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ACED Submission to the Women in STEM Decadal Plan

The Australian Council of Engineering Deans strongly supports the intentions of the Decadal Plan and would wish to be fully engaged in its further development, as well ultimately, in its implementation. As noted in the discussion paper, engineering is the largest professional area of private sector employment underpinned by STEM education, and is highly significant to Australia's future prosperity, well-being and sustainability.

ACED has a long record of engagement with promotion of women in STEM, particularly into and within engineering degrees. Relevant issues have been tackled through, and as a result of, the national reviews of engineering education conducted during 1995-6 and 2007-8, and in a subsequent project funded by the Australian Learning and Teaching Council (see attached Position Statement).

ACED's member faculties and schools have run and participated in many programs to encourage women into higher education study in engineering. The principal focus of these has been to increase enrolments and retention by women in bachelors degrees as these programs provide the platform for engineering careers and further study.

In 1983 the proportion of women in engineering degrees was 4.3%. Concerted efforts, including by funded 'Women in Engineering (WiE)' initiatives, saw this figure increase to 13.7% by 1996. Between 1996 and 2000 the proportion of women in the domestic engineering bachelor degree commencing cohort increased to 14.7%. Since 2000, this proportion has varied between 12.7% and 15.7% while the whole domestic commencing cohort has grown from 10,428 to 14,390[1]. This slow growth of participation, set beside the many initiatives to encourage women into engineering study, illustrates the difficulty of the challenge.

It must also be declared that the proportion of women in engineering varies quite widely between universities, depending on the range and mix of engineering disciplines offered and the university's location. In 2016, the domestic commencing bachelors degree participation rate ranged from 6.5% (in a small engineering school in a regional university) to 25.5% (in a large engineering school in a capital city research university). Degree programs in biomedical, chemical, environmental and civil engineering attract much higher proportions of women than aeronautical, mechanical, electrical and computer engineering.

On the positive side, recent data show that women do (on average) graduate from bachelors degrees[2] more quickly and gain higher median salaries than their male peers. Since 2012, women have comprised more than 17% of the postgraduate coursework cohort in engineering and more than 25% of the domestic research higher degree (HDR) commencing cohort and. Women also occupy more than 20% of research-only positions in engineering faculties and schools. They do,

[1] Data in this submission is from the Department of Education and Training Higher Education Statistics Unit and published by ACED at http://www.engineersaustralia.org.au/aced/resources Recent year figures do not include commencements at The University of Melbourne and The University of Western Australia, where direct admission to bachelors degrees in engineering is no longer available.

[2] Since 1980 the majority (93% in 2016) of bachelors graduates in engineering have studied programs of at least four years duration, and graduated with honours, now formalised at AQF level 8 Bachelor Honours Degree.

however, occupy only 15% of teaching & research positions, predominantly in the lower academic levels. There is much to be done to attract more women into academic posts and support their progression.

ACED anticipates that the demand for engineers in Australia will continue to increase to meet societal demands. With current domestic graduates representing only about one-third of Australia's annual demand for engineers, there may be pressure to increase local graduations further.

ACED envisages that the core focus and responsibilities of engineering to society will remain while its content and modes of practice will continue to evolve. Future engineering practice will undoubtedly have greater digital and computational content, incorporate new materials and technologies, and address ever more complex and multi-faceted human inspired problems. The increasing diversity and interconnectedness of engineering disciplines, and the human sides of engineering work (both purpose and practice) are likely to encourage more diversity in student enrolments.

We anticipate specifically, that the emerging focuses of engineering, including in bio-engineering, human-centred, sustainable and humanitarian engineering, will favour the interests of more women and attract students not currently targeting higher studies in STEM related fields. The greater challenge for ACED's members is to attract significantly more women into the areas of engineering that are more strongly grounded in physics than in chemistry and biology.

In 2017, ACED published a Position Statement *Increasing the Participation of Women in Engineering Education,* to guide action by ACED members. This drew on and updated a previous study, and is attached to this submission. Responses to the questions posed in the Decadal Plan discussion paper are drawn from this Statement.

ACED suggests a target doubling to about 30% by 2035 in the national participation of women commencing bachelor honours degrees in engineering or in the engineering stream of foundation bachelors degrees in science. Such a doubling over the current rate is a stretch target that necessarily will have to draw women from study in other fields of study. We would naturally prefer that these women are not diverted from other areas of STEM, but are the result of their realisation that engineering offers study interest and career opportunities in which their talents in the arts and humanities can find expression alongside capabilities in science and mathematics.

