BHERT-ACED-Engineers Australia: *Building Tomorrow's Engineers*
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The Review of Australian Engineering Education:
addressing the supply and quality of engineers for the 21st Century

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Project Manager

The Carrick Institute for Learning & Teaching in Higher Education funded ACED to conduct a "discipline-based" scoping project administered through UTS

The project was supported by Engineers Australia, the Academy for Technological Sciences and Engineering (ATSE), and the Australasian Association for Engineering Education (AaeE)

two quotes

- *'Engineering is the **art and science** of production that … is one of the most fundamental of human activities. … 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**'* (Auyang, *Engineering: the endless frontier*, Harvard 2004)

- *'Engineering is the **practical** means by which our greatest challenges will be solved, such as [sustaining] the environment, reducing poverty, [and improving] health and wellbeing. We engineers are **trained** and **practiced** at looking in two directions at once – both at **science** and at **business and commerce** – and **integrating** them to find an **optimal solution**. We bring a highly effective **problem-solving approach** to the challenges that come our way. **Those who wish to make a difference to the world should, I suggest, become engineers**.' (Browne, IET Catalyst, 2007)*

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the USA and UK have identified similar challenges to ours

do these quotes resonate with Australia's perception of engineering enterprises and engineering education?

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acknowledgements

- **Professor Mary O'Kane,** Chair, Steering Committee
- **Emeritus Professor Alan Bradley,** Engineers Australia
- **Professor Archie Johnston,** Dean UTS and former President ACED and **Professor John Simmons,** ACED Executive Officer who were instrumental in securing ACED funding
- **the Project Steering Committee:** Professors Mary O'Kane, Elizabeth Taylor, Peter Dowd, Archie Johnston, Phil Broadbridge, Alan Bradley, Dr Alan Finkel, and Associate Professor Wageeh Boles
- **ACED members** for making local arrangements for consultations with staff, students and industry bodies and supplying information
- **Engineers Australia** for making arrangements to consult with division committees, college boards, and the membership, and working with
- **AaeE** to provide an industry-university workshop at the Annual Conference last December

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context

- ***demand*** for engineering graduates (especially with expertise in key areas) in Australia exceeds supply: ~ **20,000 more engineers are needed**
- ***world-wide opportunities*** for engineering work abound: water, energy, transport, ICT, security, biomedical, …
- ***supply*** of students into university is ~ **static over the decade**
  - **qualified pool:** a ***declining proportion studying school mathematics*** at 'advanced' and 'intermediate' levels of the leaving certificate
  - **motivated pool**: a ***declining proportion*** of school leavers motivated ***choosing*** engineering: ~ 5% of total university commencers; in which female participation has dropped to < 16%
- ***graduate outcomes*** must respond to changes of engineering practice, and new technologies, and be achieved in the evolving environments of higher education/ industry needs/ professional expectations, etc.
- ***high attrition*** from engineering programs: of Australian undergraduate commencers: 52% males and 60% females will complete
- ***graduates*** often '***move into management***' early in careers, which may be problematic if that '***loss***' undermines the engineering enterprise

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goals and status

- to analyse these issues and provide a status report on Australia's higher education engineering education system in 2007
- to report on the impact of the 1996 Review, *Changing the Culture*
- to make recommendations to address the issues
- provide a vision statement for engineering education

- the draft report (145pp) to Carrick was submitted on 18th February
- the Carrick Institute expects to be requested to fund further work in engineering education, particularly in:
  - curriculum, pedagogy, learning
  - educator development and leadership

- the Steering Committee have proposed that ACED:
  - publish an extended executive summary (~ 16pp) as a roadmap for the future
  - lead an Implementation Team with Engineers Australia and ATSE (under the Tripartite Agreement)

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coverage: post-secondary school AQF levels, awards and occupations

AQF: vocational education & training sector accreditation	AQF: higher education sector accreditation	Engineering occupations: entry level qualification accreditation	min. years post senior sec school certificate
	Doctoral Degree		7.5
	Masters Degree	may be equivalent to a 4 year engineering degree	5
Vocational Graduate Diploma	Graduate Diploma		4
Vocational Graduate Certificate	Graduate Certificate		3.5
	Bachelors Degree (includes all 3 and 4 year, dual degrees and honours)	4 year degree for professional engineers 3 year degree for engineering technologists	3 – 4
Advanced Diploma	Associate Degree and Advanced Diploma	engineering officer (formerly engineering associate)	2
Diploma	Diploma	no designation	

