Online student portfolios for demonstration of engineering graduate attributes

Stuart Palmer
Institute of Teaching and Learning
Deakin University

Wayne Hall
School of Engineering
University of Plymouth

Engineers Australia is the Australian professional body that accredits undergraduate engineering programs. It espouses an 'outcomes-based' program accreditation philosophy, but imposes mandatory 'process' requirements for off-campus programs that are in addition to the requirements for conventional on-campus programs. The focus on off-campus engineering study raises the question: how can learning outcomes, regardless of mode of study, be effectively measured? The current answer appears to be 'graduate attributes'. The literature reveals a range of sophistication in approach to graduate attributes from identifying desirable graduate attributes, through to evidence-based certification of individual student attainment of graduate attributes. Many engineering accrediting bodies around the world identify student portfolios as a strategy for demonstrating student attainment of graduate attributes. The increasing use of online technology by students and educators alike, including as part of assessment, means that many of the reported applications of student portfolios are online portfolios. The effectiveness of online student portfolios will depend on them being embedded in day-to-day educational practice, rather than being an optional extra given a low priority by busy students. This paper presents a survey of the related literature and briefly outlines a project in progress at Deakin University to trial an online student portfolio.

Keywords: graduate attributes, student portfolios, online portfolios

Introduction – engineers' learning

In engineering, off-campus/distance study is an essential element of access to education for those in remote locations and/or seeking to upgrade their qualifications whilst employed. Internationally, engineering education accrediting bodies have moved toward outcomes-based assessment of graduate competency, but are still grappling with off-campus education. In Australia, the program accrediting body, Engineers Australia, espouses an outcomes-based approach to accreditation, but prescriptively enforces minimum mandatory residential attendance periods for students studying in the off-campus mode. The 'problem' for accreditation of higher education caused by distance education, and the inability of accreditation systems based on traditional on-campus study models to appropriately address off-campus study without stifling innovation, have been reported for many years, both in higher education generally (Eaton, 2003; Haug, 2003), and specifically in engineering undergraduate education (Bourne, Harris, & Mayadas, 2005; Daniels & Rubin, 1998; Ljoså, 1995). Both national (Carnevale, 2002) and international (Taylor, 2004) engineering accrediting bodies are struggling to make progress on the issue of accrediting off-campus study, in part due to the fact that they are still having difficulty accrediting aspects of on-campus programs (Carnevale, 2002).

It is often claimed that engineering is a special case because of the significant laboratory work component. However, there are many options for off-campus delivery (Trevelyan, 2003) demonstrating no significant difference in learning outcomes (Lemckert & Florance, 1996; Watson et al., 2004). There are some skills, such a group/team work, problem-based learning and leadership that have traditionally required proximal interaction between students. However, there also exist a range of distance education strategies for these (Aravinthan & Fahey, 2004; Brodie & Porter, 2004; Freeman, 2002). In fact, not only does the literature suggest 'no significant difference' in outcomes between on- and off-campus education, it is suggested that many traditional forms of on-campus education are not effective learning environments, with a majority of on-campus student learning occurring outside of formal class time

(Chandler, Fontenot, Hagler, & Marcy, 1999; Davies, Cover, Lawrence-Fowler, & Guzdial, 2001). Additionally, it is observed that the boundaries between on- and off-campus study are now significantly blurred, with many on-campus students making use of any available off-campus learning resources to enhance their learning and/or reduce their reliance on attendance at formal classes (Chandler et al., 1999; McInnis & Hartley, 2002), and developments in distance education can lead to transformations in on-campus teaching (Subic & Maconachie, 2004). In engineering, a focus on measuring the learning outcomes of distance education has also thrown the spotlight back on the effectiveness of measurement of learning outcomes for traditional education (Eaton, 2002). 'No significant difference' (Russell, 1999) doesn't absolve off-campus studies of the need to demonstrate effectiveness, but poses the question, how can learning outcomes, regardless of mode of study, be effectively measured? The current answer appears to be 'graduate attributes'.

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. 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 in Australia (Engineers Australia, 2005), the USA (Engineering Accreditation Commission, 2003), and the UK (The Engineering Professors Council, 2000). The theory and practice of graduate attributes in engineering education remains a current research topic; in 2005 the University of Sydney offered a PhD scholarship to research a range of issues relating to undergraduate engineering graduate attributes (University of Sydney School of Aerospace Mechanical and Mechatronic Engineering, 2005).

