Benchmarking the Learning Outcomes of Formative Australian Engineering Degrees: national and international perspectives

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Structured Abstract

INTRODUCTION
All stakeholders in higher education have interests in knowing how well award programs deliver what they intend and claim. Increasingly, benchmarking is being called upon to demonstrate that graduates achieve the target learning outcomes, at required performance standards and by performance comparisons with peers. Demonstrated outcomes benchmarking is an explicit requirement in the Australian Tertiary Education Quality Standards Agency (TEQSA) threshold standards framework.

The paper reports on benchmarking of formative engineering degree learning outcomes, from external moderation of course assessment, accreditation processes, other disciplines and professions, licensing examinations, graduate skills assessment, and from the findings of the recently completed OECD Assessment of Higher Education Learning Outcomes (AHELO) feasibility study.

PURPOSE
The paper is intended to stimulate thinking amongst the engineering education community on expanding the range of benchmarking activities, including developing and sharing further assessment materials that address program learning outcomes directly.

APPROACH
Course assessment moderation and external examiner processes provide basic benchmarking predominantly at course level. Benchmarking of program learning outcomes, such as those defined in the Engineers Australia Stage 1 Competency Standard, is largely performed by the accreditation process. The paper summarises the outcomes of accreditation visits for the last five years, arguing that the recommendations for improvement compiled by accreditation panels provide universities with insights on where their programs fall below national benchmarks. The benchmarking principles of national accreditation are extended internationally, through the Washington, Sydney and Dublin Accords, to which Australia is a full signatory.

The paper also discusses professional licensing examinations, such as that used for engineering in the USA, as a form of benchmarking graduates' knowledge, rather than the program learning outcomes. The recent collaborative development by several of the Australian medical schools of a graduate assessment test is referred to as a possible future model for engineering.

Generic graduate skills assessment is also discussed, as this has been trialled in Australia, and is widely used in USA for benchmarking individual and institutional performance. Whilst valuable, a shortcoming of such tests is that they do not reflect disciplinary differences in the realisation of generic skills, such as problem solving. In principle, this deficiency was overcome in civil engineering strand of the international AHELO study which involved final-year undergraduate students from Australia and eight other countries. The background and broad findings of this study are discussed in the context of informing development of any future similar assessment for benchmarking engineering programs.

CONCLUSIONS
Developing further good quality tests to assess students' achievement of the target learning outcomes of engineering degrees is desirable for all stakeholders in the engineering education process. These would complement course assessments, and assist engineering educators to deliver on graduate outcomes, as well as improve the validity of accreditation processes.

KEYWORDS
Benchmarking; Accreditation; Learning Outcomes; Assessment

Introduction

Benchmarking of learning outcomes in higher education, against defined standards and by comparisons between HE providers, has become a matter of increasing interest and importance. Published benchmarking criteria and outcomes provide stakeholders (governments, employers, professions, providers, parents, graduates and students) with assurance that universities are delivering graduates with the capabilities they claim. Higher education providers also use confidential benchmarking for improvement of their programs and supporting processes.

Demonstrated outcomes benchmarking by HE providers is an explicit requirement of the Australian Tertiary Education Quality Standards Agency (TEQSA), using independently set higher education threshold standards (HES, 2011), stated in the following terms:

> "*C5.5 The academic standards intended to be achieved by students and the standards actually achieved by students in the course of study [program] are benchmarked against similar accredited courses of study offered by other higher education providers*".

Furthermore, in C5.6, the provider must be

> " ... *able to demonstrate ... that students who complete the course of study have attained key graduate attributes ...* ".

TEQSA requires that the key graduate attributes or learning outcomes are defined as 'threshold standards', with those for professional programs being appropriately informed by the profession. Such standards, including those developed recently in Australia for Engineering and IT (LTAS, 2010), are invariably multi-dimensional and generic, and are typically broad statements about knowledge, application skills and personal attributes. They also elaborate and differentiate outcomes between qualification levels, such as those in the Australian Qualifications Framework (AQF, 2013). Good curriculum design will ensure that program units (courses) contribute progressively to the attainment of the overall program target outcomes.

