

Reflections on the past, present and future of Women in Engineering

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***Abstract:** For many years a Women in Engineering Forum was run in conjunction with the AEEE conference, but in recent years “women in engineering” has fallen off the radar to a large degree. There is a widespread perception that the issues of concern for women have been addressed, and that women are now incorporated into the mainstream of engineering education and the engineering profession. Yet Australia and other western countries still have participation rates for women in engineering education that are lower than any other field of education and that have stagnated or declined for the last decade. This paper reviews a range of recent data and studies to examine the current picture of women in engineering education – the statistics, student experience and faculty issues. It concludes with a look to the future – what still needs to be done?*

Introduction

From 1994 to 2005 the *Australasian Women in Engineering Forum* was run in conjunction with the annual *Australasian Association for Engineering Education (AEEE)* conference, initially as a related forum held immediately before or after the main conference, and later as a stream within the main conference. At the 2006 conference the issue of the decreasing profile of the WIE forum within the conference was debated at a plenary session “*Has Gender gone off the Agenda?*” Subsequently, in 2007 there was only one paper session devoted to “Women in Engineering” and in 2008, 2009 a single paper session devoted to “Diversity”. Hence it would seem that the engineering education fraternity consider that either the issues of women in engineering are solved, or that there is nothing new to say about it. Or, maybe it is just too hard and we have given up beating our heads against the brick wall?

This paper reviews and reflects on the issues of women in engineering, focusing particularly on education, based on 30 years of personal and research involvement in the area. It will examine a range of data and recent studies to explore the past and present situation of women in engineering and then focus on what remains to be done in the future.

Are there really so few women?

Australia

While there are certainly more women in engineering than there used to be in the mid 1980's, the percentage of women entering and completing engineering education in Australia has stagnated for the last decade. Figure 1 presents data for students commencing engineering degrees in Australia from 1983 to 2008, showing the percentage of commencing students who are women. Figures are taken from the DEEWR (formerly DEST) databases and hence are for the broad field of “Engineering and Related Technologies” from 2001, previously designated as “Engineering, Surveying” from 1983 to 2000. The data therefore include a small number of students undertaking surveying degrees, but since these numbers are very small and the proportion of women very similar, this does not have a significant influence on the outcome. The data include both undergraduate and postgraduate commencements.

In 2008 the percentage of 16.5% has finally surpassed the previous highest of 16.4% in 2001 but these data are slightly misleading due to the higher percentage of women entering postgraduate study.

Examining the data for Bachelor degree commencement only shows that this percentage in 2008 was 15.1%, still less than the peak of 15.8% in 2001. In terms of raw numbers of entrants, there were 2133 female students commencing Bachelor degrees in Engineering in 2001 and 2,377 in 2008 – an almost negligible increase. The next lowest Broad Field of Education in terms of female participation is Architecture and Building, with 41.3% in 2008 although this has also plateaued since 2000. That statistic also masks the low percentage of women in Building degrees compared with Architecture degrees.