Note: Trade Certificates (AQF Certificate III) are at two steps below the Diploma level

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nomenclature and the engineering team

- what do we mean when we use the name ‘engineer’: it almost always needs both branch and functional qualifications:
  - mechanical design engineer
  - software systems engineer
  - road maintenance engineer

- and the ‘engineer’ in the engineering team includes:
  - professional engineers (4-yr qualified)
  - engineering technologists (3-yr qualified)
  - engineering officers (technicians) (2-year post secondary school cert.)
  - engineering tradespersons (AQF Certificate III)

- in 2005 Australian universities graduated:
  - 7,937 with Bachelor of Engineers (70% domestic)
  - 139 with Bachelor of Technology (54% domestic)
  - 190 with Associate Degrees (75% domestic)
- **are the universities producing a balanced team?**

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study methodology

- focusses on curriculum, pedagogy, student demand and graduate outcomes
  - **submissions from ACED members**
  - **focus group consultations with ~ 1000 academics, students, from industry and the profession (Engineers Colleges and Divisions), and individuals**
  - **invited submissions**
  - **published material**
  - **data from DEEWR**

- started March 2007
  - **part-time Project Manager plus support from Engineers Australia**
  - **5 Steering Committee meetings (April '7 to Feb '08)**
  - **ACED Council endorsed recommendations, December 2007**

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on *Changing the Culture* (1996)

- **engineering program accreditation:** Engineers Australia's changes to focus on graduate outcomes/attributes is now operating well within engineering schools, and does not inhibitor innovation
- **engineering programs:** have greater breadth and include social, economic and environmental contexts, communication skills and teamwork, and preparation for life-long learning: generally endorsed by industry, except at the cost of 'fundamentals and report writing
- **but**
  - **student intakes -** have not risen to meet demand
  - **alliances and sharing between schools -** not much progress
  - **outreach to the school sector -** considerable activity and remains a priority
  - **engineering technlogists and engineering officers -** no progress, issues addressed in the present study
  - **staff profiles -** increasing industry and professonal experience amongst academics remains a concern
  - **industry collaboration -** mostly on a local basis; remains a concern
  - **the Advanced Engineering Centres program -** wound down, not developed, as proposed
  - **proposed National Centre for Engineering -** not established
- **overall it was a useful roadmap where leadership and resources were applied**

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vision statement

The Australian Engineering Education system:

- **provides programs of high quality, internationally accredited, industry focussed, meeting society's needs**
- **wide range of pathways and choices to attract school leavers and mature entrants**
- **produces graduates to will make positive contributions to their profession, and leadership**
- **is adaptive and responsive, collaborative and efficient**
- **in which academics and their work are highly respected, and recognised for contributions to engineering education and education research**
- **undertakes reviews to ensure continuing high levels of performance**

The report includes many examples of current excellent practice – as on the following slide

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examples of best-practice in engineering education: a platform for the future

- **advanced programs** for high-achieving students
- **foundation studies** support for able students (tested for engineering aptitude) but without specific pre-requisite knowledge
- **remotely accessible laboratories** and **project-centred engineering** curricula
- **integrated industry-based learning** that explicitly can provide contributions to competencies for professional engineer (CPEng) status
- **system/tool support for academic staff** to develop course and program profiles around learning objectives, activities and assessment around graduate attributes
- **systems** for sharing material between universities
- **industry support** for curriculum areas in high employer demand Research er stems
- **student peer-mentoring** into secondary schools, around engineering topics within school science subjects
- **student participation in international programs** such as *Engineers without Borders,* Formula SAE, and Students in Free Enterprise
- **established cooperation** between ACED, AaeE and Engineers Australia

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1. **Raise the public perception of engineering, including within primary and secondary schools, by increasing the visibility of the innovative and creative nature of the profession and the range of engineering occupations that contribute to Australia's prosperity, security, health and environment.**

Led by EA under the Tripartite Agreement, with two areas:

a) **promotion of engineering in general**

b) **recruitment of students (also relates to R6)**

8 specific action areas, involving:

