

Evaluation – The Driver of the Engineering Education Machine

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Abstract: The term evaluation applied to engineering education has several connotations. Evaluation occurs at multiple levels. At the course level academics routinely evaluate “technical” learning outcomes. These courses in turn routinely need to meet evaluation criteria set by individual institutions, such as graduate attributes, grade distributions, minimum load, student satisfaction, cohort progression and attrition. Further, at the program level, coordinators may be concerned with evaluation of total student load, overall progression and attrition. A Faculty/Division/School may be evaluated on load, student satisfaction, cohort progression and attrition, retention strategies, employer surveys and various quality indices. The capstone is the evaluation carried out by Engineers Australia, which is (partially) based on satisfying the graduate competency requirements of the Washington Accord (as interpreted and applied by Engineers Australia). This paper considers evaluation from the course to the institutional level and reviews how the latter links with the international market.

Introduction

The “future of the profession of engineering” question has been posed around the world, with the National Academy of Engineering (2004) publication “The Engineer of 2020” being a typical, but largely unquantified, response to the question. In reality the future remains unknown and engineering educators are often left floundering, guided mainly by their accrediting bodies. The ongoing rush to internationalisation has placed a new and increased emphasis for accredited programs to be recognised globally. As a result national accreditation processes require internationally recognition if their evaluation of the quality of undergraduate degree programs is to have any credence. This has a special importance as engineering graduates rely on home universities (via accreditation) to provide them with the foundation skills upon which to build an international career. While accreditation is well understood at “home”, the underlying quality assurance and associated control processes vary widely around the world. Common/core attributes within accredited programs can make internationalisation viable, but only if universities are able to evaluate both the skills and attributes of their graduates against benchmarked levels.

The definitions of assessment and evaluation provided by ABET (2009) for assessment and evaluation are appropriate for the purpose of this paper: Assessment: “*is one or more processes that identify, collect, and prepare data to evaluate the achievement of program outcomes and program educational objectives.*” Evaluation: “*is one or more processes for interpreting the data and evidence accumulated through assessment practices*”.

The complex assessment-evaluation process that flows from course, to program, to Faculty, to the institution level, is augmented in the engineering disciplines in Australia by Engineers Australia (EA) and is linked to the international market via the Washington Accord (1989). Student assessment at the course level flows through to the international benchmarking level. This paper focuses on the issues of course, program, and institutional and professional body evaluation. It is worthwhile reviewing what aspects of evaluation an Examiner, Moderator, Coordinator, Head of School, Dean and Institution may view as significant as perceptions will very likely vary significantly. It is important that the claims made of course evaluation and renewal, during the professional evaluation-accreditation process, can be substantiated and the tenuous connection between course evaluation and international acceptance as a professional engineer, be strengthened.

Course (Subject) Evaluation

The two most widely used methods of course evaluation are Student Evaluation of Teaching (SET) and Student Evaluation of Learning (SEL). Course examiners plan and hope for positive outcomes for both as these results typically are used by academics as part of annual performance reviews and at the time of promotion. Unfortunately such evaluations are often regarded by some staff with some cynicism as being “student happiness” or “most friendly academic” scores. The examiner typical employs a school/faculty/university template to obtain a set of grade outcomes that provides a form of student ranking and the awarding of “assessment” ranging from failures to high distinctions. The moderator usually acts as friendly auditor and may provide constructive comment and useful feedback. The awarded grades may even reflect the quality of learning and teaching outcomes although it is hard to be sure unless a true evaluation of the course is carried out. To the Head of School the course outcomes will most likely be reviewed in the form of cohort performance, grade distribution and the review of special cases. This kind of rough approximation allows the administration to compare courses on some measures but cannot demonstrate the link between what happened in the course and those measures and cannot therefore be considered a true evaluation.

Program Evaluation

For the Dean the collation of courses at a year level may be reviewed as part of their contribution to progression, attrition and retention within a program. Again, reasons for attrition and retention rates are complex and the contribution of the course would need to be demonstrated by contribution analysis rather than statistical comparison and this is rarely, if ever, done.

Programs will likely be evaluated administratively in a range of distinct manners. The first is related to overall student load (is it viable), the second its collated cohort progression (retained load) the third its contribution to Course Completion Questionnaire (CCQ) outcomes (reputation) and the fourth may be its ability to provide evidence that the program graduate outcomes meet the needs of the accreditation authorities. Learning outcomes from courses have historically been collated, with various degrees of success, to evaluate how program outcomes meet accreditation requirements (Wordstrom and David 2010, Danielson and Rogers, 2007, Biney and Bryant 2005, Karimi et al 2004). These approaches, usually part of the processes illustrated in Figure 2 do not evaluate the program and are input rather than output focussed. The model represented in Figure 1 (University of Wisconsin 2010), which illustrates the program logic approach used by organisations such as the World Bank, may assist with program evaluation based on outcomes.

