

# **Education beyond technical competence: Gender issues in the working lives of engineers**

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## **Abstract**

Traditionally engineering education was concerned with teaching high level technical skills necessary to produce competent graduates. More recently engineering education has recognized the need to include teamwork skills, communication – both oral and written - and management in order to produce more effective practitioners, who can model the new style engineer who is a team leader and a manager as well as a technical expert.

Drawing data from an on-going study of engineering workplace culture, this paper argues that such moves are indeed in line with the perceived needs of an increasingly diverse population of working engineers in Australia. The initial motivation for the study came from a series of investigations into the reasons behind the disproportionate retention rates of men and women in the profession which had shown that women were more likely to leave engineering than were men of similar age and experience. These studies also detailed a range of workplace areas in which women expressed higher levels of dissatisfaction. These included poor communication within organizations, feeling marginalized from the decision making networks, and being subject to discrimination and sexual harassment.

None of the engineers surveyed gave evidence of any difficulty with technical knowledge required for the job. Rather, both men and women showed evident pride in their competence in their chosen field. Many also registered their need for more skills in interpersonal relations and acknowledged that training in these areas would have been a valuable inclusion in their formal preparation for work as engineers. In addition we found evidence of gender issues around questions of communication, respect and recognition. In conclusion, the paper supports the need for broadening engineering education in order to position the profession more appropriately in the knowledge age of the 21<sup>st</sup> century.

## **Introduction**

At a broad societal level the topic engineering education embraces an array of issues that includes, but importantly is not limited to, the specifics involved in tertiary engineering courses. Firstly there is the issue of definition of the term engineer which immediately presents problems. As has been frequently noted in the literature, the title 'engineer' is widely used to describe a person whose work involves a broad range of practical problem solving skills from 'the bloke who comes to fix the fridge' to the highly skilled supervisor of the latest developments in vehicle manufacture or the construction agent for the latest power plant. Distinctions between types of engineering are rarely made and there is little to distinguish between those who have come through higher education and the others. As one of the study participants commented somewhat bitterly:

*... if you ask ninety five percent of people in the community well what does an engineer do, the first thing they think about is they fix cars, or they drive trains, so there's a misconception there straight away about what an engineer is, and I think that's a real problem and engineers the world over have done a very, very bad job of keeping the name to themselves as professionals, as distinct from trades sort of qualifications. (Male engineer, 20 years experience)*

Indeed this vagueness about the ubiquitous engineer serves to disguise the troubling feature that has also been frequently demonstrated, namely that school students have little understanding of the work of engineers and are called to make choices on the slightest of knowledge bases about which sort of engineering they will pursue. This situation immediately throws up a gender issue. Boys, who may not know much about what an engineer does, may well still recognize the profession as one appropriate for themselves<sup>1</sup>. Many girls may be similarly unaware of what is involved but they also know that it is not normally a line that girls follow. In other words a widespread ignorance about engineering accompanied by the recognition of it being a non-traditional path for girls may go some distance to explaining the ongoing gender disparity in engineering enrolments which has continued to plague engineering education in Australia.

There has been a considerable amount of work done to promote and encourage girls in the senior secondary school years to undertake engineering at University. There is evidence to support the effectiveness of these programs in terms of girls' increased numbers of enrolments. In the Universities offering support courses, along with mentoring and networking, there have been demonstrable increases in the number of females commencing and completing engineering awards<sup>2</sup>. However, the evidence is less strong for the related assumption that once young women graduate in engineering from University they will proceed unproblematically to a fulfilling career. This is an assumption that the studies described here would seek to challenge.

### **Statistical background**

In company with other western countries, women continue to be underrepresented in the engineering profession in Australia, both at student and professional levels. Higher education statistics in Australia indicate that the percentage of commencing engineering students at university who were female increased from 5.7% in 1983 to 11.7% in 1993, then rose only slowly to a peak of 15.8% in 2001. However, these percentages have since steadily decreased, down to 14.3% in the first half of 2004<sup>3</sup>. The percentage of total students completing bachelor level engineering qualifications in Australia who are female is holding steady at around 17.4%, but the percentage of completions amongst female domestic students has decreased over the last three years. These figures compare with 20.5% of total undergraduate engineering degree completions who were female in the USA in 2000<sup>4</sup>, 11.9% in the United Kingdom in 2000-01<sup>5</sup> and 20% in Canada in the late 1990s<sup>6</sup>. Engineering continues to have the lowest rate of female participation of all broad study areas in Australian universities. While women now choose courses such as veterinary science and law in slightly greater numbers than males at undergraduate level, the engineering student cohort is still 85% male overall with the next least popular area for females being architecture and building (59.9% male)<sup>6</sup>. The data also suggests that the numbers of women are lower in the more 'masculine' areas of engineering like mechanical, electrical and aeronautical, compared to say chemical and civil, although increases in numbers of women in civil engineering may reflect the popularity of environmental engineering among women<sup>7</sup>.