- **market research and economic modelling of engineering**
- **media, on the societal contributions of engineering and engineers**
- **the development of (role models)**
- **further cooperation with school education, including in mathematics and science curriculum and teacher education**
- **investigate the merits of an engineering subject in all states**

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2. Develop, promote and support the concept, reality and importance of all members of the **engineering team** - Professional Engineers, Engineering Technologists, and Engineering Officers – in the successful implementation of engineering work. Review the graduate competencies and reference standards for the qualifications at each level

Led by EA and ACED, covering three areas:

a) **standards and qualifications**

b) **international standing**

c) **student enrolments and throughput**

6 actions, including:

- **research on occupations to underpin review and revision of the Stage 1 competency standards for all three qualification levels to international standards**
- **seek government support for rapid development of new standards and curricula, taking into account school leaver attributes**
- **seek government support for support of postgraduate conversion courses to meet shortages in specific industries**
- **research on student attributes, and early career pathways**

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3. Engineering schools must develop **best-practice engineering education**, promote student learning and deliver intended graduate outcomes. Curriculum will be based on sound pedagogy, embrace concepts of inclusivity and be adaptable to new technologies and interdisciplinary areas

Led by ACED and AaeE, through their membership

16 areas of best-practice pedagogy and curriculum development, and associated staff development, are identified, including:

- understanding students' learning
- reducing male stereotypes in content and process
- holistic educational program design
- adoption and development of CDIO
- emerging engineering themes: complexity, risk, life-cycle engineering, global workflow, multidisciplinarity
- use of new learning methodologies
- more authentic laboratories
- contemporary issues and human dimensions of engineering
- improved assessment practices

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Australian Council of Engineering Deans

4. **Enhance staff and material resources to enable delivery of engineering education that is demonstrably aligned with Australia's needs, and is compliant with international standards**

Led by ACED members and consortia

8 actions, covering:

- **sharing resources and dissemination of best practice**
- **development of a national strategy for laboratory equipment acquisition, operation and utilisation**
- **incentives support for higher degree research students, and for attraction and retention of academic staff**
- **consideration of creating a national centre for engineering education**
- **increased opportunities for staff to develop knowledge of contemporary industry practice**

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5. Engineering educators and industry practitioners must engage more intensively to improve the authenticity of engineering students' education education

Led by ACED, and its membership in consortia

9 actions, covering:

- coordination of industry advisory groups as a lobbying force
- setting standards of industry engagement
- best-practice models of industry sponsorship
- increasd supported research on engineering practice
- increased number of effective joint industry-university academic appointments
- increased authenticity of students' educational experience, with resepect to knowledge of industry practice
- increased number and value of industry scholarships
- develop specialist engineering postgraduate programs in areas of demand (power, defence, water, roads, rail, aviation, microelectronics, logistics …)

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6. **Address shortages in the engineering workforce by attracting and retaining people from non-traditional backgrounds, eg. women, mature age engineers, engineers with overseas qualifications, engineers who have left the profession, and engineers wishing to articulate between qualification levels. Ensure the future needs of employers are matched by the numbers and types of programs on offer.**

Led by ACED

4 actions, covering:

- **work with the Office of Women on barriers to participation in engineering by women; reinstate (renew) Women in Engineering programs in engineering schools**
- **develop incentives for women to develop careers in engineering**
- **research (with employers) the needs of engineering qualified women wishing to return to the workforce after child-rearing, and seeking to maintain currency while in part-time to employment**
- **develop specific incentives, support and accredited (fast-track) educational pathways for qualified people and others with motivation, to enter and re-enter engineering to address shortages**

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one student's insightful comment

"Young people who are thinking about what to study at university have not really been taught what the bachelor of engineering qualification is about.

It is not just something to do if you want to design infrastructure. It is a broad-based design degree which teaches critical thinking, time management, and most importantly, how to learn. With these skills you can go anywhere, and do almost anything.

Reflecting on my program … [Engineering] has been the best training imaginable I think. Difficult, but it has transformed the way I think and approach problem-solving and learning. The best 5 year investment I could have made in my future."

joint B.Sc. B.Eng. student from James Cook University

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concluding comment

Such students give me confidence that we have sound foundations:

they are the most effective ambassadors of engineering education.