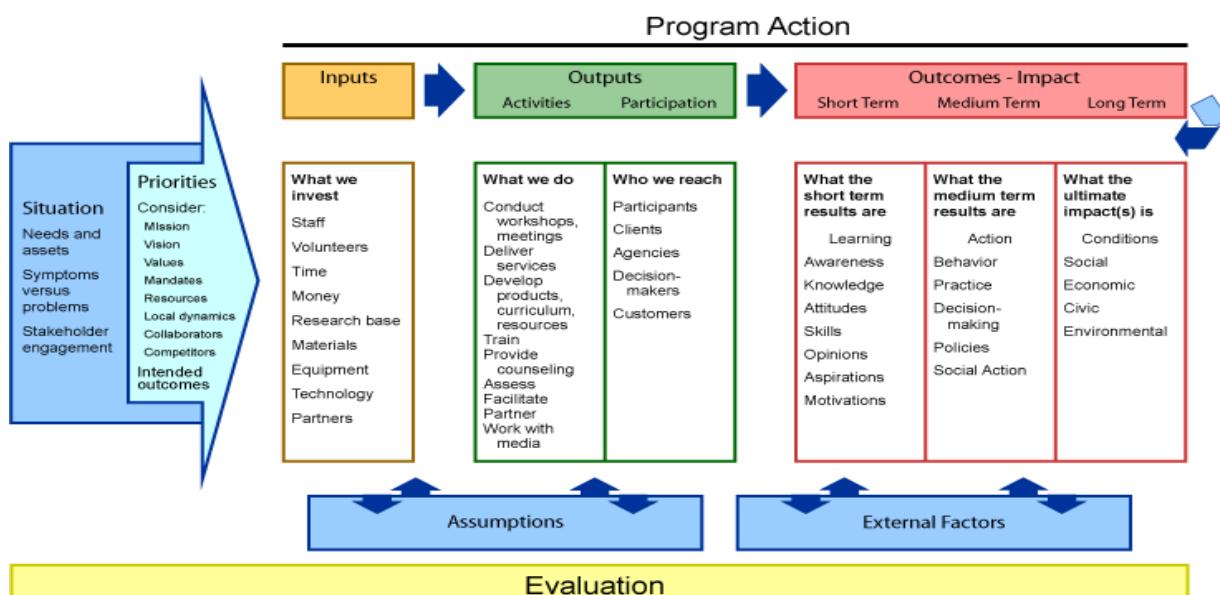


Figure 1: University of Wisconsin-Extension, Program Development and Evaluation Model

Such an approach is currently being trialled within the author's Faculty, where staff have developed a monitoring and evaluation framework that will answer questions about the worth of the program, focussing on; "*the domains of appropriateness, effectiveness, efficiency, impact and sustainability*" (Brodie and Jolly 2010). For the Dean such an evaluation will help answer the question; "Is the program worth the resources it costs?"

