



AAEE Plenary - Engineering Education: A National Integrated Approach

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Engineering Education: A National Integrated Approach

Abstract

Engineering Education in any country is influenced by the teachers, institutions, professional bodies, accreditation bodies and international agreements such as the Washington Accord. Through these various, and hopefully integrated processes, it is expected that institutions equip graduates to meet the needs of industry and the international market. Institutions (and thus teachers) must develop their graduates' attributes through outcomes based education programs that can be indirectly verified by demonstrating both high and satisfactory graduate employability. To accompany the educational process and maintain the credibility of accreditation there must be good linkages between industries, the profession, accreditation authorities, required graduate attributes and educators. To help ensure a high quality outcome educators have a responsibility to maintain not only their technical skills and knowledge but also scholarship in the learning and teaching domain. Australia is unique in the world by having very close links between the universities, the professional body, the accrediting authorities and most importantly the educators. This is achieved through an integrated approach by linking the professional industry body, Engineers Australia (EA) (who also accredit engineering teaching programs); the Australian Association for Engineering Education, a technical society of EA and the Australian Council of Engineering Deans. The outcome is a very special, active and dynamic partnership between industry, accreditation authorities and educations. This paper discusses these partnerships, advantages and challenges for the future in Australia and how the partnership flows into a global market.

Introduction

In the early part of this decade, engineering accreditation bodies worldwide reviewed their national guidelines for engineering education to consider restructuring them such that they could determine whether universities were actually delivering graduates ready for employment and, more importantly, able to cope with the future requirements of the profession. These reviews resulted in a refocusing of the engineering curriculum to outcomes rather than process. The UK's Royal Academy of Engineering highlights the importance of accreditation as an agent for evolution and change observing that, *'the accreditation process for university engineering courses should be proactive in driving the development and updating of course content, rather than being a passive auditing exercise'*. The reviews also recognised the need for the inclusion of key core graduate attributes¹⁻⁵ and the lining of those attributes to the bigger global requirements⁶. Alongside shifting professional expectations, the accreditation process is a powerful instrument in directing the education of engineers and over the longer term, the capacity of the engineering profession. Today, the recommendations of these reviews have been implemented and as well as addressing the traditional math, science and engineering fundamentals, and discipline specific knowledge, faculties must also demonstrate graduate acquisition of a broad range of key graduate attributes⁷. Graduate attributes from Engineers Australia and ABET are listed in Table 1 as being typical for those specified by accrediting bodies worldwide. The table attempts to bracket like attributes from these two bodies.

Table 1 Comparison of graduate attributes from Engineers Australia and ABET ⁸

Engineers Australia	ABET Criteria 2008–2009
Ability to apply knowledge of basic science and engineering fundamentals	(a) An ability to apply knowledge of mathematics, science, and engineering (k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice
Ability to communicate effectively, not only with engineers but also with the community at large	(g) An ability to communicate effectively
In–depth technical competence in at least one engineering discipline	(b) An ability to design and conduct experiments, as well as to analyze and interpret data
Ability to undertake problem identification, formulation and solution	(e) An ability to identify, formulate, and solve engineering problems
Ability to utilise a systems approach to design and operational performance	(c) An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
Ability to function effectively as an individual and in multi–disciplinary and multi–cultural teams, with the capacity to be a leader or manager as well as an effective team member	(d) An ability to function in multidisciplinary teams
Understanding of the social, cultural, global and environmental responsibilities of the professional engineer, and the need for sustainable development Understanding of the principles of sustainable design and development	(h) The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context (j) A knowledge of contemporary issues
Understanding of professional and ethical responsibilities and commitment to them	(f) An understanding of professional and ethical responsibility
Expectation of the need to undertake lifelong learning, and capacity to do so	(i) A recognition of the need for, and an ability to engage in life–long learning

