Australian Council of Engineering Deans

ABN 34 934 186 186

Author:	Professor Elizabeth Taylor, AO, *as President of*
Organisation:	Australian Council of Engineering Deans
Not for Profit:	ACED is an unincorporated assocation of the leaders of the 32 university Australian engineering schools
Mailing address:	c/- Faculty of Sciences, Engineering & Health Central Queensland University, CQ Mail Centre ROCKHAMPTON QLD 4702
Email:	e.taylor@cqu.edu.au
Declaration of Interest:	ACED members are partners in CRCs and recipients of ARC program grants
Date:	30th April 2008

SUBMISSION TO THE NATIONAL INNOVATION REVIEW

This submission primarily addresses issues of education and skills development for engineers, an essential profession for innovation. The major points and proposals in the submission are:

i. **The high industry demand for engineering graduates at both undergraduate and postgraduate levels is not being matched by the number of students qualified for and choosing to study engineering at Australian universities. This, combined with underfunding of both teaching and research, has the potential to severely compromise Australia's innovation system and its international competitiveness.**

ii. **Against international benchmarks, Australian engineering schools are significantly understaffed. Whilst they are performing well under this constraint, they have the potential to contribute more to Australia's innovation system if resourced at levels closer to best-practice.**

iii. **There is a need for relevant actions and initiatives to increase the public understanding and awareness of innovation, and the role of engineering within it.**

iv. **The numbers of secondary school students who include mathematics and science in their secondary school certificates, and continue to take degree studies in engineering, must be increased to maintain and grow Australia's innovation capacity.**

v. **Incentives must be developed to increase the numbers of Australian higher degree research students in engineering to sustain and grow the nation's capacity for engineering innovation.**

vi. **Scholarships must be made available to attract the most talented international engineering graduates to undertake research in Australian engineering schools, and where possible retain them after doctoral graduation.**

vii. **Incentives and support are needed for engineering schools to develop curriculum at undergraduate and postgraduate levels for engineering in emerging technological areas, and in the processes of innovation. ACED would strongly support a systematic approach to building interdisciplinary approaches (involving engineering and business for example) and sharing of resources between institutions.**

Professor Elizabeth Taylor, AO
President, ACED
c/- Faculty of Sciences, Engineering & Health
Central Queensland University, CQ Mail Centre
ROCKHAMPTON QLD 4702

Phone: +61 7 4930 9541
Fax: +61 7 4930 6703
Email: e.taylor@cqu.edu.au

viii. **Development of incentives and rewards to attract and retain more of the best doctoral graduates in engineering schools, particularly through the development of joint-industry appointments, must be a priority for investment.**

ix. **The success rate of good research grant proposals in engineering must be increased, and moves to fully funding research to reduce the subsidies from teaching revenue are necessary to ensure that universities develop and contribute core capabilities to underpin the Australian innovation system .**

x. **Universities should be fully funded to offer appropriate graduate coursework options to enhance the existing PhD programs and improve the capacity of PhD graduates to contribute to innovative research and business productivity.**

xi. **A rejuvenated CRC Program with clear benefits to both engineering research and industry capability is an essential outcome of the innovation review to ensure the continued capacity of universities to delivery quality research and commercialisation outcomes.**

---

1. The Status of Engineering Research and Education in Australia

The future success of Australia's National Innovation System will ultimately depend on creative and innovative people. Many of them will be educated as engineers, for engineering is at the heart of realising beneficial outcomes from creative and innovative ideas.

Many of the 2,800 academic staff and 5,400 research students currently in Australia's engineering schools contribute directly to the innovation system through their research, only some of which has significant competitive grant and industry funding support. Many of the 12,000 annual graduates of coursework programs will contribute to innovation through their employment.

Australia faces shortages of engineers educated at undergraduate and postgraduate levels, since:

- current high demand for engineering graduates is not being matched by an increasing proportion of school leavers qualified and motivated to study engineering;
- the universites' engineering schools are experiencing declining numbers of Australian graduates undertaking higher degree research.