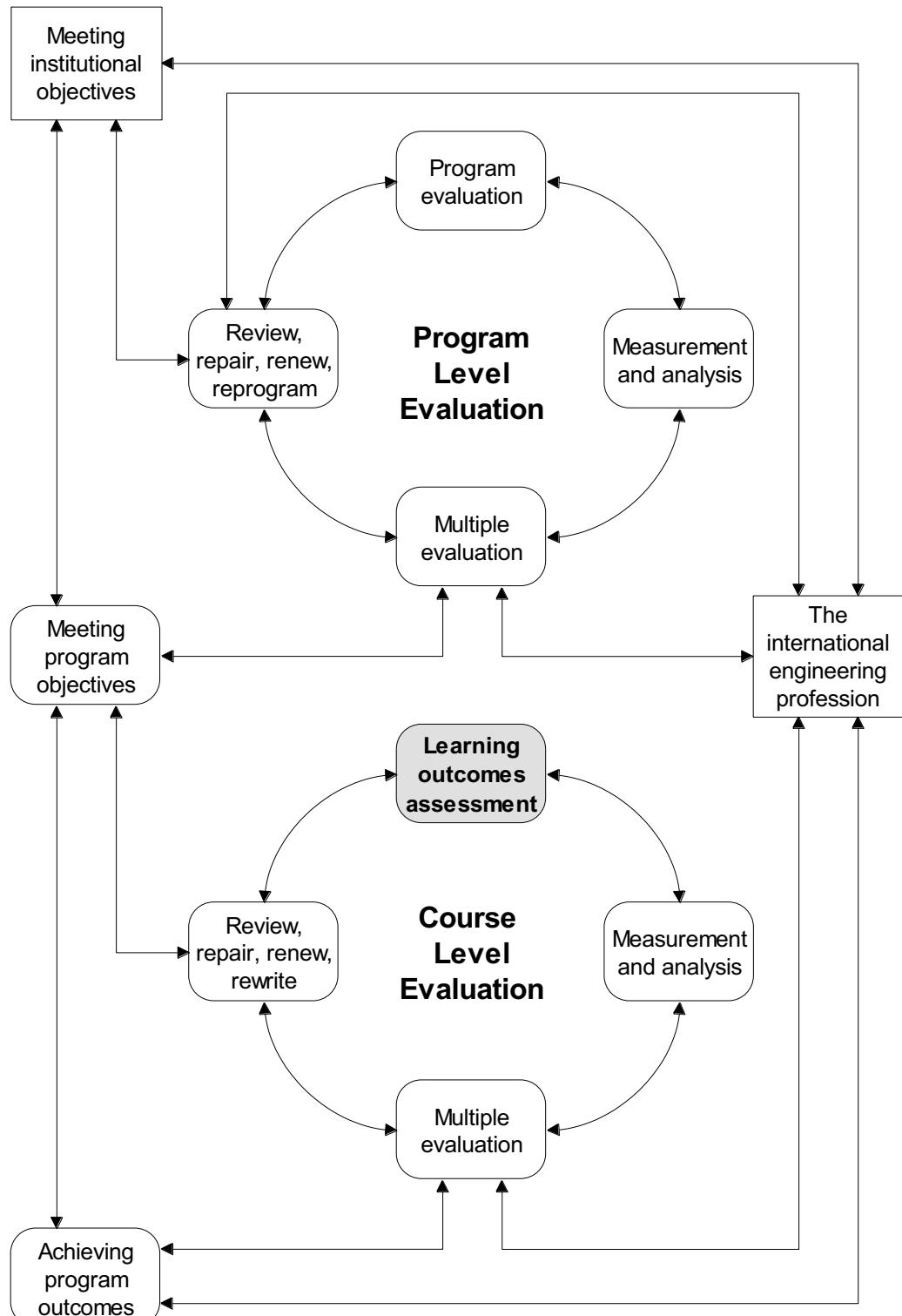


Figure 1: Linking course to Institutional evaluation

At the same time that the Faculty is trialling the new approach to evaluation, the university is implementing a new course review system where all examiners will be provided with a template pre-populated with SET and SEL outcomes, grading details, and retention and progression data. The completed template will be reviewed by Heads and Associate Deans. The intent is that the course review will be used by the Faculty to determine what course(s) and program(s) may need to be assigned resources for renewal or development.

Institutional Evaluation

At the institutional level course outcomes receive minimal scrutiny unless learning outcomes are so poor (as reflected in grades) that a public outcry occurs. The institution is typically more interested in Faculty outcomes in the form of progression, attrition and retention, often aggregated and presented as a Course and Program Review. Often KPIs are set with minimum and maximum values around those parameters, failing to recognise that very high progression may not necessarily indicate high quality learning outcomes. At the professional accreditation level very little interest is currently expressed other than how the learning objectives and assessment contribute towards graduates exiting with the appropriate attributes and competencies. Engineers Australia historically has not been overly interested in the detailed quality of assessment or failure rates (for example). The final evaluation at the course level is financial viability – does adequate load exist to justify assigned staff workload.

When learning and teaching evaluation reaches the whole of institutional level it may take the form of CCQ outcomes, or feature within the learning and teaching reports of bodies such as the Australian Universities Quality Agency (AUQA) and the Tertiary Education Quality and Standards Agency TEQSA, and publications such as the Good Universities Guide. It is interesting to note that outcomes reported by such bodies are rarely fully accepted by the sector, unless successive multiple 5 star rankings are achieved. Institutions typically use a range of templates embedded within improvement cycles in an attempt to improve published outcomes.

In some countries such as the USA there are benchmarks set by the engineering profession with perhaps the most widely known being the Fundamentals of Engineering Exam (FE) taken by most engineering graduates. The FE is administered by the NCEES (the National Council of Examiners for Engineering and Surveying) and is seen as the first step in the process leading to a professional engineer. It is designed for students who are close to finishing an undergraduate engineering degree and lasts 8 hours. In such cases institutions are ranked by such outcomes for ‘teaching’ quality based largely on retention of technical knowledge. Unfortunately such approaches do not evaluate teaching quality or learning successes in anyway nor do they evaluate the value-adding achieved by an Institution. Unfortunately only Institutions that only admit students with high ability may be deemed to be of high quality, regardless of the value added through their learning and teaching environments.

An evolving technique of evaluating student outcomes at the institutional level is the use of tools, instruments and templates and Benjamin (2008) argues the case for the use of the Collegiate Learning Assessment (CLA) to be used nationally in the USA as a means of evaluating the value adding capacity of an institution. The CLA is a computerised, open-ended test of analytic reasoning, critical thinking, problem solving, and written communication skills (Klein et al 2007) designed to measure high level cognitive skills. Analyses are conducted at the school/institutional level and results adjusted for input to determine if student outcomes at their school are better or worse than students with similar incoming ability elsewhere. The CLA has been endorsed by some national higher education commissions and has come under intense scrutiny as it may be widely adopted in the USA as yet another ranking tool. It is focussed at the institutional level as it is argued that the accrual of higher action skills through the entire learning journey is more important than the lesser (relative) contributions of a discipline such as engineering.

The Australian Council for Educational Research (ACER) is a not for profit, independent organisation that generates income through contracted research and development projects and selling products and services. Its mission is to; *“create and promote knowledge and tools that can be used to improve learning across the lifespan”*. ACER provides a wide spectrum of services in assessment and aptitude test and instruments for schools and Universities including a two and a half hour multiple choice Aptitude for Engineering Assessment (AEA) test that is said by ACER to assist with the selection of

students into engineering programs by assessing the students aptitude to “*think scientifically, solve quantitative problems, critically analyse information and display interpersonal understanding*”. Of more interest here is that ACER (2010) has been selected to head the Organisation for Economic Cooperation and Development (OECD) funded Assessment of Higher Education Learning Outcomes (AHELO), which is intended to assess higher education students’ knowledge and skills. AHELO is reported not to be about ranking or standardisation.