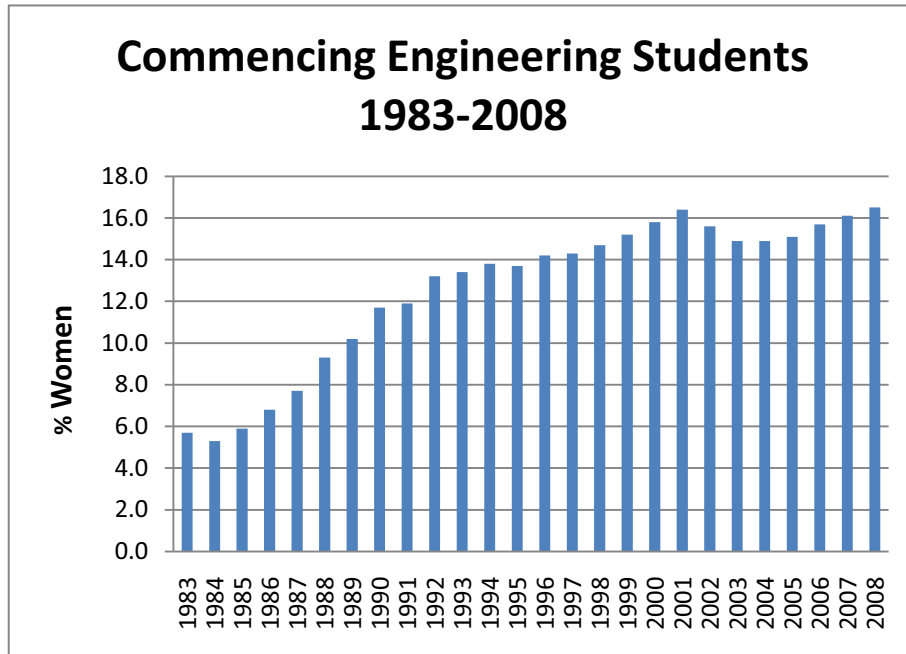


Figure 1: Percentage of students commencing Engineering degrees in Australia who are women, 1983-2008 (DEEWR 1983-2008)

International

The situation is similar in other English-speaking, western countries. In USA women comprised 18.1 per cent of total undergraduate completions in engineering in 2007-8, which was the lowest percentage since 1996 (ASEE 2009). In Canada, female graduation from undergraduate engineering degrees decreased from a peak of 21.8 per cent in 2003 to 18.9 per cent in 2007 (Engineers Canada 2009). The percentage of female graduations in engineering in the UK has not followed this downward trend, steadily increasing to 15.5 per cent in 2005-6 (UKRC 2009), but this is still noticeably lower than other European countries.

There are some countries and regions where the percentage of women graduating with engineering degrees is significantly higher than in the English-speaking countries, although nowhere is it in line with the female percentage of overall population, or of the female percentage of university graduates (refer Mills, Ayre and Gill 2010, Chapter 2 for a range of relevant statistics). The formerly communist countries of Central and Eastern Europe are generally considered to have the highest proportion of female engineers in the world but, as a result of the political and social changes since the disbanding of the Soviet Union, there has been a dramatic decrease in the percentage of women engineering students. For example in Russia, this percentage has declined from 58 per cent in 1995 to 30 per cent in 2002. Hence it seems likely that the percentage of female engineers graduating across all countries will remain stationary in the range of 15 per cent to 30 per cent at best for the near future. (Mills, Ayre & Gill, 2010)

Differences between engineering disciplines

A commonly made observation is that there are lots of women in certain fields of engineering such as Environmental and Chemical, and it is certainly true that they are better represented in these disciplines. However, it should be remembered that those specialisations with higher percentages of

females frequently represent a very small percentage of the overall number of engineering degrees awarded, since the traditional disciplines of Civil, Electrical and Mechanical engineering still make up the vast majority. For example in Canada in 2007, Chemical and Environmental engineering degrees had over 40 per cent women enrolments, but they accounted for only 9.3 per cent of all engineering degrees awarded (men and women). At the same time Electrical and Mechanical degrees, with low percentages of women, accounted for 70.4 per cent of all engineering degrees (Engineers Canada 2009). Hence, whilst there may certainly be lessons to be learned from programs such as Chemical and Environmental engineering in terms of what makes those particular engineering degrees attractive to women, it will not make much difference to the overall numbers of women engineers unless the larger, more traditional discipline areas can attract more women.

Student experience

From the mid 1980's to late 1990's there were several significant studies undertaken about the experience of women studying engineering (e.g. Beder, 1989; McIlwee & Robinson, 1992; Seymour & Hewitt, 1997). Such studies noted the "chilly climate" they experienced, with sometimes blatant discrimination from staff and fellow students. They also noted that women were more likely to leave engineering study than their male counterparts, even when they may have been achieving better grades. Recent data indicate that there have been significant improvements in many of these areas.