This table illustrates the similarities between the graduate attributes prescribed by the two major accreditation agencies, as well as the need for engineers to develop more than just technical knowledge which are necessary in an increasing global economy. The outcome is expected as a significant level of common attributes should exist, given that both agencies are signatories to the Washington Accord ⁹. Engineers now require a great depth and breadth of

skills and knowledge and engineering educators must deliver an ‘education’ and not just training in a technical discipline. Engineering students and professionals require good communication and teamwork skills and an understanding of the fluid and dynamic global, social and cultural environments in which they work ¹⁰. The expanded broad demands for accreditation have placed additional stress on an already crowded curriculum with discipline specific content being gradually eroded over the last 20 years. Australia, as are many other countries, is now debating lengthening of the base qualification for professional accreditation (in Australia this would move from 4 to 5 years). Some accreditation authorities that have historically accepted 4 year degrees have already instigated the change process. For example Engineers Ireland already specifies the programme outcomes which apply to Master’s degree engineering programmes “aimed at satisfying the education standard which will apply to the title of Chartered Engineer from 2013 ¹¹. As Australia moves to such a 5 year structure the special partnership outlined in Figure 1 provides a great opportunity for a truly well designed curriculum based on the needs of all stakeholders.

Current literature also goes on to suggest that desirable graduate attributes should be expanded to include working globally in a multicultural environment; working in interdisciplinary, multi-skilled teams; sharing of work tasks on a global and around-the-clock basis; working with digital communication tools and working in a virtual environment ¹²⁻¹⁴. If these skills are to be incorporated into engineering education in a meaningful way and in a way which is accepted by industry a true partnership must exist between all stakeholders and this partnership is central to education and accreditation.

In Australia such a partnership exists between the Australian Council for Engineering Deans (ACED), Engineers Australia (EA), and Australasian Association for Engineering Education (AAEE) with an accompanying close connection to the university system.

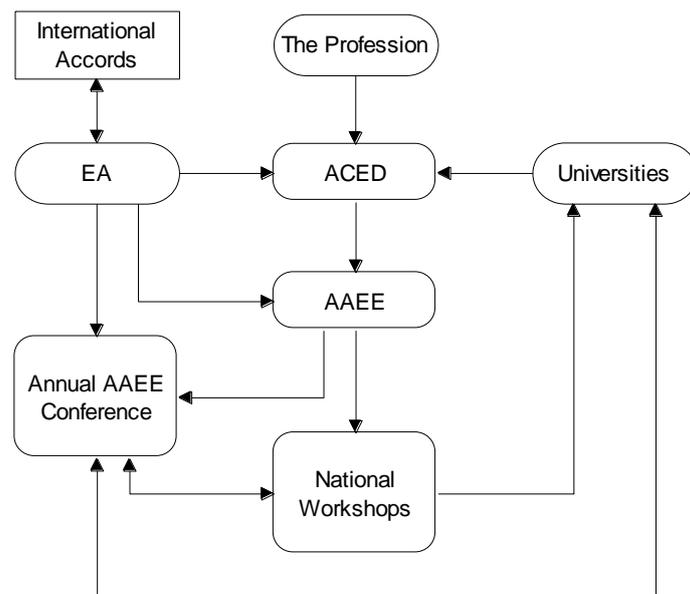


Figure 1 Australian Engineering Education Partnerships

The Partnerships

The partnership between ACED, EA, and AAEE is unique, active and dynamic. The organisations work together on a number of initiatives and reviews to strengthen the engineering profession, and in turn engineering education, to ensure Australia and New Zealand are well placed to meet the global needs of the future. The structure of this partnership and the flow of support (both financial and information) is shown in Figure 1. Background information of each of these organisations follows.

Australian Council of Engineering Deans (ACED)

The Australian Council of Engineering Deans (ACED) is an incorporated association with membership at a university level. There are currently 34 universities delivering programs accredited by Engineers Australia represented on the Council. New Zealand universities are permitted to be represented as observers. ACED's mission is *"to promote and advance engineering education, research and scholarship on behalf of Australian universities, and support engineering graduates for the profession's current and future needs"*¹⁵. The Council pursues its mission by working closely with Engineers Australia, the Australian Learning and Teaching Council, and the Australian Academy of Technological Sciences and Engineering (ATSE). The Council provides underpinning funding to AAEE based on a university levee per academic staff member through its annual membership fees. In 2013 the levee was approximately \$50 per full time academic staff member. The Council is involved internationally through its close association with EA, the OECD AHELO project and membership of the Global Engineering Deans Council.