The Australasian Survey of Student Engagement (AUSSE) consists of a number of survey instruments, constructed by ACER to; “*collect information on around 100 specific learning activities and conditions along with information on individual demographics and educational contexts. The instruments contain items that map onto six student engagement scales*”:

- Academic Challenge - the extent to which expectations and assessments challenge students to learn;
- Active Learning - students' efforts to actively construct knowledge;
- Student and Staff Interactions - the level and nature of students' contact and interaction with teaching staff;
- Enriching Educational Experiences - students' participation in broadening educational activities;
- Supportive Learning Environment - students' feelings of support within the university community; and
- Work Integrated Learning - integration of employment-focused work experiences into study.

The information collected by the AUSSE through the survey instruments are meant to be used by higher education institutions to improve student outcomes, manage resources, programs and services, and student retention and attraction. The data provided by such surveys of student feeling may or may not be useful for gauging the quality of programs. The outcomes are however, frequently used by institutions as a marketing tool. At the institutional level, evaluation is a matter of comparison with other institutions and national and international benchmarks rather than providing data to evaluate the educational achievement of programs.

Of interest to engineering educators should be the proliferation of such tools, and their application and interpretation by universities and professional bodies. In Australia all universities have a range of graduate attributes to be attained by their students but these do not measure value adding in any way and are not necessarily totally compatible with those prescribed by Engineer Australia (EA). EA does not assess institutions beyond evaluating some of their quality systems relevant to engineering and does not rank institutions, but rather sets a qualifying bar, which is rather like achieving a minimum qualifying time to be allowed to enter the engineering education marathon.

Mapping Graduate Attributes

Similar to all members of the Washington Accord, EA lists the graduate attributes/outcomes that must be developed during an accredited degree program. It is also expected by WA members that the awarding institution can demonstrate that the required program outcomes are achieved. One common approach used to demonstrate successful outcomes is to “map” how the various graduate attributes are embedded in individual courses and programs. This typically requires developing individual course matrices, using information that should form part of the course outlines/synopses routinely provided to students. That information includes such things as statements about what the successful student is expected to achieve in the course and are thus aspirational, rather than demonstrated outcomes. Such matrices need to link learning outcomes with graduate outcomes using assessment methodology. Outcomes from individual courses would then normally be collated across each program and the overall outcome evaluated.

Waters (2003) reviewed the then current situation in Australia and the UK with respect to how various universities have produced mechanisms for students to map, track and assess the development and/or acquisition of graduate attributes during their studies. Many universities provide self-assessment or portfolio building tools for students while others have developed specific courses or skills programs to equip students with the desired attributes. Waters concluded that it would be unwise to invest in software or mechanisms that “*merely mapped notional graduate attributes rather than those that*

students actually had achieved”. The authors’ experience has shown that Schools/Departments and Faculties/Divisions should drive the embedding of discipline specific graduate attributes into programs to augment those managed centrally.

Engineering specialisations may be fully mapped linking assessment, outcomes and graduate attributes in matrices developed in-house and this is a well established process carried out with variable success for accreditation purposes. To create such a matrix the course designer estimates to what extent each graduate attribute is addressed. Such an approach may be seen as being rather mechanical in nature and perhaps a somewhat imprecise measure of delivery of graduate attributes within a single course. However, when aggregated over all courses in a program, a reasonable estimate of relative delivery of attributes is obtained, albeit very little about the effectiveness of that delivery and the quality of the course and/or programs. An example of this is shown in Table 3, which provides the summation of graduate attributes for all courses within a School’s teaching programs (6 disciplines).

Table 3: An example of graduate outcomes summary

Discipline	EA Generic Graduate Attributes and Summary								
	a	b	c	d	e	f	g	h	i
Civil	30%	7%	17%	16%	4%	10%	3%	4%	2%
Comp. Systems	34%	6%	12%	19%	9%	12%	3%	3%	2%
Elec. & Comp.	33%	5%	12%	19%	9%	13%	3%	0%	2%
Elec. Power	32%	5%	13%	18%	9%	14%	3%	2%	2%
Mechanical	32%	5%	13%	18%	7%	10%	3%	5%	2%
Mechatronics	31%	6%	13%	19%	9%	12%	2%	3%	2%
Average	32%	6%	13%	18%	8%	12%	3%	3%	2%

The “a to i” in Table 3 represent the EA graduate attributes current at that time, for example “a” is the attribute relating to a good knowledge of basic science and engineering fundamentals. The percentages listed in the various cells are an indication of the amount of the course that supports development of each attribute within the program. It is important to note that the overall graduate attribute data is used to help decide if a program requires fine-tuning via adjustment of a few courses through content and assessment or via a major program review. It also substantially diminishes the likelihood of students completing a program without being made aware of their development of the desired graduate attributes. There are no target guidelines for the values in Table 3 and the data is not related to evaluating quality or effectiveness of course or programs.

Linking Academic Mapping with Industry Perception

Mapping the development of attributes within a program is a useful monitoring tool but requires external verification if to be used to assist with accreditation. Direct measures of learning are the preferred (primary) means of outcomes assessment, and can include student work and performance on normed exams (such as the Fundamentals of Engineering exam in the USA). While other methods such as surveys of constituencies are deemed to be indirect they are very useful to support the direct measures. Industry and graduate surveys are one approach that can be used to help verify that graduates have developed desired attributes during their undergraduate program. The outcomes from one such employer survey are summarised in Table 4.