Attraction, course experience and employment intentions

The experience of most women undertaking engineering degrees has certainly improved since the 1990's. In 2008 DEEWR published the results of a survey of final year engineering students in Australian Universities – *Views of Engineering Students* (DEEWR, 2008). The survey drew 1540 responses from approximately 8500 final year students, and the gender distribution of the survey respondents mirrored that of the total engineering student cohort. Some of the findings most relevant to this discussion on women's student experience included:

- 37% of females and 29% of males made the decision to study engineering after they had completed Year 12
- Males and females nominated the same top reason for being attracted to study engineering: 'enjoy problem-solving, designing and creating'. Although the top five reasons nominated were similar for males and females, significantly less females than males nominated that they had 'always wanted to be an engineer' (26% compared with 43%)
- Males and females nominated the same top three experiences gained from their engineering study: sharpening analytical skills, developing problem-solving skills and developing teamwork abilities. There were only minor gender differences in other responses.
- Males felt more prepared to commence professional engineering careers than females
- Over a third of females intended to be employed as engineers for between 5 and 10 years, compared with a quarter of males. Only 56% of females and 65% of males intended to be employed as engineers for over 10 years.
- The top five most important factors for an "ideal" engineering job were the same for both male and female respondents: 'good working conditions', 'good work/life balance', 'opportunity for variety of work', 'good pay' and 'opportunities for promotion and career advancement'.
- Women were slightly more likely to obtain an engineering graduate position than men.

These findings indicate that women and men in Australia are now reporting similar experiences and outcomes from engineering study and have similar expectations of engineering careers.

Another very pleasing improvement in student experience relates to harassment and discrimination on the basis of gender. In a recent study of student and staff perceptions on a range of indicators of gender inclusivity in engineering departments at Australian universities, respondents were asked to rate their experience on a Level from 1 to 5 for the question "How are discrimination and harassment dealt with within your program?" A Level 3 response to this question stated that "Some staff attempt to deal with discrimination and harassment in the teaching and learning environment but it is not consistent across all courses" whilst Level 5 stated that "The prevention of discrimination and harassment is consistent across all courses in the program. Inappropriate behaviour is dealt with. Policy is reinforced to

students by staff.” Although the staff response was consistently higher than the student rating, both were near 4.0 (Mills & Gill, 2009). This indicated an encouraging level of both prevention and pro-action, and without doubt would be a significant improvement on the result expected had the same question been asked in the engineering departments of the 1980-1990’s.

Retention

Retention and success data in Australia now indicate that women are more likely than men to complete engineering degrees, but the retention rates for both genders have room for improvement. There are a number of difficulties in obtaining true retention rates due to the complications of double degrees, part-time study, transferring students and students who take longer than the standard duration to complete a degree. However, a crude estimation can be made by considering DEEWR completion numbers compared with commencement numbers four years earlier. Table 1 provides this comparison for students who commenced engineering Bachelor degrees in 2005 compared with those who completed Bachelor Pass and Bachelor Honours degrees in 2008.

Table 1: Indicative retention rates for engineering students (DEEWR, 2009)

	No. of students commencing Bachelor degrees in Engineering in 2005	No. of students completing Bachelor Pass or Honours degrees in Engineering in 2008	% Retention
Male	11750	7220	61.4
Female	1921	1441	75.0
Total	13671	8661	63.4

Hence these data indicate that the retention rate for women was approximately 14% higher than for men. But they also indicate that 25% of women and nearly 40% of men who commenced engineering degrees did not complete them, so this is certainly a challenge requiring further attention.

It should also be noted that retention data from a range of international sources are contradictory and can vary widely between different institutions in the same country (Ohland et.al. 2008). Studies of women in engineering point to the fact that women who enter engineering study often have higher commencing tertiary entrance scores than their male counterparts, and have personal characteristics that include persistence, high expectations and self-confidence (NCES, 2000). Hence it may not be surprising that this self-selected minority within the engineering student cohort persist and succeed in engineering study (Mills, Ayre and Gill, 2010).

Academic staff

The presence of women academic staff in engineering schools is an important means of providing role models and mentors for female undergraduate and postgraduate students (NSF 2005). Conversely, the lack of female peers and role models can be discouraging for female students (Goodman Research Group 2002). However, the number and percentage of women faculty members in engineering is very low overall, particularly at the higher levels of full professor. In the USA in 2008 women made up only 12.3 per cent of total tenure track faculty in engineering and only 7.4 per cent of full professors (ASEE 2008). Similarly in Europe, only 5.8 per cent of full professors in engineering were female (European Commission 2006). In addition, US studies indicate that women faculty members earn less, are promoted less frequently to senior academic ranks, and publish less frequently than their male counterparts (NSF 2005). Although DEEWR statistics in Australia do not provide a gender breakdown of engineering academic staff, the situation is undoubtedly similar to that in the USA and Europe.

