Enhancing the role of women in engineering

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BACKGROUND

While there has been considerable effort to attract women to engineering, the profession has remained largely male focused. Attracting more women to it will therefore require changing the current mindset of its being a traditional male occupation. We are particularly keen to encourage women to study engineering and be better represented in the engineering workforce. Engineering programs need to be made more attractive to females. To achieve this goal, research has commenced to consider the issues that women face in engineering and its study, with a view to developing innovative approaches to attract them to the profession.

PURPOSE

The purpose of the research discussed in this paper is, through evaluating the perceived and actual barriers to women undertaking an engineering career, to develop innovative approaches aimed at encouraging women to work in the engineering environment. A study is therefore being undertaken of the issues in women selecting engineering as a career, their experiences as engineering students, and approaches for encouraging female school leavers to study engineering, with the goal of developing a set of recommendations for better encouraging women to study engineering. It is considered that attracting women into engineering through these approaches will have a positive impact on the global competiveness of the profession.

DESIGN/METHOD

A literature review of the participation of women in engineering and the issues in their undertaking engineering as a career, including a review of a range of data and studies to explore the current enrolment by women in engineering programs, their perceptions of engineering as a career, their role as engineering students and approaches to engaging them in university engineering programs, is undertaken. Using the results, the main issues in women undertaking engineering as a career and studying it at university are explored. Options to better attract women to study engineering as a profession are then developed and presented as a recommended approach to better attract women to the study of engineering.

RESULTS

This paper aids the reader to better understand women in engineering and proposes suggested approaches to address and encourage women to study engineering. It provides the basis for further detailed research aimed at the development of a set of detailed recommendations to increase the proportion of women in engineering. The increased attractiveness of engineering to women is expected to result in a better balanced engineering workforce, with a resultant improved globally competitive supply of engineers.

CONCLUSIONS

The paper reflects, from a review of the literature, the current mindset of a male dominated industry, along with the approach universities are taking to encourage women to study engineering. It also discusses a positive direction for ongoing research aimed at developing approaches for the improved participation of women in engineering studies and the engineering profession.

KEYWORDS

Women, engineering, education, competitiveness.

Introduction

While there have been considerable efforts for some time to attract women to study engineering, the engineering profession and enrolments in engineering at university have remained largely male focused. On the other hand, engineering is an exciting profession that drives change and improvement, and would benefit from the creativity and know-how, insight on issues important in the world, and the unique problem-solving approaches provided by women (Engineers Australia, 2008).

It is therefore highly desirable that the proportion of women studying and working in engineering be increased. However, despite considerable efforts to improve the participation of women in science, technology, engineering and technology (STEM) education and a number of outreach programs, many qualified young women do not seek an engineering career. For example, in Australia there are approximately five male students to every one female student studying engineering, and overall the proportion of women employed in STEM fields in Australia is undesirably low (Marginson, Tytler, Freeman and Roberts, 2013).

Factors impacting on the participation rate of women in engineering include experiences by women working as engineers (Matchett, 2011; Fouad, 2014; Engineers Australia, 2008), the nature and structure of engineering programs in universities (Hobart, Young, Mills and Gill, 2006; Mills 2011); and engagement and outreach activities, including STEM education initiatives (Office of the Chief Scientist, 2013; Marginson *et al*., 2013). These factors can be either positive or negative with respect to their impact on the number of young women engaging in engineering careers. In addition, for a variety of reasons, such as the male dominated engineering culture, a number of women who become engineers do not remain in the profession (Matchett, 2011; Fouad, 2014). On the other hand, there are a number of success stories with respect to practising women engineers, who have families, earn good incomes, travel the world and live fulfilling lives (Engineers Australia, 2008).

It is therefore desirable to encourage women to both study engineering and be better represented in the engineering workforce. To achieve this goal, university engineering programs will require to be made more attractive to female school leavers and women who may be already working in the other occupations. Research has therefore commenced to consider the issues that women face in engineering and its study, with a view to developing innovative approaches to attract them to the study of professional engineering, and to actively participate in the profession following graduation.