One benefit from the mapping exercise and employer graduate surveys is that the School could state with some confidence how employable its graduates are, and what special attributes it believed its graduates to possess. For example the School issuing the survey below could argueably claim that, “*Its graduates possess excellent discipline technical skills and have an in-depth knowledge of the role and importance of teamwork and leadership in their profession*”.

Table 4: An example of industry evaluation

Aspect	1 is disagree strongly, 2 is disagree, 3 is agree, 4 is agree strongly, 5 is agree very strongly					
	1	2	3	4	5	AV
Good knowledge of basic science and engineering fundamentals.	0	0	4	13	4	4.0
Able to communicate effectively, with colleagues and the general community.	1	1	7	10	3	3.6
Good Discipline related technical competence	0	0	5	13	4	4.0
Able to understand, identify problems and formulate solutions.	0	0	8	11	4	3.8
An appreciation of using systems approach to design and operational performance.	0	2	8	11	2	3.6
Able to act as an individual and leader in multi-disciplinary and multi-cultural teams.	0	1	5	12	4	3.9
An awareness of the principles of sustainable design and development and professional responsibilities.	0	2	10	7	2	3.4
An understanding of professional and ethical responsibilities and a commitment to them.	0	1	9	10	2	3.6
An awareness of the need to undertake lifelong learning, and a capacity to do so.	0	0	7	11	3	3.8
Overall level of satisfaction with recent engineering graduates.	0	0	3	14	5	4.1
Results of 23 Companies						3.8

AV is the average response for each attribute. The data under the Lickert scale is the number of responses received at that level.

Linking Local Evaluation to Global Recognition

It is an expectation of universities that they prepare their graduates for the global market. In the case of engineering the Washington Accord (1989) links the learning outcomes of local programs to global recognition through the Engineers Australia (EA) accreditation process. The Washington Accord (WA) and EUR-ACE® (2008) are most likely the regional groupings that readers will readily recognize. The WA is the older, more established and international body that has 13 signatory countries at present (Australia, Canada, Chinese Taipei, Hong Kong-China, Ireland, Japan, Korea, Malaysia, New Zealand, Singapore, South Africa, UK and USA) and a further 6 with provisional status. The Accord “*recognizes the substantial equivalency of programs and recommends that graduates of accredited programs in any of the signatory countries be recognized by the other countries as having met the academic requirements for entry to the practice of engineering*”. ABET (2009) is by far the largest accrediting body and members of the WA may be members of other accreditation bodies as seen in Table 5. The information in Table 5 shows how accreditation at the local level can link graduates into the global market via a number of regional accords. The Western Hemisphere Initiative derives from NAFTA (the North American Free Trade Agreement) and involves Canada, the United States, and Mexico and FEANI is The European Federation of National Engineering Associations (EUR-ACE® is discussed in more detail later in the paper).

Table 5: A comparison of some accreditation bodies

Country	Accrediting Body	Institutions/ Programs	Links
Australia	Institution of Engineers Australia (EA)	39/>350	Washington Accord
Canada	Engineers Canada	43/320	Washington Accord, Western Hemisphere Initiative
Ireland	Engineers Ireland	11/55	FEANI, Washington Accord, EUR-ACE®
New Zealand	Institution of Professional Engineers, New Zealand (IPENZ)	7/42	Washington Accord
United Kingdom	Engineering Council	>250	FEANI, EUR-ACE® Washington Accord
USA (plus 20 other countries)	The Accreditation Board for Engineering and Technology (ABET)	>600/>3100	Washington Accord, Western Hemisphere Initiative

Notes – All the countries in the above table are members of the Engineers Mobility Forum (EMF). The numerical data is approximate only and is intended to provide an idea on the magnitude of the accreditation work required. The data is for professional degrees only. The Australian data does not include combined degrees. The UK data is for colleges and universities – it is not possible to obtain the number of UK recognized programs.

The World Federation of Engineering Organisations (WFEO) could be a body that may be able to specify a set of core graduate attributes that will be recognised globally but the role appears to rest with the Engineers Mobility Forum.

Europe

The European Standing Observatory for the Engineering Profession and Education (ESOEPE) was established in 2000 to build confidence in systems of accreditation of engineering degree programmes within Europe, including "the development of standards on the competence requirements of graduate engineers". To achieve its aims, ESOEPE transformed itself into the international non-profit association, denoted ENAEE (European Network for Accreditation of Engineering Education (ENAEE, 2006).

ESOEPE also took the initiative of proposing to the European Commission the EUR-ACE® ("EUROpean Accredited Engineer") project, which was approved in August 2004. The EUR-ACE Framework Standards for the Accreditation of Engineering Programmes as approved by ENAEE (2008) lists six programme outcomes of Knowledge and Understanding, Engineering Analysis, Engineering Design, Investigations, Engineering Practice and Transferable Skills. In the EUR-ACE® system National Agencies continue to accredit study programmes and are also able to award the EUR-ACE® label if the National Agency and the programme satisfy the EUR-ACE® Framework Standards. The awarded label distinguishes between first cycle (bachelors and honours) and second cycle (masters) degrees, in accord with the European Qualification Framework, agreed as part of the Bologna process.