Many professional bodies, including in engineering, also use outcome specifications in their program accreditation processes. All graduates of an accredited program are deemed to have met the outcomes at a threshold level. Some professions and occupational registration and licensing bodies also enact their desired graduate outcomes through formal examination of individuals. Either way, these processes are forms of outcomes benchmarking against defined standards. Their result is generally binary – the standard is either met or it is not. Whilst the criteria for assessment against the standard are public, the details of an individual program or graduate assessment are normally confidential to the provider or individual. Nevertheless, a HE provider that can consistently demonstrate that most of its graduates pass this form of examination, or that gains program accreditation without further conditions to be met, can legitimately claim to be operating at the relevant benchmark standard.

Any consideration of outcomes benchmarking in higher education also leads to discussions of both ranking and excellence. National and international research ranking systems (of HE institutions and disciplines) based primarily on peer-reviewed outcomes are widely accepted. They effectively set benchmarks of excellence against which future performance can be judged. In contrast, rankings of institutions and disciplines that are based largely on subjective (peer and student) assessments of teaching performance are generally regarded as less reliable for several reasons. Their most important shortcoming is that they do not capture graduates' outcomes by validated measurements. Nevertheless, multi-dimensional descriptions such as that used in U-Multirank (2011) are gaining acceptance, as they capture the diversity of higher education, allowing in effect, a choice of benchmarks.

The purpose of this paper is to discuss how benchmarking of learning outcomes can contribute to curriculum improvements in formative engineering programs. These provide qualifications for graduates to commence practice as professional engineers, engineering technologists and engineering associates (a.k.a. technical officers). The paper summarises benchmarking and moderation of student course assessments, and the role of external examiners. The benchmarking role of program accreditation by Engineers Australia (EA) against graduate outcomes specified in the EA Stage 1 Competency Standards (EA, 2011), is discussed, showing how information from accreditation can contribute to program improvement. These principles are extended internationally via the Washington, Sydney and Dublin Accords, to which EA is a signatory.

The paper also discusses direct outcomes assessment in terms of external examinations, generic skills assessments and from the recently completed OECD Assessment of Higher Education Learning Outcomes (AHELO) feasibility study. The civil engineering strand of this project involved testing of samples of final-year undergraduate students from Australia and eight other countries. Governments and employers are particularly interested in using this form of standardised graduate assessment to benchmark and improve higher education.

Clearly, student course assessment, program accreditation and external outcomes assessment such as studied in AHELO are complementary rather than alternative processes, as shown in Figure 1. The paper concludes that having more quality outcomes-focussed assessment instruments available to engineering educators could contribute to the quality of student assessment generally, the reliability of program accreditation, and program improvement, as well as assist compliance with the requirements of education regulators.