Responses to questions follow.

1. **What changes need to occur to enable more girls and women to participate in STEM education at any level (primary, secondary or tertiary)?**

The delivered school curricula in mathematics, science and technology (digital technologies and design) must be more inspiring. They must more clearly demonstrate connections of these subjects to each other and to the creative worlds of problem solving for human improvement, including engineering. The ACARA *Technology* curriculum includes relevant principles, including systems thinking, opportunities for creative work in coding, and activities that integrate science and mathematics with studies of society and culture. Pre-service and in-service teachers must be adequately recruited, resourced and supported (including by STEM faculties) to tackle these subject areas.

There would also be value in attracting more mature-aged women into STEM studies, either for career change or in undertaking tertiary studies for the first time. Their prior studies and life

experience could often be assets to making such change. Mature-aged women taking up education or teaching degrees should also be encouraged to take a STEM major.

Improved school education will be an enabler for subsequent STEM studies and careers, but the tertiary sector must respond by increasing the attractiveness of its STEM offerings. For tertiary level engineering, specifically in the higher education sector, curriculum changes that lead growth in bio-related engineering and new materials, and that emphasise the social contexts of engineering practice (e.g. sustainability, human-centred engineering and humanitarian engineering), will attract more women to identify with the discipline. New curricula will increasingly focus on creative problem-solving, preferably in multi-disciplinary teams drawn from within and outside engineering. Students will also need to be taught by faculty with better gender balance and experience and non-discriminatory workplaces.

2. What are the most effective things we can do to change inaccurate stereotypes about STEM professionals and the range of STEM careers?

One stereotype set about STEM (beyond school) and engineering in particular, is that it is 'narrow', 'utilitarian', 'technocentric', 'not creative', 'hard to study' and 'not for girls'.

The 'application of mathematics and science' stereotype has worked well to attract boys from school into engineering, but it does not convey that solving real problems though STEM requires much more than mathematics and science. In reality, professional engineering is a socio-technical practice of negotiation and judgement that contributes to the creation of sustainable communities and uses scientific and technical knowledge to solve complex problems. This needs to be more apparent in both the school and university education processes.

The broad sets of knowledge and skills gained in a good bachelors degree in engineering opens doors; it does not constrain career options. It is evident, but may not be widely known, that many STEM graduates aspire to and succeed in developing their careers through their innovation and entrepreneurship, supported by new university and state initiatives. Raising the visibility of STEM women in movies and increasing the human and social dimensions of engineering will immediately attract more women. Articulating that engineers rise to leadership of major enterprises and in the public domain must be conveyed more effectively than it is.

Many of the required changes are in hand within engineering academe and the engineering profession, but their veracity is not being conveyed more widely. This is largely a job for the engineering profession. A related point is that Australia's public discourse appears less comfortable with using the word 'engineering' (and subsuming it within 'science') when it would be better to distinguish between their complementary roles. This is most evident in discussions of 'science and innovation', where it is rarely explicit that engineering thinking and practice are likely to produce the value from innovation, even when underpinned by new science. Members of the STEM community at least should be clear in their use of the relevant terms.

There also needs to be a whole of STEM community push for semantic accuracy, that includes as necessary, clarity about when we use 'STEM' as the integrative or collective, or when we mean its separate components, as 'S-T-E-M".

3. **What measures should we be using to determine eligibility for career recognition and progression?**

ACED and its members are proactive in ensuring women are not discriminated against in terms of eligibility in recruitment, career progression and promotion processes: this is also enshrined in institutional policies. Most ACED's member universities are involved in the SAGE (AthenaSWAN) initiative. Many ACED members have instituted schemes for ensuring women are not disadvantaged by career breaks for family duties. Academic positions for which only women may apply are being used. In addition, ACED endorses:

- valuing contributions to gender inclusivity and equity in academic appointments and promotion;
- utilising the skills of female professional engineers on a career break (especially from industry) for short term academic duties.

In summary, eligibility must be on merit and experience applicable to the job, making due allowance for career breaks.

4. **Australia has more than 330 different initiatives to foster the participation of girls and women in STEM. What type of initiatives are demonstrating the most impact in your area of interest?**

At the national level, the *Science and Engineering Challenge*, and *CSIRO STEM Professionals in Schools*, the *Power of Engineering* all get good reports from their participants. *Experience IT* in NSW has grown rapidly. As a general rule, activity-based programs and those that involve 'real STEM professionals' are likely to be more successful than passive and 'academic' events. Individual faculties' *Open Days* in which students demonstrate their projects are also likely to be more successful. Outreach activities need to span all stages of school education, as stereotypes are created very young. Every effort should be made to connect and scaffold activities to school mathematics, science and design and technology subjects.