We must support them in their careers, and assist them to promote engineering.

We must engage community at large with the power of what engineering can do to change the world for the better.

We must make the engineering curriculum an active and enjoyable learning experience.

We need to work together on implementing these recommendations to build tomorrow's engineering teams

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more detailed material follows

the ‘system’ in 2007 (1)

- 32 institutions with accredited awards at professional engineer and engineering technologist level
- significant research growth
  - co-operative research centres
  - ARC Centres of Excellence and Special Research Centres
  - several Federation Fellows
  - 80% growth in higher degree research students (5,400 in 2007)
- five program models operate accredited professional engineering programs and > 100 different degree names:
  - 4-year Bachelor of Engineering
  - dual/double/combined degrees (with science, management arts, law)
  - integrated/articulated bachelors to masters (UNSW biomedical engineering, Melbourne model)
  - accredited 3-year engineering technologist program articulating to masters (combined program accreditation)
  - additional award (eg Diploma of Engineering Practice) for embedded industry-based learning

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the ‘system’ in 2007 (2)

- **wide range of commencing student ability**
  - **UAI cut-off ranks into B.Eng range between low 50’s and high 90’s**
- **few institutions offer Bachelor of Technology programs**
  - **student market is weak**
  - **employers are equivocal**
  - **the occupation is not well defined**
- **major growth has been in postgraduate coursework programs for international students**

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statistical snapshot: 1996 - 2006

- total engineering students (persons) have increased by 35% to 66,165 (average load factor 60% in 2006)
  - internationals from 11.6% to 28.5%
  - females from 13.8% to 15.4% (max 16.0%)
- academic staffing has increased by 17.6% to 2,831 in 2006
  - research-only increased from 23.1% to 40.3%
  - female from 7.6% to 14.0%
- support staff has decreased by 17% to 1,498
  - females increased from 29.8% to 39.9% (mostly in administrative roles)
- commencing students
  - domestic student enrolments in engineering has fallen from 6.7% of total to 5.4% in 2006 (across all awards and disciplines)
- first degree graduations
  - domestic B.Eng. has ranged from 5,287 ~ 6,000 (5,603 in 2005)
  - estimated success to graduation ~ 53% (males) and ~ 60% (females)
  - part-time students have lower average course success and year retention rates
  - fewer than 200 B.Tech. and Associate Degree graduates per year

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issues raised in the consultations and submissions (1)

- declining resources for teaching (alongside increasing research focus)
  - large increase in effective student: staff ratios (>50%)
  - compromises laboratory quality and limits academic staff development
  - but high potential for rationalising and sharing
- a responsive rather than proactive culture in engineering industry
  - focusses on cyclical industries (eg mining), and traditional manufacturing, rather than innovation-led
  - perceived under-exploitation of R & D
  - industry tends to think short-term, limiting career and skills and capacity building
- relative invisibility of engineering in society and schools
  - evidence of the '*satisfied needs no longer motivate*' factor: we have mostly very reliable engineered systems
  - engineers status (and visibility) is less than law, medicine and accountancy: ineffectiveness of Engineers Australia
  - engineers in leadership positions are 'not thought of as engineers'

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issues raised in consultations and submissions (2)

- static student demand and lower levels of preparation in mathematics and science
  - Gen Y students have different expectations of education and work
  - very high range of educational ability entering B.Eng. programs
  - fewer students taking high levels of mathematics and sciences
  - required entry levels have been reduced by universities – a vicious circle
  - teacher education issues (that must be dealt with constructively)
- international issues
  - strengthening A$ (since ~ 2003) has reduced competitiveness for international students and regional (Asian) educational provision grows
  - international students welcomed but their predominance in masters programs may be problematic (without program accreditation)
- low and declining participation of women and minorities
  - women commencing engineering has fallen since 2001
- higher research degree issues
  - too few B.Eng. Graduates seek research careers, threatens the sustainability of the engineering education system

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issues raised in consultations and submissions (3)