This paper discusses enrolment by women in university engineering programs, and then examines perceptions by women about engineering and the issues related to women pursuing engineering as a career. It then discusses women as engineering students and their engagement in engineering programs through STEM and outreach programs. These topics are summarised and discussed, and then followed by a discussion about potential approaches for attracting and retaining women in engineering studies.

Enrolments by women in university engineering programs

Kaspura (2012) has authored a statistical update for Engineers Australia with respect to women in engineering. This report notes that women continue to be under-represented in the engineering profession, at considerable cost to the economy. It also states that while young women have the capacity to study mathematics and science at school, few young women study physics and are inclined to study biology or chemistry, and that all science enrolments are falling. Young women account for about 14 per cent of acceptances of places in Australian university engineering programs. This level has fluctuated over time, with an increase in more recent years. The share of masters' degree commencements was 18 per cent and of doctorates 24 per cent, which shows a tendency for women to undertake higher degrees once they complete the undergraduate programs. Completions by women were 16 per cent overall and 22 per cent for doctoral programs. Of the over 32,000 women with

engineering qualifications, more than 8,000 were not in the labour force. Women also had a higher unemployment rate than men. Fifty-seven per cent of the women's labour force was born overseas, compared with 39 per cent for men. It was noted that family responsibilities were a factor in the labour force participation by women, who were only 11 per cent of Engineers Australia membership (Kaspura, 2012).

Figure 1 shows the number of women commencing engineering programs in Australia by year, from 2001 to 2010. It is noted that there is a decrease in the middle years of the decade, followed by an increase in the later years of the decade, in both the number of commencements and the percentage of engineering programs in which women were enrolling. The proportion of commencements in all programs was 15.7 per cent in 2001, and 15.8 per cent in 2010, compared with a low point of 13.8 per cent in 2005. The proportion of commencements in entry level courses (bachelor degrees, associate degrees and diplomas) had however decreased over the 10 years of data collection, from 15.0 per cent in 2001 to 13.9 per cent in 2010 (Kaspura, 2012).

