of the undergraduate engineering accrediting bodies in Australia (Engineers Australia, 2006a), the USA (Christy & Lima, 1998; Rogers & Williams, 1998) and the UK (EPC Assessment Working Group, 2002) identify student portfolios as one possible strategy for demonstrating program outcomes and student attainment of attributes. Love & Trudi (2004) summarised the benefits of portfolios as:

- they can contain many different types of evidence
- they resolve many types of assessment problems in equity and moderation
- they provide a richer picture of students' learning and competency
- students are actively involved in the building of the portfolio
- they are well suited to authentic learning environments
- they can be used in a wide range of contexts
- they provide a means for students to manage their own professional development.

Importantly, for the task of assessing outcomes of an entire program of study, a portfolio can act as an integrator, bringing together and assessing the whole program (Manson et al, 2004), including allowing students to demonstrate attainment of particular attributes that may not have been explicitly summatively assessed at any point during their studies (EPC Assessment Working Group, 2002). Student portfolios can be designed for multiple uses, including assessment of student attainment of attributes (Rogers & Williams, 1998), assessment of the effectiveness of institutional programs in imbuing attributes (Heinricher et al, 2002; Johnson et al, 2002), and other uses for a wide range of stakeholder groups (Love & Trudi, 2004). Portfolios can help students engage more actively with, and take more personal responsibility for, their studies and assessment (Christy & Lima, 1998; Heinricher et al, 2002; Maier & Rowan, 2007), and provide a focus for student reflection on their studies and development (Ferguson, 2001; Pelliccione et al, 2005; Rogers & Williams, 1998; Toohey, 2002). Additional effort in compiling the portfolio can be minimised by basing it around assessment items/artefacts already currently produced by students (Falk et al, 2002; Heinricher et al, 2002; Lohmann, 1999). Of course, this approach can only be employed if the assessment tasks undertaken by students clearly relate to the assessment of attainment of the required graduate attributes.

While it is possible to employ a paper- or hardcopy-based student portfolio, the increasing use of online technology by students and educators alike, including in assessment, means that many of the reported applications of student portfolios are online portfolios (or e-portfolios) (Dixon et al, 2005; Love & Trudi, 2004; University of Sydney Faculty of Science, 2004; Williams & Sher, 2004). In an engineering education context, reporting on the development of the "Polaris" online portfolio system (Campbell & Schmidt, 2005), the authors noted that electronic portfolios are emerging in many disciplines, and while their reported use in engineering has been limited, it is also on the increase, with documented applications in parts of a study unit, the whole of a study unit and the whole of a program. They further noted that:

- much of the work now produced by engineering students is "electronic" in nature, hence, well suited to an online portfolio system
- a portfolio system can feature multiple examples of work and can show student development over time
- student portfolios are likely to become an important part of the recruitment process
- there is a need to strike a balance in the structure of the portfolio system between the mandatory criteria required as evidence (with the consequence of all portfolios looking identical) and giving students some freedom of expression in the content and appearance of their portfolios
- the portfolio system is a means to engage students in exercises to help them understand their developing professional skills and, by its nature, creating a portfolio is a reflective exercise, helping students to self-assess their performance and to reflect on the "whys" of their program
- providing an area in the portfolio for reflective journaling is crucial, and the Polaris system includes reflective questions to help students create descriptions of the work they deposit
- a student portfolio system has many benefits for an academic institution, including the collection of accreditation materials
- while the Polaris system has been optional for students to use, the level of use by students has grown strongly over a number of years.

The authors have elsewhere presented a case study describing the piloting of an online student portfolio structured around graduate attributes in a single unit of study, with the aim of assisting students to document and reflect on their attainment of a sub-set of engineering attributes (Palmer et al, 2008b). The authors contend that making the final shift from accrediting the program to accrediting individual student attainment of attributes could lead to a genuinely outcomes-based accreditation system that is agnostic of student study mode.

6 CONCLUSION

While it has brought some benefits, the move to outcomes-based accreditation for engineering education programs in Australia has not delivered all of the benefits that might have been hoped for. The provision of only a single set of general graduate attributes applying to all engineering disciplines means that there is wide scope for differences in interpretation between program designers and program accreditors as to what constitutes an adequate and contemporary engineering curriculum. The lack of curriculum guidance in the current accreditation system forces a reliance on comparatively small groups of "discipline experts" for fleshing out of the curriculum content – both in the design and delivery of the program, and in the accreditation assessment of the program. This can lead to myopic conceptions of engineering education and cause problems at successive program accreditations. The current accreditation system is based on a multitude of interrelated and overlapping documentation requiring the curriculum content and structure to be presented in a range of different formats. The literature suggests that the concept of graduate attributes is not generally well understood, and subject to a wide range of interpretations, so it is not surprising that this concept has not been widely and successfully adopted in Australian engineering education. The most commonly observed response to graduate attributes is a post hoc 'attribute audit' of existing programs. A fundamental limitation of the current system is that accreditation only certifies the content and structure of the academic program, not that any particular graduate will sufficiently and adequately possess all of the desired attributes. While outcomes-based education offered the promise of a more open and inclusive education experience for engineering students, a decade of operation suggests that little has changed to improve the opportunities for under-represented student groups, especially mature-age students seeking to upgrade the engineering qualifications.

There would be significant value in Engineers Australia providing additional, discipline-specific guidance on attribute development. There would be significant value in Engineers Australia simplifying and consolidating the current multi-document accreditation system. A genuinely outcomes-based accreditation system would be based (only) on the demonstrated individual student attainment of appropriate graduate attributes, which might be delivered/gained by a range of means, including distance education. To fully meet the letter and spirit of the law for accreditation, programs will need to adopt some method of certification of individual student attainment of graduate attributes – one such method would be the use of student portfolios.

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