Despite the latter trend, engineering research in Australian engineering schools has grown over the past decade, through:

- participation in the CRC program and other government programs such as ARC Special Research Centres and Centres of Excellence;
- increasing recruitment of international research students and research staff.

Medium and long-term, however, the current participation trends as outlined above, may severely limit the nation's capacity to:

- sustain and build innovative industries;
- tackle Australia's technological and engineering challenges in water, energy, manufacturing, built infrastructure, telecommunications, security, and health;
- sustain and grow engineering research enterprises, including the engineering schools.

On international benchmarks, Australia's engineering schools are underfunded for both teaching and research.

In summary:

The high industry demand for engineering graduates at both undergraduate and postgraduate levels is not being matched by the number of students qualified for and choosing to study engineering at Australian universities. This, combined with underfunding of both teaching and research, has the potential to severely compromise Australia's innovation system and its international competitiveness.

This submission comments on aspects of Australia's engineering schools that play a part in the national innovation system. The submission includes a number of suggestions for improving the performance of the engineering schools in enhancing the nation's innovative capacity and performance. We envisage many gains from looking at engineering education as a fundamental element of innovation.

Most of the data, examples and concerns are drawn from the recently completed consultative review of engineering education[1] undertaken by the Australian Council of Engineering Deans (ACED) in partnership with Engineers Australia, ATSE, and the Australasian Association for Engineering Education, and funded by the Carrick Institute for Learning and Teaching in Higher Education.

2. ACED and Australia's Engineering Schools

ACED provides "*a forum for leaders of engineering education to discuss matters of mutual concern and national importance,… and to promote research and research training in engineering*"[2]. The capacity of the university engineering system to support the national innovation system is of central interest and concern to ACED.

ACED comprises the leaders of the nation's 32 university "engineering schools", the entities responsible for engineering education and research training. In their roles as researchers (particularly those with industry-linkages) and educators the staff and students in these schools are members, or potential members of the national innovation system. The recent review (ref 1, pp31 - 45) reported:

- approximately 2,800 academic staff (full-time equivalent) in 2006, of whom almost 60% are in "teaching and research" roles, and 40% are in "research-only" positions (research associates, research fellows, research professors, etc.);
- approximately 7,000 graduates of Bachelor of Engineering awards in 2005, of whom 28% were international students;
- on average, over 1996 – 2006, approximately 5-7% of the Australian engineering B.Eng. cohort enrol in research masters degrees;
- 845 research degree graduates in engineering in 2005, of whom more than 30% were international graduates;
- the student-staff ratio associated with providing coursework programs has increased from about 14 to 21 since 1996, due to declining resource provision, and the difficulties of attracting and retaining well-qualified staff.

ACED is concerned that the number of engineering graduates per head of population is lower than many countries with whom Australia seeks to compete in innovative industries. The progression rates to engineering research degree candidature, and to coursework higher degrees in technical specialisations are lower than most comparable countries.

The current student-staff ratio is approximately 50% greater than current international best-practice and potentially compromises the quality of engineering programs, and their international competitiveness. All

of these trends have potential impact on Australia's innovation capacity, and are discussed further in subsequent paragraphs.

> ***Against international benchmarks, Australian engineering schools are significantly understaffed. Whilst they are performing well under this constraint, they have the potential to contribute more to Australia's innovation system if resourced at closer to best-practice.***

3. Engineering Underpins Innovation but has Low Visibility in Australia

A nation's engineering capacity fundamentally underpins its innovation capability. The recent review[3] of engineering education in UK stressed the absolute importance of innovative and creative engineering, and the leadership roles of engineers, to the health and vitality of that nation. In his book on the history of engineering[4] the American physicist Sunny Auyang, wrote:

> *"Modern engineering … amplifies traditional ingenuity by the power of scientific reasoning and knowledge. … It acts at the vortex, merging research and development … and industry and business"*

Successful innovation occurs within this "engineering vortex". Professional engineering is the creative and innovative activity that ultimately turns ideas into robust and reliable physical and information products and systems that have economic, social and environmental benefits. Each successive generation of engineers seeks to improve, essentially by successful innovation, on the outcomes achieved by their predecessors.