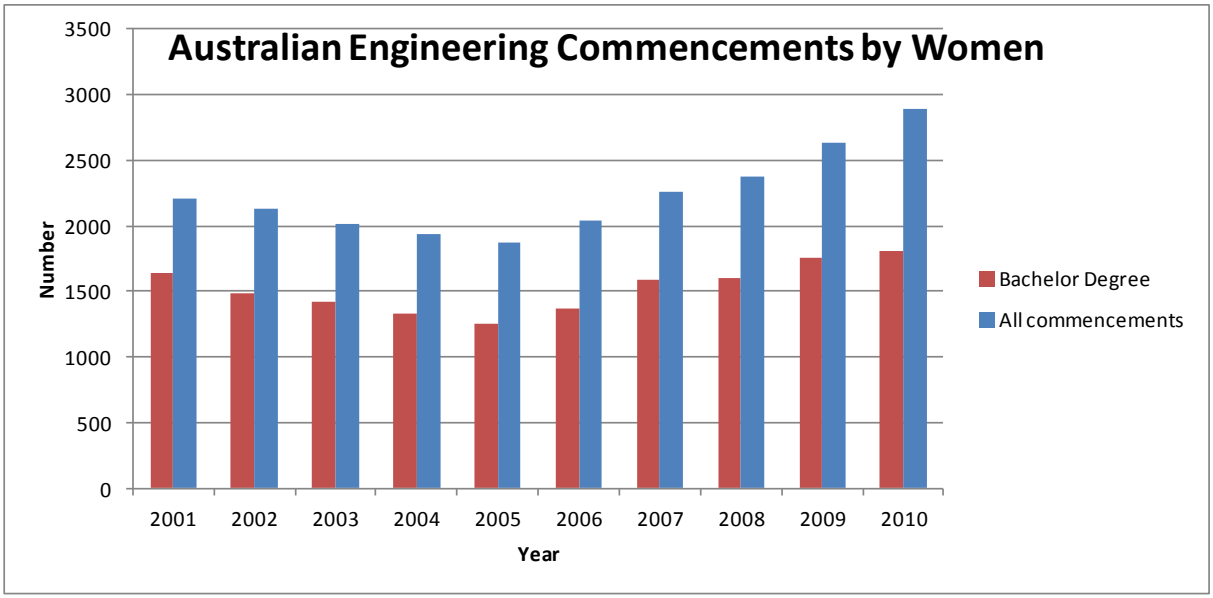

Figure 1: Australian Engineering Commencements by Women. Source: Kaspura (2012)

As an example to illustrate university engineering enrolments by women, the University of Southern Queensland, which is based in Toowoomba in Queensland, offers programs in engineering and related disciplines like spatial science, urban and regional planning and construction. The university has campuses in regional and outer Brisbane urban areas, and has a high proportion of external enrolments. In Semester 1 2014, the University had 591 female students in undergraduate and postgraduate coursework engineering and related programs, or 9.36 per cent of a total enrolment of 6,313 students. Of these students, 3,305 (of which 312 or 9.44 per cent were women) were actively enrolled in both full-time and part-time studies during that semester. The proportion of women studying full-time (who would be expected to be studying on-campus) was higher than this proportion at 12.1 per cent at 121 out of 998 students. In this university, the proportion of women students in engineering is lower than the national average, which may be a result of its regional focus.

In the United States, Yoder (2011) has reported that at that time females accounted for 18.4 per cent of bachelor degrees, up slightly from 18.1 per cent in 2010. The percentage of master level degrees awarded to women was 22.6 per cent, and women were awarded 21.8 per cent of doctoral degrees. Over the period spanning 2002 to 2011, the percentage of bachelor degrees awarded to women was relatively stable (a maximum of 20.9 per cent in 2002 and a minimum of 17.8 per cent in 2009). The proportion of bachelor degrees awarded to women in the United States is therefore slightly higher than in Australia and similar in the two countries for higher level degrees. This difference could be as a result of better

preparedness by girls for engineering studies in the United States, where roughly equal numbers of girls study science and mathematics at high school as boys (Hill, Corbett and St. Rose, 2013). In Australia, relatively few young women study physics (Kaspura, 2012).

Perceptions by women of engineering as a career

One of the potential factors in the interest in engineering as a career for women is their perceived role within the engineering workforce. Related questions include why women would choose an engineering career, and why they may or may not remain in that career.

In Australia, an Australian Government study discussed by Mills (2011) indicated that while women had similar expectations of their professional engineering careers as men, these expectations were not met in practice. The author states that a number of studies have shown that matters like opportunities for professional development, promotion, lower pay for similar work, lack of flexible work opportunities, and similar matters resulted in women leaving the profession at significantly higher rates than men. Jolly (2007) further observes that female engineers who suffer some form of discrimination or harassment tend to move on to another job rather than try to oppose the system.

In the United States, Fouad (2014) surveyed over 5,000 women who had graduated as engineers in the United States between 1947 and 2010. Of these, 62 per cent were currently working in engineering. Of the 38 per cent who had left the profession, 11 per cent did not enter the field, and 21 per cent left over five years prior to the time they were surveyed. Reasons for leaving included fulfilment of care-giving responsibilities, not being offered opportunities for advancement and a loss of interest in engineering. Most women in engineering worked in groups that were predominantly male. On average they worked 43.5 hours per week (Fouad, 2014).

This study found that women who stayed in engineering were satisfied with their jobs and careers, and had supportive bosses and co-workers. Their organisations recognised women's contributions, cared for their well-being, invested in their training and professional development, provided paths for advancement, and had supportive work-life policies and a work-life culture that supported work-life balance. Women who thought about leaving their organisations experienced excessive workload without sufficient resources, conflicting work demands, unclear expectations about work goals and standards, a career plateau, low job and career satisfaction, and climate related barriers. These barriers included undermining and incivility at work (including being pulled back when trying to succeed), being treated in a condescending manner and lack of support for managing multiple life roles. A message from the research was that women's departure from engineering was not a "woman's issue", but one related to climate issues and lack of advancement opportunities (Fouad, 2014).