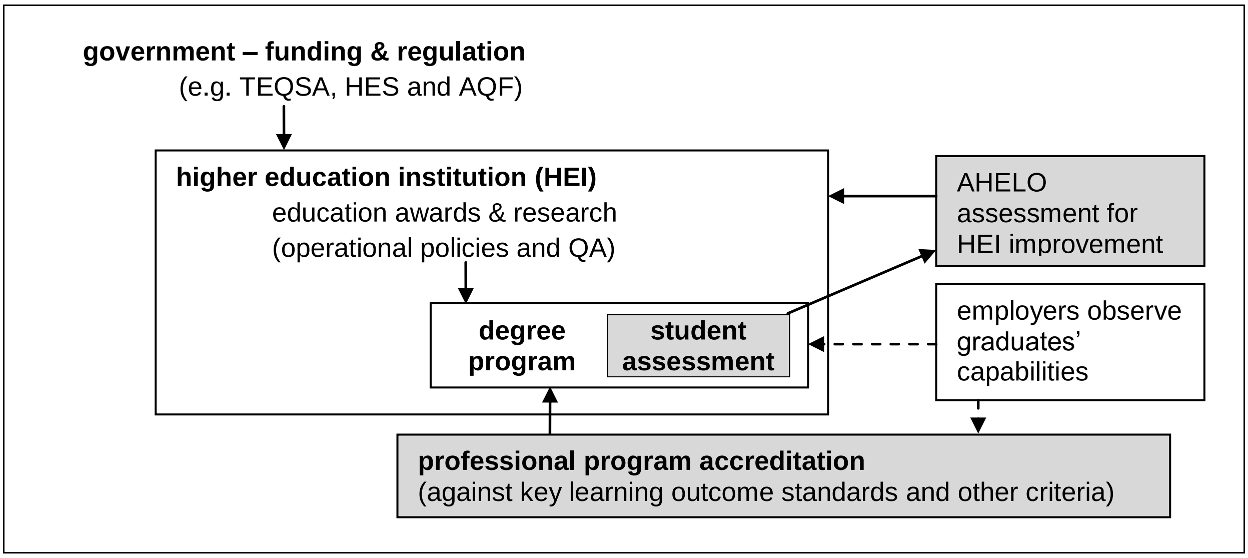

Figure 1 Contexts and stakeholders in student assessment and program accreditation

Benchmarking of Student Assessments

Student assessment and grading is a core role of university teachers. Sadler (2011) has discussed how academics' identity has been cast around their authority to grade students' work. The difficulty of setting and grading assessments is also recognised within the university system by routinely instituting peer-based processes for internal moderation of student assessment items (including marking schemes) and for student achievement, at the level of individual courses. Extensive capstone project or thesis work, even in bachelors degrees, is usually marked by two examiners.

Particularly in professional disciplines such as engineering, degree programs are more than an arbitrary collection of courses. Their target learning outcomes should be defined and the component courses constructed to build progressively the students' capabilities (King, 2012). Similarly, course assessment should be coherent and comprehensive, and aligned with defined outcomes and pedagogy (Biggs & Tang, 2007). As discussed in the next section, professional accreditation also expects to see the target program learning outcomes mapped through the component courses and their assessments. Few universities formally assess students' attainment of broadly defined learning outcomes directly, although they do assert that their graduates attain them through curriculum content and activities.

Although not used widely in Australasian bachelors degrees in engineering, external examiners add a benchmarking dimension to course and program assessment moderation. External examiners can change internal assessment grades. The University of Cambridge (2013) declares that the external examiners they employ

> "*ensure that:*
>
> - *the standards set for an award are appropriate for the qualification;*
> - *the standards of student performance are comparable with similar programmes or subjects in other UK institutions with which they are familiar*; ..."

There are examples of cross-institutional benchmarking of engineering courses in Australia. The eleven-member Group of Eight Engineering Deans and Associates have benchmarked the assessment of final year projects for several years. This is performed after final assessment by each provider as a standards calibration exercise, and can lead to subsequent year improvements in the scope and expectations of project work, and its assessment. A current Office of Learning & Teaching project (OLT, 2012) involving six engineering faculties is developing best-practice guidelines for final year projects, including benchmarking outcomes based assessment practices with industry partners and with the EA Stage 1 Competency Standards.

Outside engineering, detailed work on improving the reliability of academics' assessment in accounting is also being undertaken in a partnership of 17 business faculties, with funding support from the OLT and accounting professional bodies (OLT, 2011). This is

> *"seeking to collaboratively develop and implement a national model of expert peer review for benchmarking learning outcomes against nationally-agreed thresholds"*

All these processes are essentially confidential peer-reviews of institutional student assessments. They certainly can contribute to improvements in assessment and curriculum, and can assist a provider to satisfy TEQSA's benchmarking requirements. The Australian engineering education community also looks to professional accreditation to satisfy these requirements, as discussed in the next section.

Benchmarking by Professional Program Accreditation

Engineers Australia (EA) has been a national leader amongst professions in establishing graduate attributes (learning outcomes) in its Stage 1 Competency Standards and in using them in accreditation of formative (entry-level) professional engineer, engineering technologist and engineering associate (technician) qualifications.

In summary, EA considers programs against three broad criteria: the *operating environment*; the *program* (specification, design and delivery) and the *quality systems* that support the environment, program and students (EA, 2013). Benchmarking itself is expected as part of the quality system. An accredited program produces graduates who possess the 16 defined 'elements of competency' in the Stage 1 Competency Standard: *knowledge and skills* (6 elements); *engineering application ability* (4 elements); and *personal and professional attributes* (6 elements). On the basis of documentation and a visit to the program provider in which all stakeholders are engaged, the accreditation team makes a holistic judgement against the criteria, and (via the Accreditation Board) provides the HE institutions with a detailed report on their *findings*, *commendations* and *recommendations for improvement* (on which providers are expected to report on actions taken, at their next accreditation visit), as well as *recommendations on program accreditation*.