It is more difficult to obtain conclusive statistics regarding the participation of females in the professional engineering workforce in Australia, due to differences in the definitions of engineering professionals used in various databases. However, membership statistics from the Institution of Engineers Australia (the learned society for professional engineers in Australia, recently renamed Engineers Australia) indicate that women constituted 4.0% of total membership in 1998 (excluding students), increasing to 5.6% in 2005. Of the female members (again excluding students) 49% were less than 30 years old in 1998, and 81% were less than 40 years. In 2004 these figures were 47% under 30 and 78% under 40<sup>8,9</sup>. These figures compare with females constituting 10.6% of employed engineers in the USA in 1999<sup>10</sup>, 9.6% of engineers and technologists in the UK in 2002<sup>11</sup> and 9% in Canada in 2002<sup>12</sup>.

### **Current engineering education requirements – technical experts**

The skills and attributes required of the modern engineer are different from those of previous generations. As expressed by Beaufait (1993):

*To practice engineering in the world of the 21st century, I strongly believe that our students must not only have a solid foundation in the liberal arts, but must also have an awareness of how our society functions, the problems it faces and how it deals with these issues. Our society needs engineers to move out from the computer and into public service. It is also becoming more important for our students to learn something about management. Not only must the engineer of tomorrow be a team member but a team leader. This aspect of an engineering student's education is more important than learning the latest analytical technique that the faculty member has just published.*<sup>13</sup> (p. 1640)

The modern engineering profession deals constantly with uncertainty, with incomplete data and competing (often conflicting) demands from clients, governments, environmental groups and the general public<sup>14</sup>. Engineering requires skills in human relations as well as technical competence. Whilst trying to incorporate more human skills into their knowledge base and professional practice, today's engineers must also cope with continual technological and organisational change in the workplace. In addition, they must cope with the commercial realities of industrial practice in the modern world, as well as the legal consequences of every professional decision they make.

Engineering programs in Australia and USA are accredited through an outcomes-based assessment, which requires them to demonstrate that their graduates are achieving a set of specified learning outcomes, and the means of demonstrating this is left to each university to decide and implement. This will usually include demonstrating that the quality management systems are in place for components such as course development, teaching and learning, staff development, etc. that will ensure that these outcomes are met, as well as some follow-up surveying of recent graduates. There are also some requirements in each country for increased management education, design education and industry relevance of programs.

In the United States, accreditation of all undergraduate engineering programs is carried out by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology, Inc. (ABET). ABET specifies eleven engineering graduate outcomes that summarise the fundamental abilities and outcomes required of graduates from all engineering programs. Of these outcomes, five address issues that could be considered to be non-technical and people related, namely:

- An ability to function on multi-disciplinary teams
- An understanding of professional and ethical responsibility
- An ability to communicate effectively
- The broad education necessary to understand the impact of engineering solutions in a global and societal context
- A knowledge of contemporary issues<sup>15</sup>

In Australia, accreditation of engineering programs is carried out by Engineers Australia (EA). The EA documents list a set of 10 generic attributes that engineering graduates should develop to a substantial degree during their undergraduate education, which arose directly from the Review of Engineering Education<sup>16</sup>. Like the ABET criteria, several of these specifically address non-technical, people related skills, namely:

- Ability to communicate effectively, not only with engineers but also with the community at large
- Ability to function effectively as an individual and in multi-disciplinary and multi-cultural teams, with the capacity to be a leader or manager as well as an effective team member
- Understanding of the social, cultural, global and environmental responsibilities of the professional engineer, and the need for sustainable development
- Understanding of professional and ethical responsibilities and commitment to them<sup>17</sup>

These criteria are further developed with guidance on explicit learning experiences that should be incorporated within the curriculum. Of most specific relevance to this study are the experiences recommended to develop the second dot-point above, team work, which are:

- Managing time and processes, prioritizing competing demands
- Achieving trust and confidence of colleagues through competent and timely completion of tasks
- Professional interaction with peers and other professional to achieve a collective outcome
- Recognizing the value of diversity, interpersonal and inter-cultural skills and effective network relationships that value and sustain a team ethic
- Mentoring others and the acceptance of mentoring
- Capacity for initiative and leadership whilst respecting others' agreed roles<sup>18</sup>.