ACED funds and undertakes significant work that contributes to improving the quality of engineering education and for example led a consultative study *"to address the supply and quality of Australian engineering graduates for the new century"*. The Council contributes very actively to national debates on relevant issues and has made strong submissions to numerous national reviews including the National Innovation Review, National Research Training Review and the Higher Education Review. ACED is a founder member of the Australian National Engineering Taskforce.

The Council has very close links with AAEE and in addition to the underpinning levee is represented on the AAEE executive and funds a small special pool of around \$25,000 per year. AAEE may submit innovative projects that strengthen engineering education across the nation for funding and for example in 2012-2013 AAEE was able to win funds to deliver several projects including "Closing the loop: good practice to good research to good practice"; "EA/AAEE Accreditation and Curriculum Design workshops"; "Awareness and Application of Outcomes Based Education by Engineering Educators" and sponsorship of the AAEE winter school for Research in Engineering Education.

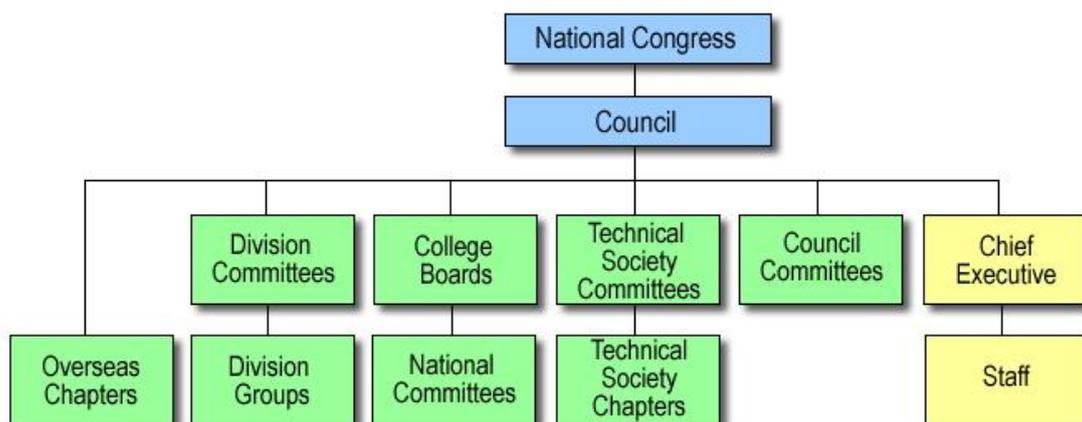
Engineers Australia (EA)

EA is the national body for professional engineers with over 100000 members embracing all disciplines of the engineering team. Activities undertaken by EA cover Migration Skills Assessment, Professional development, Chartered Status for Engineers and Program Accreditation¹⁶.

The objectives of the accreditation process “are the maintenance of internationally benchmarked standards, the promotion and dissemination of best practice and the stimulation of innovation and diversity in engineering education”. Accreditation of an academic program is based on three main areas: the learning and teaching environment; the structure and content of the program and the institutions quality assurance framework. EA does not prescribe details of the program or content but does require demonstration of appropriate education objectives and prescribed graduate attributes, the educational design and review processes and the monitoring framework (<https://www.engineersaustralia.org.au/about-us/program-accreditation>).

EA is a signatory to the Washington, Sydney and Dublin Accord. The structure of EA is shown in Figure 2. The Australasian Association for Engineering Education is a Technical Society within this structure. EA is also represented on the Executive Committee of the AAEF by their Associate Director of Accreditation. The Accreditation Board is one of the Council Committees in the organisational structure shown in Figure 2 and as such reports directly to the Council.