The recent Australian review (ref 1, pp 89 – 92) reported on the low level of public perception of the broad role of engineering and the work of engineers. This is described by many engineering students as "invisibility" within their secondary schools. Similar findings have been observed in UK studies[5], a nation with much stronger engineering traditions than Australia.

The consultation in the review suggest that the dominant broad perception of engineering in Australia is of building and maintaining physical infrastructure, rather than creativity, innovation, competitive edge, and business. Contributors to the review suggested that Australia "*lacks a culture of research-led engineering … that is celebrated as a major contributor to the economy*". Engineering students reported the television programs *New Inventors* and *Mythbusters* as having good engineering elements. The former program certainly contains good examples of innovation and potential commercialisation, although most of the inventions presented would probably fall outside the formal national innovation system. The roles of engineers and engineering in headline companies in the minerals and biomedical industries (for example) are less readily recognised than the "science breakthroughs" that are reported almost daily in the media. Recommendation 1 of the review proposes a number of actions around increasing the public awareness of engineering.

In relation to formal research-led innovation, the university engineering community would seek to work closely with its colleagues in science and mathematics, and the business and design schools, to increase understanding and engagement of the public with all dimensions of innovation.

> ***There is a need for relevant actions and initiatives to increase the public understanding and awareness of innovation, and the role of engineering within it.***

4. The Limited Supply of Graduate and Postgraduate Engineers from Australia's Engineering Schools

Australia's engineering capacity – and hence its broad innovation potential – is underpinned by the universities' production of suitably qualified graduates (at all levels), and by the specific research programs they undertake. There is widespread concern that Australia has too few engineers to meet current and future demand.

Undergraduate education

The recently completed review (ref 1, 54-57) reported that graduate employment rates for first degree engineering graduates are good, and starting salaries have been consistently amongst the top five professions for several years. Despite high demand for graduates, the size of the pool of qualified Australian school leavers who are motivated towards engineering has remained fairly static over the past decade. Accordingly, ACED believes strongly that:

> ***The numbers of secondary school students who include mathematics and science in their secondary school certificates, and continue to take degree studies in engineering, must be increased to maintain and grow Australia's innovation capacity.***

Recommendations 1 and 6 of the review include actions to assist school education in science, mathematics and engineering, and also to increase the range of pathways for mature people and migrants to enter engineering, and to increase the proportion of women and indigenous students. Recommendation 3 addresses curriculum improvements, including measures to increase the retention ad success rates to graduation.

Research training

University-based research training to masters and doctoral levels is described by many as the "engine-room" of university research, and is a critical element to building the nation's high-value innovation capacity. Many graduates of research degrees in engineering ultimately take leading roles in innovation-led enterprises. The relatively low rate of progression by Australian graduates from first degree to postgraduate research studies in engineering severely limits the capacity of the universities' engineering schools to undertake research. **Nationwide, Australian commencements into engineering research doctorates and masters actually fell from 823 to 701 between 1996 and 2006** (ref 1, derived from Table 3 p35).

Australia's engineering schools have responded well to demand by international students, particularly at postgraduate levels. International higher degree research graduate numbers increased from 268 to 578 during 1996 – 2006. Further increase in these numbers depends to an increasingly significant extent on engineering schools being able to offer tuition and living scholarships, as our engineering schools are in competition worldwide for the best available talent.

ACED celebrates the internationalism of the engineering research schools, but is concerned about the opportunity cost of Australian engineering graduates' low level of participation in high-end research. This limits potential innovation, and constrains the sustainability and growth of Australian engineering industry, its research establishments, and its engineering schools.

The review recommended a number of actions in this area, here summarised as:

> ***Incentives must be developed to increase the numbers of Australian higher degree research students in engineering to sustain and grow the nation's capacity for engineering innovation.***
>
> ***Scholarships must be made available to attract the most talented international engineering graduates to undertake research in Australian engineering schools, and where possible retain them after doctoral graduation.***

5. Engineering Education for Innovation

The engineering schools are committed to providing high-quality education at all levels, including research training. Improving education for innovation is intrinsic to that commitment.