- industry support is generally strong, especially in regions
  - where is the next generation of skilled draftspersons coming from (not from VET/TAFE) ?
  - is there a place or engineering technologists and 3-year degrees?
  - can the universities support migrant engineers more effectively
- engineering education
  - do we use good models of education for engineering practice?
  - sustainability is inadequately embedded in most programs
  - too much specialisation in undergraduate programs
    - but not much take-up of postgraduate programs
  - inadequate treatment of engineering design
  - too little attention on fundamentals
  - too much or too little mathematics?
  - insufficient focus on project management
  - insufficient material on risk and reliability (statistics)
  - need to develop future focus on engineers as the profession responsible for complex, multidisciplinary systems, and new technologies …
  - an engineering degree should be seen to be an excellent generic (science-based) education for business, leadership, …

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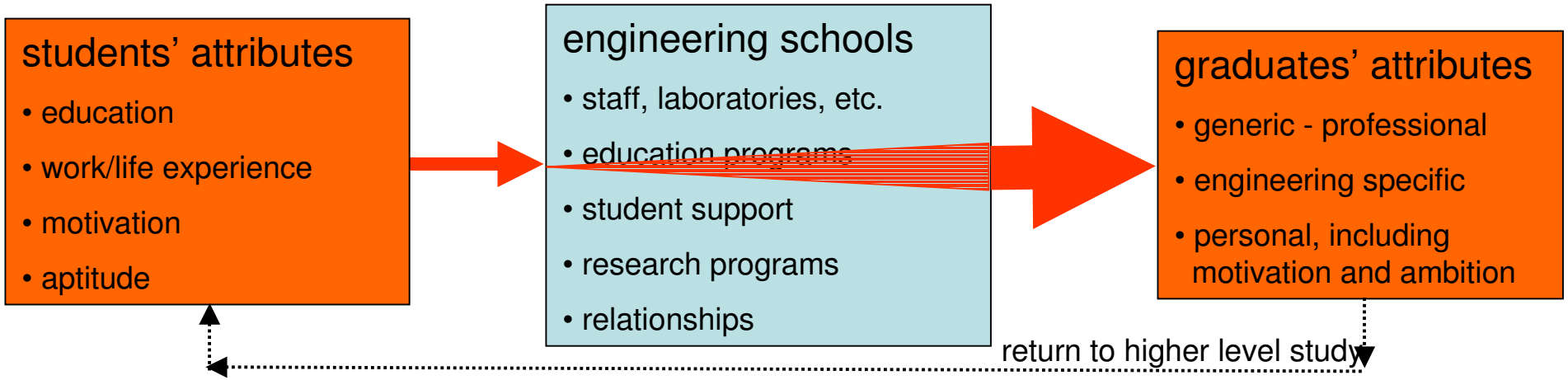
engineering education is about increasing students' capabilities through the education programs they experience – hence study focus is on the engineering schools