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. There is some suggestion that it is the generic attributes that are the most important (Hager, Holland, & Beckett, 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. While there are examples in the literature of efforts to compile lists of graduate attributes for engineering (Scott & Yates, 2002), in reality, Australian undergraduate engineering programs have no shortage of direction in this regard, as Engineers Australia identifies the graduate attributes it expects to find in an accredited program, and the hosting institution almost certainly has its own list of graduate attributes it aims to develop in its students.

In the literature related to graduate attributes, there can be observed varying levels of sophistication in approach. The range includes:

* identifying and prioritising desirable graduate attributes (Scott & Yates, 2002)
* identifying where and at what level in the curriculum attributes should be covered (Atrens, Truss, Dahl, Schaffer, & St John, 2004; Chapman, 2004)
* designing assessment to explicitly measure graduate attributes (Yeo, 2004)
* evaluation of the effectiveness of delivery of graduate attributes (Bullen, Waters, Bullen, & de la Barra, 2004), and
* evidence-based certification of attainment of graduate attributes (Williams & Sher, 2004).

As noted previously, for engineering, the applicable graduate attributes have already been specified, at least in the general sense. They may need to be interpreted into more meaningful specifications for particular engineering disciplines (Falk et al., 2002; Leathwood & Phillips, 2000). In Australia, Engineers Australia goes no further than a single list of generic graduate attributes for all undergraduate students. In the USA, the Accreditation Board for Engineering and Technology (ABET) provides general criteria, as well as specific program criteria for each of the engineering disciplines it accredits. In the UK, the Engineering Professors Council (EPC) provides generic requirements and more detailed 'exemplar benchmarks' for four engineering disciplines.

Once the list of appropriate graduate attributes has been agreed upon, there is a need to consider where in the program/curriculum the various attributes will be addressed. This is because: a) no single element of a program could hope to be responsible for more than a small part of the total graduate attribute formation; and b) each attribute will, typically, involve staged development across the program, increasing in depth and sophistication as the student progresses through their studies (Hager et al., 2002). How attributes are developed in each unit of study and how they are addressed by the entire program of study, though obviously related, are not the same thing (Curtin University of Technology Learning Support Network, 2004). Implementing graduate attributes in a program of study is a complex process, and there must be coordination in curriculum design to ensure adequate coverage of the required attributes (Jolly, 2001). The common, core units in a program of study carry a particular burden in the coverage of graduate attributes, and the use of elective or optional units for sole exposure to particular attributes should be avoided (Yeo, 2004).

The appropriate manner in which student attainment of a desired attribute should be assessed and reported remains an active question, including in engineering education (EPC Assessment Working Group, 2002; University of Sydney School of Aerospace Mechanical and Mechatronic Engineering, 2005; Volkwein, Lattuca, Terenzini, Strauss, & Sukhbaatar, 2004). Students may want a single normative mark that allows them to easily compare their performance with their peers, while employers may wish to see the level of student attainment of attributes measured against some identified criterion (Cummings, 1998). There exists a significant literature on approaches to assessing various attributes (Bowden, Hart, King, Trigwell, & Watts, 2000a, 2000b, 2000c, 2000d; Bullen et al., 2004; Deakin University, 2003; Felder & Brent, 2003; Graduate Attributes Sub Group, 2002; Sharp & Sparrow, 2002; Toohey, 2002), but these generally provide only illustrative strategies for assessment, and do not consider levels or grades of competency. Systems of grading of student competency for graduate attributes do exist, including:

- four levels of demonstrated learning/performance (information, knowledge/comprehension, application and analysis, and wisdom/problem solving) (D. Campbell, Bunker, Hoffman, & Iyer, 2004; Christy & Lima, 1998)
- development of rubrics that include descriptions of levels of student competence for each attribute, for use by staff (Kellog, 1999) and students (Williams & Sher, 2004), and
- a complex system based on Hauebstein's conceptual framework for educational objectives that includes five categories of competence in each of four domains (cognitive, psychomotor, affective and behavioural) (Holzl, 2000).

There is guidance available from those who have travelled down the road of embedding graduate attributes in undergraduate programs. Lohman (1999) suggests that the four 'essential elements' for ABET engineering program evaluation are:

1   a concise statement of the purpose of a degree program and its general educational objectives
2   a list of the principal expected outcomes to be achieved by graduates
3   a list of methods used to assess student achievement of the expected outcomes, and
4   a description of the process used to systematically document the use of assessment results.

Lohman (1999) also offers 'seven suggestions' to those developing outcomes-based assessment in engineering:

1   focus first on what is important to your institution; focus second on what is important to external constituents
2   improve first existing assessment measures and processes
3   share information and collaborate as much as possible
4   clarify terminology and establish key elements of the assessment plans early in the development process
5   identify benchmark institutions and key constituents
6   gather data and lots of it, and
7   develop a system to document the use of results.