Graduates from accredited programs at the professional engineering level are expected to have developed "*creativity and innovation skills*"[6] The recent review (ref 1, pp 66 -74) reported that engineering schools are increasingly addressing issues of creativity through active-learning, including problem-based learning. In many instances challenging problems are drawn from industry. More than half the engineering schools have first year-students working on the international *Engineers Without Borders Challenge*[7], providing them with the opportunity to explore innovative solutions to globally difficult problems. All accredited degrees require extensive project work, much of which is drawn from industry or from research programs.

ACED is committed to supporting continual improvement of engineering programs to meet industry and professional demands. The review (ref 1, pp 12-13) reported on the trends for engineering careers to be directed towards high levels of technical specialisation, or complex project management. Amongst the former will be the need for some engineers to have deep engagement with new technologies, including those based on the biological sciences. These are likely to feature strongly in future innovative industries.

However, the processes of innovation are underdeveloped in most university engineering coursework curricula. Given limited resources, ACED considers that:

> ***Incentives and support are needed for engineering schools to develop curriculum at undergraduate and postgraduate levels for engineering in emerging technological areas, and in the processes of innovation. ACED would strongly support a systematic approach to building interdisciplinary approaches (involving engineering and business for example) and sharing of resources between institutions.***

6. Research and Research Training in Engineering Schools

<u>Academic staffing issues</u>

Research is often the prime interest of staff appointed to academic positions (designated as "teaching and research") in engineering schools, but rarely are newly appointed staff (other than those appointed to professorial positions) provided with large establishment funds. Success in the national research funding schemes often takes several years, despite schemes such as those for early-career researchers. Further, new staff have to get to grips with teaching, restricting their capacity to undertake and lead research. Establishing and undertaking research in most university engineering schools is a real challenge. Most doctoral graduates in engineering choose to progress their careers in industry, where their work is likely to be better supported, and their rewards and career paths are clearer.

Most engineering schools are currently experiencing considerable difficulty in appointing suitably-qualified academic staff. These concerns, together with the value of closer working with industry are discussed in more detail in the review (ref 1, pp 43-45, p84 and Recommendations 4 and 5). It would be in the interest of the national innovation system for:

> ***Development of incentives and rewards to attract and retain more of the best doctoral graduates in engineering schools, particularly through the development of joint-industry appointments must be a priority for investment***.

Innovation from publicly funded research

Most publicly funded research in university engineering schools, including that undertaken without specific project funding provided from competitive grants, is positioned at the pre-competitive stages of the knowledge-innovation cycle. Some is basic research, but most has a potential commercial application in the mind of the research leader. Most research is undertaken with research assistance and is a vehicle for research training.

The complex challenge for most engineering academic researchers is to develop the conceptual framework for commercialisation of their research findings, and develop the practical financing and industrial linkages sufficiently early in the research process to maximise the value of their ideas and findings. University commercialisation arms play a critical role in this process, and many ACED members could report good outcomes from having them. ACED would also urge that Commonwealth support mechanisms for entrepreneurship and innovation are linked with those operated at the State level. Where research is publicly funded, but also has industry support (such as via the ARC Linkage scheme), the pathway to commercialisation should be clearer. A further element of complexity in this class of research is to embed research training appropriately.

Whilst the distribution of public funds for research must be merit-based and invested for national benefit, the funds available within Australian engineering schools compared with other countries appear to be low. The average success rates in the ARC grant schemes are lower than the merit of the applications deserves. Furthermore, research grants are not fully funded, putting more pressure on teaching revenue, itself less per student in real-terms compared with a decade ago. ACED would support system changes in order that:

> ***The success rate of good research grant proposals in engineering must be increased, and moves to fully funding research to reduce the subsidies from teaching revenue are necessary to ensure that universities develop and contribute core capabilities to underpin the Australian innovation system.***

Research training for innovation

Engineering PhD programs do not normally require their candidates to track commercialisation paths for their discoveries, and perhaps that should not change. Nevertheless, many doctoral graduates do commercialise their work, and there is a strong case for requiring most, if not all, doctoral candidates to undertake some studies in the processes of innovation and commercialisation. Such programs have been developed and introduced into a number of Australian universities, and ACED endorses this development strongly.