The normal accreditation cycle for established programs is five years, although the *full accreditation* term may not be granted, or may be granted on condition that critical issues are addressed. These are most likely to be in areas of leadership and resources, and are expected to be addressed and reported to the Accreditation Centre by a specified date. New programs are granted *provisional accreditation* if they are on track to meet the requirements; full accreditation will normally be granted after an accreditation team has seen a sample of the first cohort of graduates. Providers can reasonably claim that their accredited engineering qualifications meet the second TEQSA benchmarking requirement quoted in the Introduction of this paper.

Although EA accreditation is voluntary, Australia enjoys strong support from all of the 35 universities and 5 TAFEs providing accredited programs. In March 2013, EA listed 359 professional engineering programs with full or provisional accreditation, and 33 and 15 for engineering technologist and engineering associate, respectively. The list of programs with full and provisional accreditation is published on the EA Accreditation website (EA, 2013).

The EA Accreditation Centre provides an annual report to both the Council of Engineers Australia and the Australian Council of Engineering Deans (ACED). This includes a summary of the Centre's previous year's work, including a statistical summary of outcomes, and information about the areas in which commendations and recommendations for improvement were made. These data are summarised in Table 1 for the last five years.

Table 1 Summary of accreditation visits and outcomes, 2008 – 2012

Accreditation activity and outcomes	2008	2009	2010	2011	2012	totals
Accreditation visits	16	20	20	15	18	89
Programs considered for accreditation	115	153	96	132	141	637
Full accreditation for 5 years	73	52	58	78	52	313
Limited term accreditation	8	6	3	9	12	38
Provisional accreditation (new programs)	23	52	26	25	34	160
Interim Report or Deferred Decision	8	43	9	20	43	123
Identified areas for improvement: references per visit report						**average**
Curriculum design and delivery	1.8	2.4	0.6	1.9	2.2	1.8
Outcomes specification and curriculum mapping	1.3	1.3	0.9	1.1	0.9	1.1
Staff numbers, development, culture & leadership	0.9	1.0	0.8	0.9	0.9	0.9
Students' self-reflection and development as stakeholders in their education and profession	1.0	0.8	0.5	1.1	0.8	0.8
Exposure to engineering practice	0.7	0.9	0.4	0.5	0.6	0.6
Industry Advisory Processes	0.6	0.7	0.5	0.5	0.6	0.6
Assessment, moderation and benchmarking	0.6	0.7	0.2	0.4	0.8	0.5
Quality systems (e.g. for curriculum design)	1.1	0.4	0.4	0.1	0.6	0.5
Facilities and technical support	0.5	0.5	0.5	0.2	0.4	0.4

The accreditation visits may cover all the engineering programs offered by a provider (a 'general review') or may cover only one or two programs, such as those offered at an offshore campus, or those in transition from provisional to full accreditation. Over the 5-year cycle some programs may therefore have several accreditation visits. The upper set of data in Table 1 demonstrates that the majority of eligible programs gain full 5-year accreditation. Those that do not (being deferred or requiring to provide an interim report) have to meet conditions set by the Board, or gain only limited-term accreditation.

Each of the accreditation visits provides information to assist the provider to continue to meet the required standards. The areas for improvement summarised in the lower part of Table 1 can be interpreted as follows. From the 'average' column, *on average*, visit teams make seven recommendations for improvement. Reports are most likely to contain recommendations on improvement in the curriculum and in specifications of graduate outcomes and mapping. Thus, on average, it can be concluded that providers do not fully meet the EA expectations in these areas, whereas they have mostly satisfactory quality systems and facilities, and other areas on which fewer recommendations are made. An individual provider can interpret recommendations as being in areas in which they are not meeting a national benchmark. Noting these trends, to assist providers to improve outcomes specification and curriculum mapping, during 2011-12, EA and AAEE (with financial support from ACED) provided a number of workshops on this topic.

The principles embodied in the EA accreditation have been extended internationally via the educational accords overseen by the International Engineering Alliance (IEA, 2013) and, in Europe, the European Network for Accreditation of Engineering Education (ENAEE, 2012). Their members are national accreditation bodies. Both the IEA and ENAEE have established graduate attribute standards and rigorous processes for membership, and each grants privileges to the providers and graduates of their members' accredited programs.