Figure 2 Organisational Structure of Engineers Australia ¹⁷



Australasian Association for Engineering Education (AAEE)

AAEE (a technical society of EA) represents a vibrant community passionate about transforming engineering education across Australasia by promoting best practice in scholarly teaching, application of research results into improving educational outcomes and forming collaborative links with high quality engineering education communities across the world. The general mission of AAEE is to improve the quality, relevance and performance of engineering education in Australasia. AAEE overall goal is to be proactive in supporting and developing engineering education networks, teaching innovations and apply the results of engineering education research to teaching which lead to measurable improvements in educational outcomes and high quality publications. The Association is operational managed though an Executive Committee elected by the members at its annual general meeting held at its annual national conference. As indicated earlier both ACED and EA have representation on the Executive group. It is the Executive that awards the annual conference on a competitive basis, plans the annual workshops and bids for funding from ACED. The

outcomes for 2010 to 2012 are listed in Table 2. It is also worth noting that the tyranny of distance has not deterred its effectiveness, which is an important consideration given that Australia has almost the same land area as mainland USA.

Table 2 Projects and Initiatives of AAEE

Project	Objectives
Establish AAEE Champions in every academic institution (2011 – ongoing)	<ul style="list-style-type: none"> • Aim of increasing AAEE identity and communication • AAEE Champions would provide key dissemination points for AAEE, Champions would work with their engineering Dean to help maintain ACED/AAEE/local community links. • assist in local arrangements for AAEE events.
ERA ranking of AJEE	<p>Aim to have the AJEE and conference proceedings listed on the ERA rankings</p> <p>AJEE is a ranked journal and is currently listed on SCOPUS and applying for inclusion in Thompson ISI</p>
<p>AAEE Postgraduate Winter School for Engineering Education Research (2011)</p> <p>AAEE Winter School for Research in Engineering Education (2012)</p>	<p>Open to academics and higher degree students who are interested in improving their educational research skills. The objectives of the intensive residential school are:</p> <ol style="list-style-type: none"> 1. Be able to describe the differences between positivist and constructivist epistemologies in engineering education research and the implications of these differences for their research. 2. Identify good practice in data collection methods, including interviews and surveys, and develop strategies for improving their own practice as necessary. 3. Develop an understanding of the ongoing role of writing in the research process and strategies for their own practice.
Evaluating Learning and Teaching Strategies Workshops (2011, 2012)	<p>The aim of this workshop is to equip engineering academics with a systematic approach to gathering evidence about the outcomes and impacts of their teaching and learning strategies which can be used to refine teaching, guide curriculum building and enhance promotion and tenure applications.</p>
Joint Engineers Australia/AAEE Accreditation Workshops (2011, 2012)	<p>The six one day workshops presented across Australia focus on</p> <ul style="list-style-type: none"> • The revised Engineers Australia Stage 1 Professional Competencies • Top down learning outcome mapping and design (based on the revised competencies) and constructive alignment • Accreditation process
Closing the loop: good practice to good research to good practice project (2012)	<p>Aim</p> <ul style="list-style-type: none"> • to make practitioners more aware of what research already exists in engineering education, how to present their own work as research in order to contribute to the