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 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 complete their studies, 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 which ensure that a program will contain opportunities for students to learn and practice desired attributes, and processes which seek to certify actual student attainment of graduate attributes. Student portfolios are one means by which individual attainment of graduate attributes can be assessed.

Student portfolios – a possible technological solution

All three of the undergraduate engineering accrediting bodies in Australia (Engineers Australia, 2005), 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 graduate attributes. Love & Trudi (2004) summarise the benefits of portfolios as follows:

- 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, and
- 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, Pegler, & Weller, 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 delivering graduate attributes (Heinricher et al., 2002; Johnson, Gerstenfeld, & Zeng, 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), and provide a focus for student reflection on their studies and development (Ferguson, 2001; Pelliccione, Dixon, & Giddings, 2005; Rogers & Williams, 1998; Toohey, 2002).

It has been found that the portfolio requirements and the structure/format in which portfolio items must be submitted need to be designed around the intended use of the portfolio, and made clear to students who will be using the portfolio (Allan, Zylinski, Temple, Hislop, & Gray, 2003; Heinricher et al., 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. It is well known that students take a strategic approach to study, and the learning activities they engage most fully with are those most clearly associated with what will be assessed (James, McInnis, & Devlin, 2002). Not surprisingly, it has been observed that attaching assessment credit (marks) to the completion of portfolio tasks is an effective motivator for student engagement (Christy & Lima, 1998; Heinricher et al., 2002; Toohey, 2002). Others reporting the use of student portfolios for the assessment of outcomes in engineering education include (Cummings, 1998), (Plumb & Scott, 2000) and (Sharp & Sparrow, 2002).

The effective use of a student portfolio as a tool for evidence-based demonstration of attainment of graduate attributes assumes that the portfolio is part of an integrated curriculum design process (Christy & Lima, 1998; Lister & Nouwens, 2004; Love & Trudi, 2004) that encompasses: a) identification and articulation of required graduate attributes; b) sequencing the staged development of these attributes

across the duration of the program; c) developing assessment tasks to authentically measure the attainment of the desired attributes; and d) having in place a summative assessment process to review the completed student portfolio. In a different discipline (teaching), but for the same purpose, it has been reported that a number of studies have indicated the benefits of portfolios for teacher preparation, and for addressing program accreditation requirements (Tran, Baker, & Pensavalle, 2005/2006).

While student portfolios are often presented as the panacea for a multitude of educational ills, a range of authors have noted possible issues with the use of portfolios: the term 'portfolio' has a multitude of meanings; portfolios are used for many purposes; and the understanding of, and approach to, assessment employed by the assessor(s) are likely to influence student learning as much as any particular assessment vehicle (Godinho & Wilson, 2005). Portfolios provide 'discernible traces of performance', as distinct from the actual performance of a skill or the application of specific knowledge, hence, their contents are open to interpretation by assessors (Hay & Moss, 2005). In the context of the assessment of professional standards and professional accreditation of teachers (a scenario not dissimilar to the assessment of student attainment of attributes required for graduate membership of the engineering profession), it has been noted that portfolios structured around tightly specified professional criteria may lead to a conformity of outcomes that is not in the best interests of students or the profession (Ferguson, 2005). We need to be aware that simply changing the assessment format does not absolve us of the need to critically consider the purposes of assessment, what will be assessed, who will perform the assessment, and the criteria that will be employed in assessment.

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, Dixon, & Pelliccione, 2005; Love & Trudi, 2004; University of Sydney Faculty of Science, 2004; Williams & Sher, 2004). Rogers & Williams (1998) suggest that the benefits of online portfolios include:

- ease of use
- gives students secure control of their portfolio
- a multimedia archive of the material can be produced
- the portfolio contents can be searched
- materials can be easily updated and replaced
- students and staff can access the portfolio online, anytime
- portfolio marks can be automatically logged and managed
- students can be provided with feedback online, and
- the portfolio structure can be aligned with the required graduate attributes, so that student submissions are focused on the outcomes to be measured.

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 note 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, and
- 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.