To explain by example, each of the 15 national signatories of the Washington Accord has undergone international peer-based admission and periodic review process to ensure that its own graduate learning outcome standard for accrediting professional engineer qualifications aligns with the Washington Accord graduate attribute exemplar (IEA, 2013), and that its processes for accreditation are substantially similar to those of other signatories. Each signatory also agrees to recognise the graduates of other signatories' accredited degrees as equivalent to their own. These graduates know that they possess a qualification that is internationally benchmarked. Global employers should therefore have confidence in the equivalence of the core capabilities of all graduates possessing a degree accredited by any Washington Accord signatory.

Direct Assessment of Graduates' Learning Outcomes

Licensing and other examinations in professional disciplines

Program accreditation, as described, does not test directly the target learning outcomes of each potential graduate. To enter many professions, including engineering in some countries, graduates are required to take to take a licensing or registration examination. A reasonable expectation would be that such examinations encompass the threshold level expectations of employers and the profession, and link closely to the degree outcomes.

The best-known external examination in engineering is the Fundamentals of Engineering (FE) examination run by the National Council of Examiners for Engineering and Surveying in the United States. The FE consists of 180 multiple choice questions, to be answered in 8 hours (NCEES, 2013). The first half consists of 120 common questions in 13 knowledge areas covering fundamental mathematics, sciences, engineering sciences, engineering economics, and business and ethics. The second half has 60 questions on knowledge of one engineering discipline. The FE questions do not explicitly cover target graduate attributes, such as engineering synthesis and design, sustainability and systems thinking, innovation, teamwork and communication skills.

The NCEES publicly reports the pass rates for each discipline area: first-time FE takers achieve, on average 78% success, but repeaters only 40%. Individuals who do not pass are provided with a diagnostic report of their performance in each knowledge area. NCEES can provide engineering schools with their cohort's results. Most ABET accredited engineering schools support their students to take the FE during their final year of their bachelor degree, but the extent to which the schools use their FE results to shape or improve their curriculum is not known. Clearly, the FE examination sets a benchmark of engineering knowledge that is supported by the American engineering profession and their state licensing bodies.

Engineers Australia, the Institution of Professional Engineers, New Zealand (IPENZ) and their equivalents in many other countries have not instituted FE type examinations, since they require accredited programs to include and assess students' fundamental and discipline knowledge at the required level. As noted in the previous section, accreditation also requires providers to produce evidence that students are attaining the overall program outcomes (e.g.

in the EA Stage 1 Competency Standard). Any individualised external testing of students' capabilities in areas such as engineering design or teamwork require a different methodology from multiple-choice testing of 'atomised' knowledge, as discussed in the next section.

Space does not permit discussion of licensing examinations in other professions. One interesting and relevant Australian project, however, has been the collaborative development of a national assessment of medical students' learning outcomes. In the Australian Medical Assessment Collaboration (AMAC, 2012), with funding support from the OLT and professional input from the Australian Council for Education Research (ACER), nine Australasian medical schools have developed an assessment framework and 120 assessment items, validated by clinicians. The instrument has been trialled with 500 students and evaluated, with institutional and student-level benchmarking reporting.

Generic skills testing of graduates

Benchmarked testing of graduates' generic skills has been developed largely to satisfy graduate employers and governments that investment in mass higher education is not at the expense of outcome standards. A Graduate Skills Assessment (GSA) test of writing, problem solving, critical thinking and interpersonal understanding was trialled in Australia more than a decade ago in 28 universities (ACER, 2001). The most widely used GSA test today is the American Collegiate Learning Assessment (CLA, 2013), which:

> *"uses performance-based tasks ... to evaluate critical thinking skills of college students. The CLA+ measures critical thinking, problem solving, scientific and quantitative reasoning, writing, and the ability to critique and make arguments.*
>
> *Over 700 institutions—both in the United States and internationally—have used the Collegiate Learning Assessment to benchmark value-added growth in student learning at their college or university compared to other institutions".*