The Australian regulations also specify that students must be exposed to professional engineering practice integrated throughout their program, and the strong recommendation that this exposure should include a minimum of 12 weeks of first hand experience in an engineering environment, outside the educational institution<sup>19</sup>.

Unlike the USA documents though, the Australian regulations also give some specified elements and suggested proportions of the learning experience of a four-year program that those elements would comprise:

- Mathematics, science, engineering principles, skills and tools appropriate to the discipline of study (not less than 40%)
- Engineering design and projects (approximately 20%)
- An engineering discipline specialisation (approximately 20%)
- Integrated exposure to professional engineering practice, including management and professional ethics (approximately 10%)
- More of any of the above elements or other elective studies (approximately 10%)<sup>20</sup>

This indicates that despite five of the ten attributes relating to non-technical skills, the expectation is still that 80-90% of the program will be devoted to technical skill development.

### **Studies of women's and men's experiences in engineering workplaces in Australia**

A survey of retention and work satisfaction levels among men and women engineers and ex-engineers was conducted by the National Women in Engineering Committee of Engineers Australia in 2000<sup>21</sup>. The survey findings indicated that women are leaving the profession in greater proportion than men. The study also found evidence to support assertions that the cultures of many engineering workplaces are female, and family, unfriendly and that engineering in Australia continues to be a hostile professional environment for many women, and one in which the career progression of male engineers is favoured.

The authors have since undertaken two follow up studies to the Engineers Australia survey described above, which have aimed to provide experiential data that could bring to life the survey statistics. In the first study we conducted a total of 51 in-depth, semi-structured interviews with 41 women and 10 men engineers around Australia in 2002. It is acknowledged that the sample of men and women interviewed was not large enough or selected in a way that could claim to be representative of the engineering profession as a whole in Australia, nor of all women engineers. However, the sample was broadly representative of the range of ages, employment sectors and engineering disciplines indicated for women in the Engineers Australia statistics. We interviewed women in rural, urban and remote areas. We endeavored to include in the sample women who fit a variety of life circumstances, perspectives and ages in order to ensure that a diversity of opinion was heard. Of the women interviewed, 26 were currently in engineering or engineering-related positions (including management roles in engineering), four had left the profession, eight were planning to leave or thinking of leaving, and three had gone back into engineering after having left. Of the men interviewed, nine were currently in engineering or engineering-related positions (including management roles in engineering) and one was thinking of leaving the profession.

The second study, still on-going, involves a total of five case studies being undertaken at various engineering organizations, to examine gender and workplace culture issues at each workplace. Each case study involves an electronic survey of engineering personnel, in-depth interviews with a range of engineering professionals and para-professionals, managers, administrative and support staff at each workplace, analysis of workplace documentation and a focus group conducted with women engineers in the workplace. The first two case studies are nearing completion. One was conducted at a large engineering utility organization that was previously public service but was privatized nearly a decade ago. The second case study involved a large international corporation in the resources sector. Data from both the first qualitative study and the focus group interviews from the completed case studies in the second study have been used in this paper.

### **Engineering education as preparation for work?**

A striking feature in the accounts of many of the engineers we interviewed was the degree of consensus about the positive aspects of being an engineer, aspects that many relished in their daily experience but also ones that were generally overlooked by the non-engineering populace, as in:

*... you don't, people don't realise that you couldn't do virtually anything in life without it being designed by an engineer somewhere along the road, the road, the car, the chair you're sat on, the computer you use, every time you open the tap or flush the toilet, every time you whatever, it's been designed somewhere along the line by an engineer, and people don't realise that, so we've sold ourselves very, very badly and the overall public impression of an engineer unfortunately is someone who gets their hands dirty (Male civil engineer, 20 years experience)*

This sense of personal pride and achievement was echoed in a range of ways, most often connected with a reported sense of capability in terms of problem solving, derived at least in part from being good at the hard subjects of maths and science.

A claim that ran counter to their pride in the work was the frequently reiterated complaint concerning the degree to which their professional education had failed to connect with the 'real world' of engineering work.

*But I had no experience of engineering really and when I got part way through my degree I sort of went oh engineers were inventors once upon a time, and I think I like this engineering gig. But even then I struggled throughout uni to place the learning I was doing with what it was going to mean to get out into the real world. (Female engineer, 10 years experience)*

For some this meant that the point of much of their learning was not realised until they had the chance to apply it in real experience. The call for more practical experience in their university courses became a familiar theme in the discussions.