On the other hand, there are positive stories about women in engineering. An Engineers Australia publication tells stories about women in engineering who have not only been successful in their profession, but who also enjoy working as engineers. The messages from this publication are that engineering needs women, women are good for engineering, engineering is good for women and the world needs women to be engineers (Engineers Australia, 2008).

Similarly, a recent United Kingdom survey of the gender talent gap in oil and gas engineering found that 75 per cent of the women who responded to the survey said that they felt welcome working in the industry, that 89 per cent would encourage a female friend to pursue a career in the industry now and that 82 per cent planned to stay in the industry for the next two to five years. There was also a strong long-term view of viability of the industry, and other energy sectors, for women. On the other hand, 45 per cent said that they did not receive the same recognition as their male colleagues. Suggestions for what companies could be doing to attract women included educating women early about the industry, giving women a chance to undertake challenging roles, and providing equal benefits and opportunities. Work-life balance and family time were important (NES Global Talent, 2014).

Overall, the above research indicates that there are both positives and negatives with respect to engineering as a long-term career for women. The positives are likely to result in a reputation for engineering as a desirable profession for women and hence lead to an increase in enrolments by women in engineering programs. Conversely, the negatives would be expected to lead to a decrease in enrolments. Therefore, a logical first step in increasing the proportion of women in engineering programs is to ensure that the profession has a good reputation as a career of choice for women. Achieving this result would require addressing a number of the issues identified in this section, including workplace climate, recognition, challenging roles, advancement, work-life balance and family friendliness.

Women as engineering students

As discussed above, engineering tends not to be a career of choice for women. A number of reasons have been advanced for this position, such as culture, personal traits, perception and education (Hobart *et al.*, 2006; Mills 2011). There are also a number of other areas of concern, such as the engineering culture, which itself is likely to be a considerable barrier to both the study and practice of engineering by women.

Hobart *et al*. (2011) undertook an online survey of students studying engineering at the University of South Australia, which resulted in 253 responses, of whom 37 were women, and also conducted interviews with a smaller sample of students (nine females and four males in a single focus group). The interviews expanded on the survey, and further investigated aspects of engineering study from the interviewee's perspective. Thirty-eight percent of the female respondents answered "yes" to the question "have you experienced sexual discrimination?" A common response was that such discrimination often came from older males who believed that women should not be engineers. One student mentioned that the structure of engineering courses in general, and the teaching styles employed, often used male oriented examples. Nine per cent of males had also experienced some form of sexual discrimination during their studies, such as the offer of women-only scholarships.

Jolly (2007) similarly makes the observation that prescribed behaviour characteristics (for example, a focus on technical skills, male attitudes, work habits and social behaviours that tend to be make focused) tend to predominate on campus. There is potential to change this approach, and with it attitudes to and by women with respect to engineering.

Engaging women in engineering programs

Students who study engineering require good skills in English, and in mathematics, physics, and possibly other sciences (the STEM skills). In this respect, the Office of the Chief Scientist (2013) in Australia has stated that if we are to meet whatever challenges lie ahead, a vital part of our investment must be in the whole STEM enterprise, which will provide Australia with expert practitioners and a knowledgeable and receptive community, including the social sciences and humanities. This view is supported by Marginson *et al*. (2013). In 2009, Australia continued to rank well in STEM subjects, being equal seventh of all nations in science and equal thirteenth in mathematics on the PISA (Programme for International Student Assessment) performance scale. On the other hand, the average PISA mathematics score for Australia declined between 2003 and 2009. It is further stated that Australia is relatively strong in participation at tertiary level in the sciences as a whole, but weak in mathematics and engineering. New Zealand has a similar profile. Marginson *et al*. (2013) also note the severe gender imbalance in Australian tertiary enrolments in STEM programs, which is similar to other countries, particularly in engineering. It is claimed by these authors that the proportion of women employed in STEM fields in Australia is undesirably low.