	<p>universities' research quality measures</p> <ul style="list-style-type: none"> • how to apply the results of engineering education research to teaching which lead to real (measurable) improvements in educational outcomes and high quality publication
AAEE Annual conference	Held annually since 1989 the AAEE Conference showcases scholarly and research work in engineering education. Conference has grown steadily and in 2012 had 260 conference delegates.
AAEE Excellence Awards	<p>Three awards offered annually and announced at the annual conference</p> <ol style="list-style-type: none"> 1. Australian Council of Engineering Deans National Award for Engineering Education Excellence - Awarded for excellence in learning outcomes via degree programs, discipline majors or other significant initiatives that have produced outstanding and enduring outcomes (\$10000) 2. Award for Engineering Education Research Design – Award for rigorous, innovative and transferable research design in the field of Engineering Education (\$5000) 3. Award for Engineering Education Engagement – Award for fostering an excellent standard of engagement with colleagues or students recognising a collegiate approach to learning and teaching, research and a sharing of expertise. (\$5000)
AAEE Newsletter, web page, wiki; special interest groups	AAEE has numerous methods to communicate with the engineering education community and other interested stakeholders. It supports a number of special interest groups e.g. first year experience, PBL, Engineering Education Research Methods etc
Associate Deans Teaching and Learning annual meeting	AAEE takes responsibility for convening ADTL's annual meeting as part of the annual AAEE Conference. The main objective is to ensure is that there is effective engagement between the ADTLs to disseminate and strategise around future actions for engineering education improvement
Engineers Australia Mega-Conference 2014	EA organised multi-strand conference. AAEE is involved to showcase engineering education.
Chartered Status for Academics	Working party to define indicators of attainment suitable for engineering academics to obtain chartered professional status within EA.

Table 3 Summary of Recommendations from Engineering Education Review ¹⁸

Recommendation	Responsible Organisations	Other Stakeholders
Recommendation 1: raise the public perception of engineering	Engineers Australia, working with ATSE and ACED	APESMA, ACEA, AAEE, BHERT, BCA, TAFE/VET; engineering businesses; government departments who own and operate engineering infrastructure; and the school education sector.
Recommendation 2: refine the definition statements for engineering occupations and graduate qualification standards	Engineers Australia and ACED	TAFE/VET, ATSE, AAEE
Recommendation 3: implement best-practice engineering education	ACED and AAEE	
Recommendation 4: improve resources for engineering education	ACED and AAEE	universities, Engineers Australia, ATSE, BCA, governments
Recommendation 5: engage with industry	Engineers Australia, with ACED	Engineers Australia and ACED with industry and business Partners
Recommendation 6: address shortages by increasing diversity in engineering workplaces supported by engineering education programs	Engineers Australia and ACED with industry and business partners	AAEE, Engineers Australia, ATSE, and industry

Engineering Education in Australia

The study undertaken by the Australian Council of Engineering Deans partnering with Engineers Australia, the Australasian Association for Engineering Education and the Academy of Technological Sciences and Engineering, and funding from the (then) Carrick Institute for Learning and Teaching in Higher Education Ltd provides the most comprehensive summary of the state of engineering education available. The study aimed to

examine “*the state of the engineering education system, with respect to its ability to meet future challenges*”¹⁸ and is a good example of the integrated partnering approach taken in Australia. The review gave six major recommendations and also provided comprehensive data on many aspects of engineering education which support the claim on the strengths and weakness in our current system. The recommendations, responsible organisation and stakeholder groups are summarised in Table 3. This illustrates the close liaison within the partnership in identifying strategies to keep engineering education in Australian at the forefront of innovations.

Engineering Graduations

Engineering attracts a relatively small proportion of higher education students at the undergraduate level with only approximately 6% of commencing students starting in engineering programs. This combined with are high attrition rates (48% for men and 40% for women) means Australia only graduates approximately 8000 students from three and four year engineering bachelor programs well below needs and as such the average age of engineers in Australia is slowly rising and in 2010 was 42 years¹⁹. Since 2008 there has been increase in both offers of places by universities to study engineering and an increase in acceptance of those places¹⁹ reflecting the good job prospects and starting salary of graduates due to the economic climate in Australia. Engineering programs also have one of the highest funding levels per student from the Commonwealth and student fees. For example in 2011 universities received AUS\$23,154 for an engineering student while a business student generated \$10,873 income in comparison. However, engineering and related technologies still has one of the lowest acceptance rates by females of any discipline¹⁹.

To illustrate the shortfall consider that Australia graduated around 9500 domestic engineering graduates including 5384 at the professional level in 2009¹⁹. Around the same period (2009-2010) Australia permitted the immigration of 9120 engineers¹⁹. It is worth noting within context that this strategy was largely permitted to satisfy the demands of the extractive industry sector. Much data is available for international comparison and that data consistently indicates that Australia produces far too few graduates and makes up its shortfall through immigration.