*From a uni point of view it would have been good to have a closer working relationship between university and industry and ... still it would have been great to have some sort of partnership arrangement with a couple of organizations, do research work for them that was actually practical and useful sort of stuff (Male electrical engineer, 13 years experience)*

*So much dawned on me when I first started working about what my engineering degree had been trying to teach me and it was just studying in a vacuum until then. It's great that I've got some sound mathematical background, I don't know whether I use anything past first year maths, but at least I think it was sound that I did it. (Female engineer, 10 years experience)*

For some of these engineers the progression into the workplace was one of increasing pleasure in recognizing their capacity to get the job done. On the other hand several of the women took a different tack in their assessment of their preparation for professional life:

*At university I think that they should teach people about business ethics, and behavioural skills, like more, well I don't know, most people, maybe I've only got a problem because of my upbringing, I don't know, but I don't have ... there was no way to practice your skills, or they should encourage people to be more involved in debating or to be more involved in those type of networks that are there ... so like the mentoring is just like compulsory to me... (Female civil engineer, 12 years experience)*

For this speaker her lack of preparation for work was very much in terms of the social skills needed to participate in professional working life – a lack much more often mentioned by the women interviewed than the men. Some of the men also recognized their need for a different

educational preparation for life as a professional engineer, but their position was couched within a more formal learning curriculum, as in:

*... curriculum can still be quite academic to a large extent, like the calculus sort of stuff, I'm happy to learn it, mental gymnastics sort of stuff, but to have a better appreciation of the way that businesses work and industries work, understanding just simple things like management structures, credential requirements of a business, to have a better understanding, so you're not walking out completely green, like engineering you know a bit and you're a little bit confident with some stuff, when it comes to the whole business thing and particularly the way you get treated by them, to have a bit better understanding of that, just to prepare people a bit better, sort of the cut and thrust of it all. (Male electrical engineer, 13 years experience)*

For many of the women interviewed, the issue of gender formed a recurrent theme in their recollections of their university education as well as their current situations. For example one woman's rueful comment on her university years:

*I was just totally overwhelmed, I'm like oh no, what am I doing, and all these boffins around me, all these guys around me that had you know had played with computers since they were kids, they had the Dick Smith Fun Way electronics kits, they'd done all this stuff and I had no idea, the first time I sat in front of the computer it was well what is this for, what am I doing, I thought computers were just word processors, just glorified word processors so even the concept of what is programming it's just babushka, but I was having a great time and I had a great bunch of friends and I suppose that helped me through university. (Female electrical engineer, 12 years experience)*

For some women the hierarchical structure of the engineering workplace, in which professionally qualified engineers are placed in supervisory role over more experienced but less qualified workers, combined with gender issues, caused a significant degree of difficulty:

*When I was one year out they put me in charge of, as a workshop supervisor for four months in charge of about, I don't know, seventeen men, and I was twenty two, and some of the men (that's their way of progressing from a tradesmen up to a supervisor is acting in that role), so I'd also taken away their training by being slotted in above them. ... so some of these guys, when I started in the job, were really dead against me being there, didn't want to help me, and but by the end of it, I got over that with them and I had done a good job. ... but to throw me in the deep end with no supervisory training, no nothing, I can remember every morning I would go in and my hands would be sweating and you know, it's probably, it was a really great experience at the end of it, I showed them, really, that's how I felt at the end, but, it was hard to beg in with. (Female engineer who has left the profession)*

Through our assemblage of stories such as these we have developed a picture of the engineering workplace. By and large the 'room at the top' across a range of levels within engineering workplaces is dominated by male bodies and masculine interests. Just about all the people that the engineers identified as boss were male. While the 'old guard' of engineering pioneers is close to retirement engineering companies are rebuilding themselves in a more entrepreneurial mould with the help of middle range men trying to achieve their place in the sun. In this picture there is considerable jockeying for position. Professional meetings become sites for manoeuvring in which the chance to be heard appears increasingly less of a democratic right and more of an insider trade. Apart from the recent graduate trainees, nearly all the women recounted stories of being overlooked, marginalized, or worse

still undermined in their professional capacities, and they felt they lacked any interpersonal training which might have helped them to deal with the situation. This is despite the fact that, at the official policy level, the companies were committed to the principles of Equal Opportunity and keen to recruit more women.