While it is important to improve female participation in STEM studies at school level, it is one factor only in encouraging more women into engineering. While, for example, in the United States roughly as many girls study mathematics and science courses at school as well as

boys, women earn only 20 per cent of bachelor level degrees in physics, engineering and computer science (Hill *et al*., 2010). Reasons for this low participation rate at tertiary level include the effects of societal beliefs and the learning environment. Such matters may be able to be addressed by providing a "growth mindset" environment that encourages the achievement of girls in mathematics and sciences, providing a broader overview of STEM fields in introductory tertiary courses, and improving department culture to promote the integration of female faculty. A further environmental step in improving the participation and success of women (both at university and in the workforce) may be for both men and women to interrupt the unconscious thought processes that lead to negative views of women in "masculine" job positions (Hill *et al*., 2010).

Outreach programs to women and girls can also play a significant role in attracting women to the study of engineering programs. For example, the University of Southern Queensland conducts a number of outreach programs aimed at attracting female students to engineering and it related disciplines. Such programs include outreaches to schools, active participation in STEM programs, and the specialised Go Women in Engineering, Science and Technology program (Go WEST) (University of Southern Queensland, 2014), which provides support, networking, awards, scholarships and other initiatives for women.

Other universities have initiated similar programs. For example, the University of Technology Sydney (2014) has a long-standing initiative aimed at redressing the low rate of female participation in engineering and information technology by communicating the opportunities in them as choices of study and career. The University of Auckland (2014) has a Women in Engineering program that offers opportunities for young women to use their unique problem-solving skills and creativity to solve complex problems, thus bringing a new dimension to the engineering field. This initiative offers a range of support programs for women in engineering.

Review of Issues with respect to women practising and studying engineering

The discussion above has explored positive and negative issues with respect to women practising and studying engineering. These issues are further reviewed below**.**

Women practising engineering

Overall, it is concluded that women practising engineering have considered it a worthwhile profession to enter. While a considerable proportion of women are happy and successful in their profession, others have left it as a result of issues that are primarily related to high work demands, limited opportunity for challenging positions and career advancement, exposure to a male culture including undermining and incivility at work, and organisations that are quite inflexible with respect to multiple life roles, such as family commitments. Work-life balance, challenging positions, opportunities for advancement, and good mentors tend to be strong enablers in maintaining women in the engineering workforce.

Other professions that have previously had a minority of women participants have successfully addressed the gender imbalance. For example, it has been reported that in medicine and law in the United States, in which as recently as 1970 women made up 9.7 per cent of the nation's doctors and 4.9 per cent of lawyers, the proportion of women as at 2010 had increased to 32.4 per cent of doctors and 33.4 per cent of lawyers. One factor in this increase of women in these professions was increased opportunity to study these professions. Another factor was the shift, over a generation, of women's career aspirations (Mitchell, 2012). By contrast, the teaching profession is highly feminised in Western societies. Its challenge is to attract high quality people – both male and female – into the profession. Gender balance in this profession remains an equality issue, which is desirable to embed in policy thinking on teaching and teacher education (Drudy, 2008).

Women as engineering students

There are a range of university programs that develop the skills of and a love for science, technology, engineering and mathematics in girls. Universities and professional organisations also conduct outreach programs to schools with respect to young women in science and engineering, including special scholarships. These programs have had some success in Australia, where the number of female engineering students in Australia at the bachelor degree level has tended to rise since 2005 (see Figure 1).

There is also a likely link between the education experience of women studying engineering programs and their subsequent experience in practice. In particular, the male focused culture of the university engineering cohort may tend to discourage women from undertaking an engineering career. Therefore, the study program may require adjustment to better prepare women for engineering careers from the cultural and organisational aspects. Addressing these matters at the university level has the potential to increase the proportion of women studying and working in engineering, and may ultimately lead to changed work cultures as new graduates of both sexes move into engineering practice.