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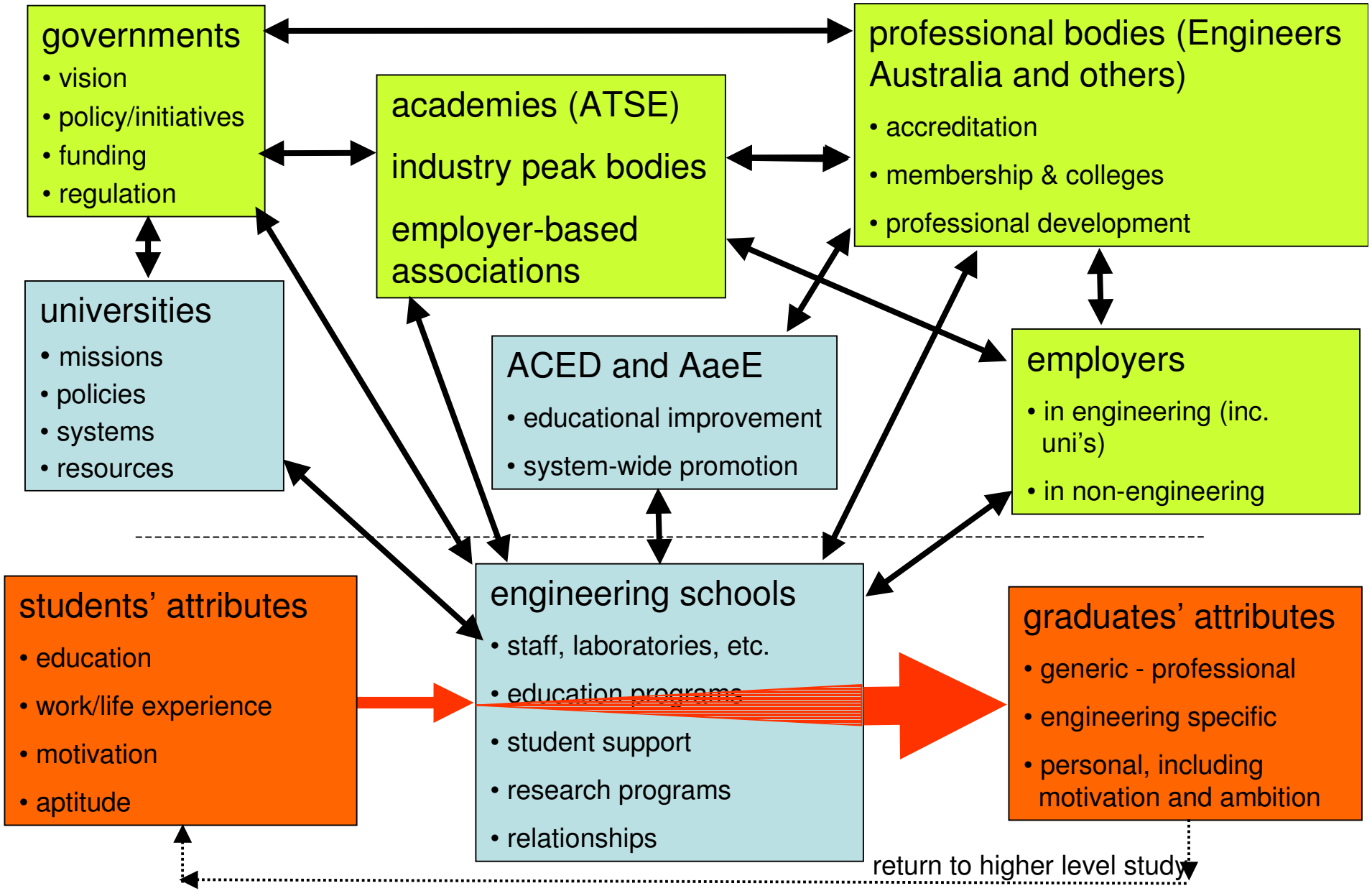

adding system components (stakeholders) influencing engineering schools

totals: engineering students (persons) and staff (FTE) 1996, 2001 and 2006

students - award	1996	2001	2006
research	3,632	4,402	5,413
coursework masters	4,029	5,962	9,202
bachelors	41,053	47,919	51,550
total	**48,714**	**58,283**	**66,165**
% female	13.80%	16.00%	15.40%
% international	11.60%	19.50%	28.50%

staff (FTE)	1996	2001	2006
academic	**2,407**	**2,479**	**2,831**
% research-only	23.10%	31.50%	40.30%
% female	7.60%	10.60%	14.00%
support staff	**1,799**	**1,590**	**1,498**
% female	29.80%	36.10%	39.90%

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commencing student data (persons)

award level	1996	2001	2006
research	1,091	1,189	1,439
coursework masters	2,195	3,402	4,560
bachelors	12,223	14,160	14,142
associate degree	335	269	602
total	**15,881**	**19,266**	**21,099**
% female	13.9%	15.7%	15.3%
% international	15.1%	27.4%	34.0%
domestic commencers (all awards)			
engineering	**13,439**	**14,031**	**13,931**
health	26,730	29,969	39,283
natural science	32,785	20,999	20,943
information technology	inc. elsewhere	17,436	8,198
law, business and society	115,062	135,454	145,742
total	**219,817**	**244,491**	**256,382**
% engineering	6.1%	5.7%	5.4%

graduates in engineering: 1996, 2001 and 2005

award level	1996	2001	2005
research	450	626	845
coursework postgraduate	1,462	2,069	3,492
4-year bachelors	6,006	7,616	7,937
3-year bachelors	inc. in above	103	139
associate degree	206	184	190
total	**8,336**	**10,711**	**12,794**
% female	13.6	17.1	17.1
% international	15.8	26.7	40.8

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