There is, nevertheless, a lack of good quantitative evidence of how outreach events influence school students' decision making. While there is often positive feedback from those participating, the commencing numbers into engineering don't reflect this impact very convincingly.

All outreach programs are likely to have some impact on prospective students, but the reality is that some are more effective than others, and a few may perpetuate the problem through ill-conceived messaging. Evaluation often stops at attendance numbers and satisfaction surveys. A more rigorous and transparent evaluation of outreach programs would be highly desirable. ACED would support an investigation of how current programs are monitored and evaluated as the first step to producing a best practice guide to 'Women in STEM' program evaluation.

5. **What societal and regulatory issues (i.e. not STEM-specific) will have the greatest impact on women in STEM, and how should we address those that are barriers?**

The most desirable societal (cultural) barrier to lower would be general acceptance of poor performance in mathematics, or ignorance of science. ACED would, for example, like to see all students take some mathematics and science in the secondary school certificate. This mathematics should be at the highest level at which they can succeed, and should be aimed at raising significantly the proportion of school leavers with basic calculus-based mathematics. This in turn, should be the

normal entry level for all students intending to progress in STEM or any other quantitative field. A change of this nature would clearly increase the pool of school leavers eligible to continue in STEM.

A second societal issue is to address gender issues, including prejudice and unconscious bias in classrooms (at all levels of education) and in workplaces. These are persistent issues within engineering education and the profession that must be dealt with proactively through further training in gender and diversity.

6. Progress towards gender equity in STEM will require changes. How do we address the challenge of backlash and resistance to these changes?

Most engineers and engineering enterprises want to increase the participation of women in their enterprise because they know that diversity will improve the quality of their activities. The contributions of women are frequently celebrated and publicised as exemplars of role models. Any resistance to gender-specific appointments, and support and promotion, for example, need to be countered by strong and consistent management and explanation of the long-term value of having women at all levels of every enterprise.

7. If Australia is to take a strategic approach to improving the participation of girls and women in STEM, where would effort best be placed?

Improving the school science, mathematics and technology curricula is essential (see response to Qu1) and reducing the inaccurate stereotypes (see response to Qu2) should be high priorities.

At the university level, the importance of having more women in academic positions in engineering faculties and schools, and especially in leadership roles, cannot be understated for their importance as role models for students, enrolled and prospective. Every effort must be taken to recruit and promote more women (also see Qu3).

ACED has noted that most of the Women in Engineering (WiE) outreach programs were disbanded since 2000. Arguably, they – or their functions – need to be reinstated on a national basis, to:

- engage enrolled women students in outreach, mentoring, peer tutoring and leadership roles, thereby developing their confidence and capabilities for subsequent participation in the workforce;
- contribute, often very significantly, to student recruitment initiatives;
- attract diverse stakeholders who bring valuable resources to universities;
- demonstrate explicitly how the presence and contributions of women at all levels are valued, sending clear messages to students and staff about faculty commitment to equality of opportunity.

ACED recognises that reinstated WiE programs will need to incorporate current thinking on gender equity. Female students are likely to have and perceive diverse needs. WiE initiatives may benefit all students and contribute to faculty collegiality and performance. A mainstreamed WiE program would address the earlier points, and:

- have responsibility for recruiting and supporting women students, against agreed metrics;
- contribute to marketing and other publications to frame engineering as a field that requires a broad range of skills, has strong social and human dimensions, and connects to many other disciplines and professions;

- provide students and academics with diversity training that explicitly addresses sexual harassment and gender-bias that can impede students' learning;
- contribute to workshops on learning styles, and to ensuring that faculty and school polices, processes, and documents are gender-neutral, and inclusive;
- provide leadership in the design and implementation of gender-neutral and inclusive curricula, and capacity to provide gender equity critique and analysis in reviews of programs and course units.

In addition, ACED supports its members to consider widening admission criteria to attract women (and others) with the potential to succeed in engineering, and ensure suitable curriculum support. Offering incentives to girls to school education referred to in Qu1 and scholarships for subsequent study would also raise the profile and attractiveness of engineering and STEM more broadly.