Exploratory review – women in engineering

In order to further explore the issues with respect to women both practising as engineers and studying engineering, an exploratory review was conducted of a small number of women in engineering positions in remote areas who were studying or had studied engineering by distance education, mainly at the University of Southern Queensland. The results indicated that overall these women:

- Faced few difficulties in studying in remote areas.
- Were not disadvantaged when applying for a position.
- Were not disadvantaged financially through studying remotely.
- Faced only very limited discrimination as a women living in a remote area.
- Have been treated equally with others in both the education and work environment.

A number of these women indicated that it is hard to balance studying remotely with work and family commitments. The main area of assistance requested from the University was provision of online recorded lectures.

Summary of Opportunities and Issues

The above discussion has led to the following main linked areas in which the authors consider that further research with respect to attracting and retaining women in engineering courses at university is required:

- The reasons why some women see engineering as an exciting, challenging, satisfying career while others leave the profession.
- How existing programs for attracting women to engineering courses can be developed, with the aim of increasing the proportion of women studying engineering.
- What changes can be made in the development and teaching of engineering programs at university to make them more friendly to women students, and to prepare women for an engineering career.

Research has commenced to further investigate the above questions, with a view to developing an integrated approach to attract more women to both the profession of engineering and its study at university.

Attracting and retaining women in engineering programs

As a first step in this research, a number of suggested approaches for attracting and retaining women in university engineering programs, based on the discussion in this paper, are outlined below, under the three linked areas for research outlined above.

Changes to the engineering profession and industry

Engineering firms want to work more productively. In order to do so, it is recommended that they incorporate gender equity programs that teach staff and stakeholders how to stimulate and realise the benefits of gender equity, thus creating an improved work environment. In this respect, organisational cultures could be changed to embrace diversity and flexibility as an ongoing commitment to the entire company (Australian Human Rights Commission, 2013, p. 10). Similarly, engineering workplaces could be encouraged to recognise change.

Human resource departments could be encouraged to take an active role in gender diversity by mandatory courses and training programs that change the workplace culture to think more conclusively of women's needs, and to develop women's strengths in the workplace. As part of this process, ongoing feedback could be obtained from women in order to recognise the areas where they may struggle. A mentoring system, where a woman commencing work is mentored by a male, thus assisting both genders, is highly desirable.

Changes in university engineering programs

In a world where organisations are actively promoting gender diversity in non-traditional roles it is important to develop in women the skills they need to enter a male dominated field. An example of such education could be conducting workshops and other educational activities to teach women how they can assimilate into a male dominated profession.

Universities could incorporate awareness about biasness and encourage women to participate in courses that have strategies in place that facilitate the work of women and how they can potentially succeed in a male-dominated role. Stronger emphasis could also be placed in engineering programs on the social, cultural, health and safety aspects of engineering. In addition, it is recommended that activities involving students of both sexes in group work, such as problem based learning, be undertaken.

Enhanced approaches for attracting female university students

It is suggested that a goal be set for the proportion of female students in engineering programs that would provide a well balanced profession from a gender point of view. Given experiences in the United States, an initial goal of 20 per cent of women as engineering students would be reasonable, with a longer term goal of 30 per cent. In order to achieve these goals, existing outreach programs would be maintained and further developed. In addition, approaches to gender equity, in conjunction with high schools, could be supported on a regular basis. Doing so would be expected to challenge workplace gender politics.

Conclusion

It is concluded that while the number and proportion of women studying and practising engineering remains quite small, there are a number of opportunities to overcome bias and make women feel more confident about undertaking rewarding engineering careers. Approaches to do so are discussed in the three linked areas of changes to the engineering profession and industry, changes in university engineering programs and enhanced approaches for attracting female university students

Research has commenced to address these areas, with a view to developing a strong, linked set of recommendations for enhancing the role of women in engineering over time.

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