A recent example offering the promise of increasing the number of PhD graduates with relevant skills in commercialisation is the extension of the ATN Universities' Graduate Certificate in Commercialisation,

offered through their e-Grad School, to all PhD candidates in the Cooperative Research Centres program. Over time this has the potential to significantly increase the awareness of the innovation process in early career researchers proceeding to industry and university appointments. This, and other broadening coursework options taken as part of PhD programs will lead to better qualified graduates entering the innovation system, but would need to be widened significantly to make an early impact on the uptake of intellectual property by industry. In summary:

> ***Universities should be fully funded to offer appropriate graduate coursework options to enhance the existing PhD programs and improve the capacity of PhD graduates to contrbute to innovative research and business productivity.***

The Cooperative Research Centre program

The CRC scheme has allowed many engineering schools to develop large, deep and enduring pre-competitive research relationships with industry, usually in multi-research provider and multi-industry partnerships. Many of their research programs and projects have found commercial application, and led to formation of independent for-profit businesses. Participation in the CRC program would appear to have contributed significantly to the doubling of research-only academic staff in engineering from 557 to 1,140 since 1996 (see ref 1, Table 10, p 42).

The CRC program has been successful for building engineering research, and training more engineering researchers in engineering schools. In addition there are examples where the CRC program has added value to Australia's innovation process by educating PhD graduates with experience in industry-focused research and with the capabilities to understand and work with a wide range of industry sectors. However, there are some significant impediments to university engagement in the CRC program and we question:

- whether the funding and reporting requirements are suitable to support very large distributed partnerships, where most of the public funds are absorbed in administrative costs;
- whether it is legitimate to call for large cash contributions from universities, who are already providing substantial in-kind contributions of academics staff, essentially as a subsidy to the CRC;
- whether there could be better arrangements for making in-kind contributions of contract research staff (as compared with those on contining appointments);
- whether other processes (such as the ERA) will provide a disincentive for universities to invest in staff and student commitments to CRCs and whether or not models can be developed to ensure that engineering research is valued for both its quality and its contribution to innovation.

With this in mind we welcome the concurrent review of the CRC program, and wish to see the program strengthened under clearer guidelines that encourage universities to contribute quality engineering research as well as provide an environment that supports effective innovation and commercialisation. These should lead to both industry outcomes and a growth in internationally competitive research capacity within universities. In summary:

> ***A rejuvenated CRC Program with clear benefits to both engineering research and industry capability is an essential outcome of the innovation review to ensure the continued capacity of universities to delivery quality research and commercialisation outcomes.***

7. Conclusion

The Australian Council of Engineering Deans offers this submission to the Review of the National Innovation System to support the further development and refinement of the system. Please contact me, or ACED's Executive Officer, Emeritus Professor Robin King (rking@eng.uts.edu.au), if you seek any further information.

Professor Elizabeth Taylor, AO
President, Australian Council of Engineering Deans

---

[1] King, R , 2008, *Addressing the Supply and Quality of Engineering Graduates for the New Century*, a scoping report for the Carrick Institute for Learning & Teaching, http://www.carrickinstitute.edu.au/carrick/webdav/site/carricksite/users/siteadmin/public/Grants_DBIprojec_engineeringquality_project%20report_25march08.pdf

[2] ACED 2004, extracts from the Constitution, Australian Council of Engineering Deans, revised 2004

[3] Royal Academy of Engineering 2007, *Educating Engineers for the 21st Century*, Royal Academy of Engineering, UK, London

[4] Auyang, S Y, 2004, *Engineering: an endless frontier*, Harvard University Press, Cambridge Mass.

[5] Royal Academy of Engineering & Engineering Technology Board 2007, *Public Attitudes to and Perceptions of Engineering and Engineers*, commissioned study by BRMB Ltd.

[6] *Stage 1 Competency Standard for Professional Engineer*, Engineers Australia, 2004

[7] *Engineers Without Borders Challenge* 2008: http://www.ewb.org.au/ewbchallenge/