8. Is there anything else you have not yet covered in your response which could improve gender equity in STEM?

ACED has recently embarked on the first stage of a national review on the Engineer of 2035, to focus on future expectations of engineers and recommend on changes in engineering education. (The graduates of 2035 have already started school; by the time they graduate from engineering there will be profound changes to the content and pedagogy of their education.) Increasing the gender diversity of the engineering profession more rapidly is a strong theme of the review. This goal aligns specifically with that the Decadal Plan, and ACED sees mutual benefit in being involved with further work on the Plan.

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ACED President 2016-8

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ACED AUSTRALIAN COUNCIL OF ENGINEERING DEANS

Position Statement **March 2017**

Increasing the Participation of Women in Engineering Education

Improving engineering education is critical to recruiting and retaining more women in the engineering profession

The Vision

Engineered infrastructure, services, products and systems serve everyone, yet Australia's engineering profession does not reflect the country's gender balance. Higher numbers of women in engineering study and then practice will enhance the profession's capabilities to tackle future demands. The education of all engineers will benefit from being more inclusive of women and their perspectives.

Numbers and Issues

While engineering has expanded exponentially in technological scope and societal impact, the engineering profession in Australia has not achieved gender equality.

- In 2011, women were 14% of the 257,382 ***engineering graduates*** working in Australia[3]. Many of these women were educated overseas or came to Australia to study.
- In 2015, women were 16% of the 20,544 ***domestic students commencing study*** in university programs (all award levels) in Engineering and Related Technologies[4]
- Over 2000 to 2015, the proportion of women in the ***domestic undergraduate commencing*** cohort (mostly in 4-year bachelor degrees) averaged 14.1%, with a slight increase to 15.2% in 2015. (The total cohort increased by 50% to 15,000 over this period.)
- Women's ***participation in engineering study*** more than tripled from 1983 to 2000, from 4.6% to 14.7%.

The participation of women in engineering differs amongst its branches. In 2015, women were 14.4% of the Australian ***bachelors degree graduates in engineering***[5], and about:

- half of the biomedical engineers;
- 25% of the mining and chemical engineers combined;
- 15.4% of the civil engineers (the largest branch);
- less than 10% of the graduates in aerospace, electrical and electronic, and mechanical and related branches.

These data indicate women's preferences for branches of engineering that focus on people and communities.

Increasing the participation of women in engineering (and STEM) degrees in Australia and similar countries has been a priority issue for three decades that has been addressed by many university-based and other outreach programs to prospective school students.

Perceptions that women have lower abilities and intrinsic interests in STEM have been countered by evidence[6]. Girls' lower participation rates at school and beyond are attributed to their lower levels of confidence in subjects such as mathematics. Furthermore they are more influenced (than boys) in their study decisions by their perceptions of identity and ability, and aspirations.

Women do (on average) graduate from engineering more quickly and gain higher (median) starting salaries than their male peers. Yet women (on average) progress in their engineering careers more slowly, partly due to career breaks; and many leave the profession early because of its non-inclusive work culture[7]. University employment offers engineering women better prospects: they occupy more than 20% of research-only positions in engineering, the pathway to an academic career. Nevertheless, women hold only a small proportion of higher level academic positions.

Challenges

ACED and its members recognise that increasing the numbers of Australian women in engineering study needs to be tackled urgently. Three areas stand out for action.

Career preferences: clearly, women are differentially attracted to biomedical engineering and environmental engineering, but these, and similar emerging branches offer relatively fewer career opportunities. The work (and study) cultures of aerospace, electrical, electronics, mechanical and industrial engineering are evidently strongly masculine.

Pathways into engineering study: the conventional post-school path into engineering study is biased against women and compounded by other trends. For example, the proportion of girls taking the Year 12 Advanced Mathematics subject has declined over the past decade, alongside decline of total enrolments in that subject[8]. Making Advanced Mathematics (and Physics) prerequisite subjects for engineering limit the pool of women who might even consider taking engineering at university.

Curriculum inclusiveness: the interests of women (and other minority groups) must be incorporated in the design and implementation of the university engineering curriculum. This is likely to be achieved though curriculum that emphasises the social contexts of engineering practice, and is delivered by a gender-balanced academic staff team.

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[3] *Australia's STEM Workforce*, Office of the Chief Scientist, Australian Government, 2016

[4] Department of Education and Training, Australian Government. https://www.education.gov.au/ucube-higher-education-data-cube. The field of education 'Engineering & Related Technologies' includes aviation and spatial sciences and technologies.