Linking Attributes to Professional Competency

Similar to Washington Accord covering mutual recognition of tertiary level qualifications, the Asia-Pacific Economic Cooperation (APEC) Engineer Agreement of 1999 covers recognition of equivalence at the practising engineer level in 21 participating APEC countries. The Engineers Mobility Forum (EMF) agreement formed in 2001 operates the same competence standard as the APEC Engineer agreement but any country may join. Members of the WA are members of the EMF and may also be members of the APEC agreement. There are International Engineering Alliance (IEA)

meetings held every two years with the last being in 2009 at Kyoto Japan and the data in Table has been extracted from the Version 2 Graduate Attributes and Competencies approved at that meeting (IEA 2009).

Table 6. Graduate attributes and professional competencies

Graduate Attribute (12)	Professional Competency (13)
1. Engineering knowledge	<ul style="list-style-type: none"> • Comprehend and apply universal knowledge • Comprehend and apply local knowledge
2. Problem analysis	<ul style="list-style-type: none"> • Problem analysis
3. Design/development of solutions	<ul style="list-style-type: none"> • Design and development of solutions
4. Investigation	<ul style="list-style-type: none"> • Evaluation
5. Modern tool usage	
6. The Engineer and Society	<ul style="list-style-type: none"> • Protection of society
7. Environment and sustainability	<ul style="list-style-type: none"> • Legal and regulatory • Judgment
8. Ethics	<ul style="list-style-type: none"> • Ethics • Responsibility for decision
9. Individual and team work	
10. Communication	<ul style="list-style-type: none"> • Communication
11. Project management and finance	<ul style="list-style-type: none"> • Manage engineering activities
12. Lifelong learning	<ul style="list-style-type: none"> • Lifelong learning

It is not expected that there be a direct link between all graduate attributes and professional competencies and the row groupings in the above table are not those of the EMF and reflect only the author's attempt to link the two. Of interest to delegates at this conference is the introduction of "research" into the descriptors of some of the attributes. For example the WA level descriptors for Investigation is; "*Conduct investigation of complex problems using research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions*".

Examples of Program Evaluation-Accreditation

The following section use the United Kingdom, USA, New Zealand, Ireland, Canada and Australia as examples of how individual members of the WA use the guidelines outlines in Table 6 in their relevant accreditation processes.

The United Kingdom

The Engineering Council has recently updated the handbook used for the accreditation of degrees in the UK (2010). The new handbook recognises the establishment of the Engineering Accreditation Board (EAB 2008) that manages the accreditation process, which involves its Licensed Members. The handbook sits within the UK Standard for Professional Engineering Competence (UK-SPEC) (Engineering Council 2010). The Council has been granted the right to license the award of the EUR-ACE® label within the EUR-ACE® (2008) framework, administered by the European Network for Accreditation of Engineering Education (ENAE 2007). Chartered Engineering involves the award of either a Bachelor with Honours in engineering plus either an appropriate masters degree or an accredited integrated MEng degree.

The general learning outcomes cover knowledge and understanding, intellectual abilities, practical skills and general transferable skills, plus five specific learning outcomes for engineering listed below for the Bachelors (Honours) level). The weighting may be varied to allow for program designers to compensate between the elements of each of the outcomes. This is to promote diversity by allowing program designers to focus on the strengths of their universities and schools and thereby produce graduates with special attributes unique to that program. The Council provides detailed content under each of the five learning outcomes, however the components reflect those listed in Table 6 and the reader is referred to the Council (2010) for detailed content of all outcomes.

1. Underpinning science and mathematics, and associated engineering disciplines.
2. Engineering Analysis.
3. Design.
4. Economic, social and environmental context.
5. Engineering Practice

At the MEng level the general learning outcomes include those for the Bachelors programmes plus additional enhanced outcomes. The specific learning outcomes are re-characterised under the same five specific outcomes and for example the Engineering Practice outcome adds:

- A thorough understanding of current practice and its limitations, and some appreciation of likely new developments;
- Extensive knowledge and understanding of a wide range of engineering materials and components;
- Ability to apply engineering techniques taking account of a range of commercial and industrial constraints.

The United States of America

It is assumed that the reader is familiar with the processes of the Accreditation Board for Engineering and Technology (ABET) (2009). ABET is recognised by the Council for Higher Education Accreditation (CHEA) as the organisation responsible for accreditation of programs leading to degrees in applied science, computing, engineering, and technology and its lists are widely accepted by the National Council of Examiners for Engineering and Surveying (NCEES). Engineering programs are evaluated by the Engineering Accreditation Commission (EAC) using criteria that are updated annually (2009). The ABET-EAC lists nine criteria for Baccalaureate Level Programs and Criterion 3 (Program Outcomes), lists eleven outcomes in which engineering programs must demonstrate student attainment, again similar to those in Table 6.

Under Criterion 5 – Curriculum, one year of combination of college level mathematics and basic sciences is specified. One and one-half years of engineering topics (sciences and design) is also required plus a general education component that complements the technical content of the curriculum. Supplementary requirements exist for named engineering programs and for example Mechanical Engineering programs must demonstrate that “*graduates have the ability to: apply principles of engineering, basic science, and mathematics (including multivariate calculus and differential equations) to model, analyse, design, and realise physical systems, components or processes; and work professionally in both thermal and mechanical systems areas*”. On the other hand, Engineering Management programs mention the need for knowledge of the stochastic nature of management systems, but no mathematics.