The test has two components. In the performance task, students have 60 minutes to address an issue or present a solution to a real-world task. In the selected-response task, students have 30 minutes to respond to 25 questions on scientific and quantitative reasoning, critical reading, evaluation and critiquing. Students can draw on information in accompanying documents and data. After comprehensive psychometric analysis, cohort results are provided to the institution. Graduating students "*can also use their verified scores to provide potential employers with evidence of their work readiness skills*." (CLA, 2013)

OECD Assessment of Higher Education Outcomes (AHELO) feasibility study

A recognised shortcoming of generic skills testing as described above is that actual generic skills are contextualised by discipline. Engineering problem solving has characteristics that are different from problem solving in medicine or law, for example. To explore international graduates outcomes testing in discipline areas, during 2008-12 the OECD scoped, commissioned and oversaw the AHELO feasibility study. The goal of AHELO was to develop and test the feasibility of a methodology to provide higher education providers with internationally benchmarked data to inform directions for improvement. ACER led the international consortium that developed: test instruments in generic skills (using CLA), in economics, and civil engineering; participant (institutional, faculty and student) survey instruments; and translation, implementation and analysis protocols.

The design and development of the civil engineering test instrument has been reported at a previous AAEE conference (Hadgraft et al., 2012). Designed to be taken in 90 minutes, it contained multiple-choice questions (MCQs) on engineering principles and processes, and constructed response tasks (CRTs) to test problem solving and 'engineering thinking'. The test thus combined features of both the FE examination and the GSA test described above. Examples of the instrument items are included in the final project report (AHELO, 2013).

During 2012 the test was administered to 6,078 final year civil engineering undergraduates in 92 higher education institutions in nine countries, including Australia, with eight engineering schools participating. After item scoring, validation, and comprehensive psychometric analysis, each student was assigned a score from which cohort statistics can be compiled. Some MCQ items and some CRTs that were not done sufficiently well by any cohort, were dropped from the final analysis. This indicates the contextualisation of even a broadly global discipline. Each of the participating universities has been provided with a report on the performance and characteristics of its own cohort, in relation to that of all participants.

Students' performance on the civil engineering instrument items ranged widely. The overall cohort averages were also widely spread, indicating that the items and the test overall has discriminating power. The students' average performance on many items was lower than expected. This is attributed to the test items being completely unseen, and that the context in which the problem-solving CRTs had to be answered was clearly very different from the group work setting typical of most good engineering programs.

At the time of writing, the participating Australian schools have not come together to discuss what they learned from their cohorts' results. Such information, individual and collective, will be important to any further developments of external outcomes assessment in Australia: any test will need to be seen to be adding value. Some participating countries have reported benefits: the instrument has increased their academics' interest in learning outcomes and in the importance of encouraging students in 'engineering thinking'. Some participating countries are keen to develop similar tests in other engineering branches.

A general problem with AHELO was providing incentives for student participation, particularly in countries like Australia. One of the less prosperous countries gained high participation by adding the AHELO test to its own compulsory generic skills test, another used the moral argument that "*participation would be contributing to national development*".

The OECD regards AHELO as having successfully proven feasibility, and may therefore pursue the development of internationally applicable test instruments in other disciplines, and protocols and systems for larger national and institutional participation. Given its strong interest to date, Australia is likely to be a participant in any future AHELO.

Conclusions

This paper has discussed the complementary benchmarking roles of moderated student assessment of courses and projects, accreditation and external independent assessment of learning outcomes. Interest and experience in the latter is growing, particularly amongst governments and employers, and in higher education.

In Australian formative engineering programs, course level outcomes could be improved by more extensive national and international benchmarking of content and assessment. Program learning outcomes are primarily being benchmarked by external accreditation processes, rather than by direct assessment. Emulating our medical colleagues in AMAC, Australian engineering education could be enhanced by developing and using a high quality test battery for assessment of engineering learning outcomes.

Over time, this model could be promulgated amongst IEA Accord signatories to further validate their graduate attribute exemplars as globally benchmarked standards of formative engineering education qualifications.

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Acknowledgements

The authors acknowledge the contributions of members of accreditation panels and the Engineers Australia Accreditation Board to the work described. The first author acknowledges Dr Daniel Edwards and others at ACER who led the AHELO project; and members of the International Engineering Experts Group for their insights and contributions to the successful implementation of the AHELO civil engineering strand.

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