[5] Data compiled by ACED, see http://www.engineersaustralia.org.au/aced/resources

[6] *Busting Myths about Women in STEM*, Office of the Chief Scientist, Occasional Paper 13, Australian Government, Nov 2016

[7] J E Mills, et al, *Challenging Knowledge, Sex and Power: gender work and engineering*. Routledge 2014

[8] F Barrington & M Evans (2014), Aust. Math. Sciences Institute. http://amsi.org.au/publications/participation-year-12-mathematics-2004-2013/

Recommendations for action

These issues and challenges were explored in an ACED-led project[9] during 2008-11. ACED endorsed the recommendations, but despite much activity, the challenges persist. The following recommendations update ACED's position.

Recruiting and supporting women students

To double the current commencing student participation rate to 30% will not be possible without effort. Most of the university-based *Women in Engineering (WiE)* programs were disbanded during the last decade. Arguably, they – or their functions – need to be reinstated to:

- engage enrolled women students in outreach, mentoring, peer tutoring and leadership roles, thereby developing their confidence and capabilities for subsequent participation in the workforce;
- contribute, often very significantly, to student recruitment initiatives;
- attract diverse stakeholders who bring valuable resources to universities;
- demonstrate explicitly how the presence and contribution of women at all levels can be valued, sending clear messages to students and staff about faculty commitment to equality of opportunity.

ACED recognises that reinstated WiE programs will need to incorporate current thinking on gender equity. Female students are likely to have and perceive diverse needs. WiE initiatives may benefit all students and contribute to faculty collegiality and performance. A mainstreamed WiE program would address the earlier points, and:

- have responsibility for recruiting and supporting women students, against agreed metrics;
- contribute to marketing and other publications to frame engineering as a field that requires a broad range of skills, has strong social and human dimensions, and connects to many other disciplines and professions;
- provide students and academics with diversity training that explicitly addresses sexual harassment and gender-bias that can impede students' learning;
- contribute to workshops on learning styles, and to ensuring that faculty and school polices, processes, and documents are gender-neutral, and inclusive;
- provide leadership in the design and implementation of gender-neutral and inclusive curricula, and capacity to provide gender equity critique and analysis in reviews of programs and course units.

In addition, ACED supports its members to consider widening admission criteria to attract women (and others) with the potential to succeed in engineering, and ensure suitable curriculum support.

Recruiting and supporting women academic staff

The importance of having more female role models amongst the engineering staff cannot be overstated. ACED endorses relevant measures including:

- proactive recruitment of women academics;
- ensuring women staff have adequate opportunities for being mentored for their career development;
- valuing contributions to gender inclusivity and equity in academic promotion and appointments;
- utilising the skills of female professional engineers on a career break for short term academic duties.

ACED strongly supports its members to engage with the SAGE *(AthenaSWAN)* initiative[8], introduced recently into most universities to support women in STEM disciplines.

Improving the curriculum

The engineering curriculum is never static, under pressure from new science, new technological tools and the demands of employers for graduates with 'job ready skills'. ACED's member universities will continue to provide a wide range of accredited engineering degree programs that reflect their institution's philosophy, regional needs, and student demography. Such variety of curricula is a strength of the system provided by ACED's member universities.

The low participation of women in engineering study exposes a systemic weakness in curriculum with over-emphasis on fundamental science and technological application. Rather, the curriculum needs to reflect these and the social contexts of engineering application. Greater emphasis on human-centred design and sustainable development will reflect contemporary needs for all engineers, and attract more women, and other minorities.

ACED supports its members to develop coursework programs and research in academic cultures that respond to these demands, and that use a wider palate of pedagogies, assessments, physical spaces and resources, including engagement with industry.

The way ahead

A major increase in the proportion of women in engineering study will not be easily won. Within the engineering faculties and schools, dominant cultures prevail and their members can be blind to their own assumptions. Engineering, often and accurately stereotyped as a masculine profession, conducted in a masculine organisational environment, has a long way to go.

By taking the actions proposed in this paper, ACED and its members will make a positive difference to the engineering profession, for the benefit of society at large.

[9] E Godfrey & R King (2011) *Curriculum specification and support for engineering education: understanding attrition, academic support, revised competencies,* pathways *and access.* *http://www.olt.gov.au/project-curriculum-specification-support-uts-2008*

[8] Science in Australia Gender Equity (SAGE) project. https://www.sciencegenderequity.org.au/science-in-australia-gender-equity-sage-pilot-2015/

Australian Council of Engineering Deans Inc.

The membership of ACED is a senior academic representative of each of the 35 Australian universities that provide professional engineering degrees accredited by Engineers Australia. ACED's mission is to promote and advance engineering education, research and scholarship on behalf of the Australian higher education system.

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