In addition to any pedagogical or professional issues, the introduction of technology in education typically creates a range of technological and staff and student development issues. There are a range of possible technological solutions for implementing an online portfolio system that need to be considered, including commercial/proprietary systems, open source/public systems and in-house/custom developed systems. It is noted that a key technological issue with most online portfolio systems is storage capacity – the typical file space limitations of most systems may limit the number and types of media files uploaded by students (education.au limited, 2005). For example, a student video of a few minutes duration may result in a file of tens of megabytes in size, which will be impractical to upload into an electronic portfolio system (and later on, to view) without broadband Internet access. Once technological issues are overcome, user issues may arise. Students need to learn how to use the portfolio system. One approach is to employ the portfolio system in a foundation study unit to develop technological competency for all commencing students, relieving academic staff from having to teach this in later study units (Tran et al., 2005/2006). A automated step-by-step or 'wizard' input process can be provided for students to configure/initialise their portfolio, and a structured question process can be provided for students to upload and reflect on their work (M. I. Campbell & Schmidt, 2005). Academic staff also need to learn how to use the system. On-going use of the system by academic staff can be expedited if the system embodies a database structure and/or workflow process based on the relevant graduate attribute standards, type of learning activities employed, required evidence of student learning and other performance expectations of assessment (Tran et al., 2005/2006). As with most applications of technology in teaching and learning, the effectiveness of online student portfolios will depend on them being embedded in day-to-day educational practice – design of curriculum and syllabus, development of study materials, conduct of teaching and learning, and assessment – rather than being an optional add-on, likely to be given a low priority by busy students with many demands competing for their time (education.au limited, 2005).

Online student portfolio trial at Deakin University

A trial of an online student portfolio for the documentation of student attainment of graduate attributes in the undergraduate engineering program is currently in progress at Deakin University. Based on the required graduate attributes of both Engineers Australia and Deakin University, and using the direction found in the literature, a sub-set of five attributes have been chosen for the trial. The trial has been embedded in a final-year study unit that addresses professional practice issues. Students are asked to deposit 'evidence' (written work, presentations, computer programs, audio recordings, videos, photographs, etc.) of, and reflection on, their attainment/understanding/development of the specified graduate attributes. The online portfolio submissions have marks assigned to encourage completion of the assessment task.

While the trial is still a work in progress, an initial student questionnaire was administered to establish the students' initial understanding of graduate attributes and student portfolios. The response rate was 60.8 %, and there was no significant difference between the class population and the respondent sample group in the demographic dimensions of gender, mode of study and course of study. While more than half (52.1 %) of respondents were aware that Engineers Australia specifies required graduate attributes, only one third were aware that Deakin University does the same. One third of students did not appreciate the link between study and assessment, and the development of graduate attributes. Exposure to student portfolios was low; less than half (43.8 %) of respondents understood the purpose of a student portfolio, and prior use of student portfolios was reported by less than one in six (14.6 %) respondents. It is likely that students encountering a student portfolio for the first time will require proper orientation to understand the purpose and operation of any portfolio system. Generally, the results from the initial questionnaire, while interesting, will primarily form a baseline reference point for comparison with the end of semester follow-up questionnaire results.

Conclusion

There is little doubt that graduate attributes will continue to be a focus generally in higher education, and certainly in engineering education. If accreditation of undergraduate engineering programs is genuinely outcomes-focused, then, accreditation systems should be based on graduate attributes that are able to be articulated/specified, that are tangibly demonstrable, and that are open to delivery by range of processes/modes. There will almost certainly be a move toward certification of individual student attainment of graduate attributes, rather than simply certifying that programs of study provide opportunities for students to participate in activities designed to develop particular graduate attributes. Certification of individual student attainment of graduate attributes may provide the reassurance that professional accrediting bodies need to genuinely focus on student and program outcomes, rather than retaining prescriptive process requirements depending on the mode of study.

Student portfolios are one means for collecting artefacts, performances, reflections and other evidence to document student attainment of graduate attributes. Given the growing influence of online learning environments, coupled with the fact that much student work is now electronically generated, it is likely that online portfolios (e-portfolios) will play an increasing role in the graduate attributes arena. As with any application of technology in teaching and learning, pedagogical issues will be coupled with issues of technology and user development. Portfolios, electronic or otherwise, are a vehicle for student assessment, and while offering new possibilities in sophistication, do not absolve academics from fundamental considerations of the purposes of assessment and the strategic role assessment plays in guiding student study and learning.

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Acknowledgement

Author contact details

Stuart Palmer, Institute of Teaching and Learning, Deakin University, Geelong Waterfront Campus, VIC 3217, Australia. Email: stuart.palmer@deakin.edu.au

Wayne Hall, School of Engineering, Faculty of Technology, University of Plymouth, Drake Circus, Plymouth, PL4 8AA, United Kingdom. Email: wayne.hall@plymouth.ac.uk