New Zealand

The Institution of Professional Engineers New Zealand (IPENZ) (2009) accredits professional engineering degree programs that meet the standards inherent in the Washington Accord. An accredited program is expected to provide graduates with generic attributes substantially equivalent to the IPENZ Graduate Competence Profile for Professional Engineers across the following areas, which mirror those agreed as guidelines for use by members of the Washington Accord in setting graduate competencies.

Technical Foundations	Personal Foundation	Supporting Knowledge
Academic education Knowledge of engineering sciences Analysis and problem solving Design and synthesis Investigation and research Risk management	Team Work Communication	The engineer and society Management and financial Practical knowledge

Ireland

Engineers Ireland has formally accredited engineering degree programs since 1982 (2007). Currently the education standard for the professional title of chartered engineer is an honours Bachelor of Engineering Degree and from 2013 will be a Master Degree in Engineering. Engineers Ireland has determined that six areas of study are necessary to achieve the required programme outcomes and at the Bachelor of Engineering Degree (Honours) level and programmes must enable graduates to demonstrate attributes similar to those in Table 6. At the masters level the demonstrated outcomes are increased to seven with the main difference being related to, “*the ability to design and conduct experiments and to apply a range of standard and specialised research tools and techniques*”. Interestingly Engineers Ireland provides guidelines on the entry standard to engineering programmes in an attempt to ensure that entrants have a reasonable prospect of completion.

Ireland (as part of European Union) is one of the 31 signatories to the 1999 Bologna Declaration and was a participant in the ensuing Prague Communiqué of 2001, the Berlin Summit on Higher Education in 2002 the Bergen/Norway meeting of 2005. Engineers Ireland is also one of the 25 members of FEANI (The European Federation of National Associations of Engineering) and its degree programs are recognized in those countries as satisfying the educational standard required for registration as a charted engineer. Engineers Ireland is able to award the EUR-ACE® (2008) label.

Canada

Engineers Canada accredits Canadian undergraduate engineering degree programs through its standing committee, the Canadian Engineering Accreditation Board (2009). The Accreditation Board lists twelve attributes that the institution must demonstrate that its graduates possess. Those attributes are readily mapped to those in Table 6.

Curriculum content is rigorously defined and an Accreditation Unit (AU equal to one hour of lecture – 50 minutes of activity) is used to provide guidelines to universities for content. An entire program must include a minimum of 1,950AU. Mathematics (195 AU) and natural science (195 AU) must be a minimum of 420AU in total, engineering science (225AU) and engineering design (225AU) a minimum of 900AU and complementary studies a minimum of 225AU (2009). Thus some AUs are left to allow the institution to define the particular attributes of their graduates. The Accreditation Board expects that the Dean, or equivalent and staff teaching engineering science and/or design, to be engineers licensed to practice engineering in Canada

Australia

Accreditation in Australia is undertaken by Engineers Australia (EA 2008), with the evaluation task being to: “*accredit those programs which are adjudged as preparing their graduates adequately for entry to the profession and admission to membership of Engineers Australia in the grade of Graduate - career category - Professional Engineer, Engineering Technologist or Engineering Associate as appropriate*”. Accreditation is linked to the National Generic Competency Standards published and maintained by Engineers Australia (2008). Graduates from an accredited program should have attributes very similar with those listed in Table 6.

Program content is not rigidly prescribed and the guidelines for content are outlined below, where the percentages denoted are indicative proportions of the total learning experience measured in terms of student effort:

- Mathematics, science, engineering principles, skills and tools appropriate to the discipline of study (not less than 40%),
- Engineering design and projects (approximately 20%),
- An engineering discipline specialisation (approximately 20%),
- Integrated exposure to professional engineering practice, including management and professional ethics (approximately 10%),
- More of any of the above elements, or other elective studies (approximately 10%).

Conclusions

Evaluation processes in engineering should be seen to flow seamlessly from the course to program level to inform graduate attributes and the meeting of attributes required by Engineers Australia and the Washington Accord. Those graduate attributes are then built upon to meet the professional competences endorsed through such bodies as the EMF and APEC at the International Engineering Alliance meetings. The latter allows links to be made between local and global core attributes and supports the internationalisation of engineering. An explicit mapping process supported by external validation and national accreditation helps support claims that programs are truly international.

Notwithstanding the above it is worth noting that such evaluation is Faculty or institutional focussed, that is, it is input evaluation, not outcome evaluation. It exists to say how well an engineering program is performing against external (international) norms. This is a necessary and important function, but it is quite different to evaluating the effectiveness of single courses or even programs, which would typically seek to demonstrate, if what was done resulted in observed outcomes (good and/or bad). This type of course and program evaluation is assumed to exist and underpin the claims made during accreditation processes but rarely does exists within a university and it is this ground level form of evaluation that is lacking.

International developments surrounding the accreditation of engineering programs are occurring very quickly as illustrated by EUR-ACE, the EMF and Western Hemisphere Initiative. The international trend in accreditation of engineering programs has been to continual move away from specifying program content to graduate attributes/outcomes. There has also been a move toward the MEng becoming the base level entry for professional accreditation. The extra year within the MEng level stage one enables extension of both technical and professional competencies and this trend will be a challenge for Australian engineering educators.