By and large the men interviewed in the second study – and there were more of them at each site than women – appeared unaware of the difficulties experienced by their female colleagues. The men subscribed to a discourse in which males were positioned as ‘good blokes’ and ‘mates’ and they believed in their own rhetoric of a fair go and equal opportunities. The women were also familiar with these discourses which include sanctions against complaint and ‘whingeing’. For some, having participated as ‘one of the blokes’ it was impossible to acknowledge the particular problems they experienced as women, equally impossible to credit the ones who did complain with being justified. When reflecting about the adequacy of their educational preparation as engineers they were able to make evaluative comment about the problems inherent in their current experience.

### **And the solution? Implications and conclusions.**

Thus far the picture we are developing in terms of workplace culture involves male and female University educated young professionals entering long established workplaces in which the cultural norms have been set in a masculinist tradition. While some aspects of their daily working lives may be equally shocking to the young male entrants as the young women, they have an automatic entry and acceptance by virtue of being male. Not so their female peers. The women in our studies constitute a minority and tend to feel themselves as somewhat anomalous in the workplace, despite the fact that some of them have considerable work experience. For some of these women and their male colleagues the solution to this situation is to minimize or hide the fact of their femaleness, so they can be treated as ‘one of the blokes’. While this strategy is evidently successful in affording some women engineers a less contested engineering identity and easier workplace relations, it does little to address the masculinist culture of the engineering workplace. If anything the strategy contributes to the culture of male dominance with the women as pseudo males who actively deny their gender in order to ‘pass’ as an engineer.

For others the preferred tactic is to use ‘feminine wiles’ which may mean to present themselves as woman in the role of wife, daughter, mother in a family relationship to the males – a strategy which further positions women as family first, rather than professional peer. Once again such tactics promise little in the effort to overcome the culture of male dominance but work to effect a sedimentation of masculinist practice by confirming the male positioning of the man responding as husband, son and/or father in keeping with the game being played.

One of the most surprising outcomes of the study thus far concerns the degree to which the women engineers assert their amazement at discovering the ongoing reality of gender distinction in their normal working lives. They describe themselves as shocked and unprepared for anything like the flagrantly sexist practices they encounter. In focus group discussions, some of the more experienced women describe the ways in which they consciously play to the men in order to get their way, but more women at all levels describe the difficulties they experience in being heard in professional meetings or having their ideas taken up in workplace discussions. Being heard would appear to be a necessary first step in getting one’s ideas across, being noticed as a professional. While some of the engineering

firms have embarked on what seems to be a popular and well developed mentoring program, women report that once you are through the program and in a position to compete with male colleagues for promotion to the next level or for a supervisory position the men's networks close ranks and mobilize against women's advancement.

And the men themselves appear to be unaware of what is happening. They are comfortable with the mentor role, and happy to see themselves assisting female colleagues, especially if such colleagues are junior in age and status to themselves. But in the case of women who aspire to the senior ranks the male colleagues appear to subconsciously feel the need to reassert their superior knowledge and capacity for the job and they comment on the likely difficulties women will encounter in this hard technical or managerial work, the pressure to meet deadlines and the need to take a hard headed approach to the job in hand.

The cultural practices we have described require more education for both men and women engineering students about aspects of the social and political dimensions of the typical engineering workplace. This type of professional education would ensure that young skilled people do not enter the workplace as technically competent but naïve players in a world constrained by gendered world views and practices. Courses which introduce students to the formal and informal aspects workplace culture would alert entering engineers to existing conditions and provide them with an array of strategies whereby they could operate without having to conform to stereotypical roles currently available. Such courses would have to incorporate a statistical breakdown of current participation in engineering and an argument about the benefits of working for increasing diversity which better reflects developments in the Australian population as a whole.

In concluding we endorse the recommendations made in the most recent publication of Engineers Australia concerning the specific sorts of learning experiences that should be incorporated into the existing curriculum for engineering education. In this spirit we would anticipate a greater degree of equity to emerge in engineering workplaces in terms of a more diverse professional labour force who share a more developed awareness of issues to do with inclusivity and respect for peers who are different from themselves. We share a concern that the notional time allocation to be devoted to such learning remains at just 10% of the whole and would suggest the adoption of measures whereby these principles be incorporated wherever possible throughout the course work. We would further urge the principle of students spending a specific amount of time engaged in practical work experience to be taken as a serious commitment by both the engineering placement supervisors and the University. Professional education is best practised as a shared partnership between industry and the university. In engineering this means that academic learning and practical application must be seen to be working in unison to create a sense of joint endeavour and mutual respect. In our view these measures would contribute to the betterment of engineering education and the profession as a whole.

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