Clearly improvements need to be found to address the shortfalls in intake of students and retaining those students who do begin engineering programs. Approaches to this include increasing the numbers of school leavers who have the prerequisite study and the motivation to study engineering; improve retention amongst engineering students by improvements in curriculum and teaching; alternative entry pathways to encourage a more diverse student cohort into engineering including women, mature age students and overseas qualified graduates who need to attain Australian accreditation.

ACED and EA have been active in this area with increased promotion of engineering as an attractive career choice with initiatives like “The Power of Engineering”²⁰, “Engineers Week – Make it so”²¹, Robogals²² and many scholarships for target groups including high academic achievers, women in engineering and social justice type scholarships. These

activities sit well in the broader spectrum of such initiatives to attract minority groups within Australia and largely mirror similar, but more extensive programs that exist within the USA²³. Much of the scholarship of supporting curriculum change to retain engineering students has come from members of AAEE and is reported through the annual conference and the international journal published through EA, the Australian Journal of Engineering Education.

Graduate Qualities

To maintain the high profile Australian graduates have in the international workforce and the changing requirements of engineers to meet local, national and international needs, the partnership between EA, ACED and AAEE is a distinct advantage. As outlined in Figure 1 there is a direct link from internationally accepted graduate attribute (such as in WA) and educators with AAEE providing a key nexus. Engineering Educators have a responsibility to develop the required graduate competencies. EA as the professional industry body responsible for accreditation of engineering programs has a great impact on curriculum development. Recently EA revised graduate attributes to address changing trends and as such impacts on curriculum development. The Engineers for the Future Report¹⁸ states that employers are “generally satisfied with current engineering graduates” and “Many graduates are employed in global companies where their skills are demonstrated as the equal of those from other nations that have stronger engineering”. However, current graduates are poor at report writing (as are graduates in general) and have less grasp “fundamental” than those of earlier generations.

Student-staff ratios have consistently increased to the point where the ratio is approximately a third high than internationally accepted norms for comparable engineering schools¹⁸. “Australian engineering academics are under considerable pressure to favour research over teaching, and to undertake high administrative loads” and “there is inadequate provision of educational training, professional development, incentives and rewards for improving engineering teaching and undertaking engineering education research”¹⁸.

In response AAEE funded by both EA and ACED run numerous workshops and professional development activities in universities as outlined in Table 2. The glue in the tripartite partnership is AAEE, as it is that association that ensures the ability to deliver graduate attributes are embedded in well designed programs supported by the engineering education managers (ACED) with facilitation by the professional accrediting body (EA).

Conclusions

Engineering Education in Australia is in a unique position having an integrated approach to accreditation, education scholarly activities and education research both of which consider industry and academic perspectives. The key organisations of AAEE and EA are highly valued by many colleagues around the world. AAEE is a technical society of Engineers Australia (EA), a Technical Interest Group of the Institution of Professional Engineers New Zealand (IPENZ), has formal representation on the Australian Council of Engineering Deans (ACED), and is creating greater ties with the New Zealand Council of Engineering Deans

(NZCED). AAEE and its members benefit greatly from the financial support, input to decision making and collaboration in special projects. As outlined the Figure 1 the tripartite arrangement allows a flow of information both from and to the world stage, to and from individual academic staff through a matrix supported by engineering education managers (ACED) and the Australian accreditation body (EA). These links form a strong partnership ensuring Australian graduates are well placed on the world stage.

Other benefits are the focus on engineering education research, strong input and feedback from industry on the qualities of current graduates and future needs and validation that links graduated into the global engineering market. Whilst some aspects like recognition of engineering education research as a valid and well resourced research path need further strengthening the continuous collaboration between all parties ensures important issues have the ways and means of being discussed and resourced.

The link between accreditation, industry and academia is important and the partnership and collaboration guarantee engineering education in Australia is relevant, valid and producing world class engineers ready for the challenges of the future.

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