References

- Accreditation Board for Engineering and Technology, Inc, (2009). *Accreditation Policy and Procedure Manual – Effective for Evaluations During the 2010-2011 Accreditation Cycle*. ABET Inc, Baltimore.
- Australasian Survey of Student Engagement (AUSSE). Accessed at <http://ausse.acer.edu.au/> on 23 September 2010.
- Australian Council for Educational Research ACER to lead global higher learning study. Accessed at <http://www.acer.edu.au/media/acer-to-lead-global-higher-learning-outcomes-feasibility-study/> on 24 September 2010.
- Australian Council for Educational Research. Accessed at <http://www.acer.edu.au/> on 23 September 2010.
- Accreditation Board for Engineering and Technology, Inc. (2009) Criteria for Accrediting Engineering Programs – Effective for Evaluations During the 2010-2011 Accreditation Cycle. ABET, Baltimore.
- Brodie, L. & Jolly, L. in press, *Providing ongoing just in time professional development in engineering education*. Paper presented to the AaeE 2010 Past, Present and Future, Sydney, Australia, 5-8 December.
- Benjamin, R. (2008). *The Contribution of the Collegiate Learning Assessment to Teaching and Learning*. Accessed at <http://www.collegiatelearningassessment.org/> on 16 August 2010.
- Biney, P. O. and Bryant, M. O (2005). *A Novel Strategy for the Direct Assessment and Improvement of Engineering Programs Developed and Implemented by the Prairie View A & M University*. Proceedings of the 2005 ASE Conference.
- Canadian Engineering Accreditation Board (2009). *Accreditation Criteria and Procedures - For the Year Ending June 2009*. Engineers Canada. Ottawa, Ontario.
- Danielson, S and Rogers, R. (2007). *A Methodology for Direct Assessment of Student Attainment of Program Outcomes*. Proceedings of the 2007 ASEE Conference and Exposition, Pages AC 2007-878.
- ENAE (2007) *ENAE Standards and Guidelines for Accreditation Agencies*. Accessed at <http://www.enaee.eu/enaee/presentation.htm> on 19 September 2010.
- Engineers Australia (2008). *Accreditation Management System – Education Programs at the Level of Professional Engineer. Document G02 – Accreditation Criteria Guidelines*, Engineer Australia, Canberra.
- Engineers Australia (2008). *Accreditation Management System – Education Programs at the Level of Professional Engineer. Document S04 – Linking Accreditation with the Engineers Australia National Competency Standards*, Engineer Australia, Canberra.
- Engineers Ireland (2007). *Accreditation Criteria for Engineering Education Programmes*. Engineers Ireland, Dublin.

- EUR-ACE (2008). *Framework Standards for the Accreditation of Engineering Programmes*. ENAEE Accessed at <http://www.enaee.eu/enaee/presentation.htm> on 19 September 2010.
- International Engineering Alliance (2009). *Graduate Attributes and Professional Competencies*. Version 2. Accessed at <http://www.washingtonaccord.org/IEA-Grad-Attr-Prof-Competencies-v2.pdf> on 25 September 2010.
- IPENZ (2009). *Requirements for Initial Academic Education for Professional Engineers – Version 3.1*. IPENZ, Wellington.
- Karimi, A., Clutter, K., and Arroyo A. (2004). *An Example of Course and Program Outcome Assessment*. Proceeding of the 2004 ASEE Conference and Exposition. Session 1793.
- Klein, S., Benjamin, R, Shavelson, R and Bolus, R. (2010). The Collegiate Learning Assessment - Facts and Fantasies. Evaluation Review. A journal of Applici Scocial Resrecah. Vol.31, No5.
- National Academy of Engineering (2004). *The Engineer of 2020*. The National Academies Press, Washington, 2004.
- NCEES. *The Fundamentals of Engineering Exam*. Accessed at <http://www.ncees.org/> on 23 September 2010.
- The Engineering Accreditation Board (2008). *Terms of Reference and Constitution*. Accessed at <http://www.engab.org.uk/media/45527/eab%20terms%20of%20reference%20april%202010.pdf> on 19 September, 2010.
- The Engineering Council (2010). *UK Standard for Professional Engineering Competence*. The Engineering Council. London. UK.
- The Engineering Council (2010). *The Accreditation of Higher Education Programmes*. The Engineering Council. London. UK.
- University of Wisconsin (2010). *University of Wisconsin-Extension, Program Development and Evaluation Model*. Accessed at <http://www.uwex.edu/ces/pdande/evaluation/pdf/LMfront.pdf> on 27 September, 2010.
- Washington Accord (1989). *The Washington Accord* Accessed at <http://www.washingtonaccord.org/Washington-Accord/> on 15 September 2010.
- Waters, D. *Mapping generic graduate attributes*. University of Tasmania Flexible Education Unit Report, 2003.
- Western Hemisphere Initiative. Accessed at http://www.worldexpertise.com/global_accreditation_trends.htm on 15 September 2010
- Wordstrom, G and David, J. P. (2010). *A Syllabus – Based Assessment and Evaluation Tool for ABET Program Accreditation*. Proceedings 2010 ASEE Conference. Page AC2010-1207.
- World Federation of Engineering Organisations. Accessed at <http://www.wfeo.net/AboutUs.aspx> on 25 September 2010.

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