Women in the professional engineering workforce

The DEEWR (2008) survey indicated that women have similar expectations of their professional engineering careers as men when they are final year students. The unfortunate reality is that for many women these expectations are not met in practice. While women enter the workforce at similar rates and sometimes marginally higher starting salaries than men, this is not sustained. Studies in Australia, USA and UK (for example Mills *et al.* 2008; Hewlett *et al.* 2008; Greenfield *et al.* 2002) repeatedly

show that women continue to face a number of difficulties in the professional workplace relating to opportunities for professional development, promotion, lower pay for similar work, lack of flexible work opportunities and so on. This results in women leaving the profession at significantly higher rates than men.

What remains to be done?

This brief review indicates that there has been significant progress made with regard to the situation for women in engineering, most notably in the area of student experience and retention. The Australasian engineering education fraternity can be slightly pleased with this result, but we must not become complacent as there is still much to be done.

Attracting more women

The first challenge lies in attracting more women to engineering study. We should not be content to accept that figures of 15% are good enough. Realistically, engineering will never be 50/50 male to female, but we should aim to achieve at least the figures of 25-30% that are common in Europe/ Eastern Europe and South America. Much of this work needs to be done in primary and high school years, but universities have a responsibility to support this through ongoing outreach programs. In the past, this role was often undertaken by *Women in Engineering* programs, but unfortunately very few of these remain. The recent review of engineering education conducted by the ALTC recommended that such programs be reinstated (King, 2008). Outreach to female high school students should NOT be seen as the responsibility of the few women academics in engineering, who are already frequently taking on more service and support work than their male counterparts.

It is true that the current Australian approach to curriculum choices and emphasis in high school mean that far fewer students in total, including women, undertake senior level mathematics and science than compared with other regions of the world. This means that the pool of students able to gain direct entry to engineering after high school is relatively small and unfortunately decreasing. However, that should not be accepted as an automatic excuse for lower participation rates of women in engineering. As noted earlier, many studies show that both men and women don't decide to do engineering until they have left high school anyway. There are already a range of Foundation Studies, Associate Degree and other alternative entry routes available for students to gain entry to engineering programs if they have not done the required maths and science subjects at high school. These access programs should be more widely marketed and engineering degree programs become more flexible to accept students from a range of different backgrounds, rather than just the traditional school leaver with advanced maths, physics and chemistry.

Supporting and retaining women in engineering education and the workforce

Although the retention rate for women in engineering study in Australia now appears to be better than that for men, neither rate is acceptable when we are losing nearly 40% of those students who commence engineering degrees at a time when there is a shortage of qualified professionals in the field. There is still much work to be done by the engineering education fraternity to improve the standard of teaching and student support provided to all students. This will be even more important if we are able to attract more students from a wider variety of backgrounds through alternative access programs. The most essential areas to work on to attract women to and keep them in engineering education were summarised by King (2008) within Recommendations 3 and 6 of his report as follows:

- Define and implement inclusive curriculum for engineering: reducing male stereotypes within the curriculum, and revitalising the best of the *Women in Engineering* programs. (p. 107)
- ... identify the major barriers to higher participation of women in engineering education, and reinstate and reinvigorate *Women in Engineering* programs within engineering schools (p. 112).
- Develop, with government and industry, incentives, including suitable bridging programs, support and opportunities to encourage engineers and others with motivation from non-traditional educational backgrounds (overseas qualifications, science degrees, VET, lack of pre-requisites) to enter and re-enter the profession, on fast-track accredited educational pathways. (p. 112)

The final challenge, probably even greater than that of attracting women to engineering, is keeping them in the professional engineering workforce after 5-10 years. If we lose 25% of women who enter engineering at university and then a further 50% within 10 years of graduation (e.g. see statistics in Hewlett et al, 2008) then we would have to work extremely hard at the 'attraction' stage to end up with remotely reasonable numbers of women in the professional workforce. It makes much more sense to attack the issue at all three stages of attraction, education and professional experience and engineering educators are primarily concerned with the first two. But there is certainly an awful lot of work still to do in the employment sphere and that is primarily the responsibility of engineering employers, professional associations and government.

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