LEADERSHIP IN ENGINEERING EDUCATION FROM K12 TO UNIVERSITY: KEY TO IMPROVING DIVERSITY IN THE ENGINEERING PROFESSION

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ABSTRACT

The engineering profession within Australia has failed to attract young women for the last decade despite all the effort that have gone into promoting engineering as a preferred career choice for girls. It is a missed opportunity for the profession to flourish as a heterogeneous team. Many traditional initiatives and programs have failed to make much impact or at best incremental improvement into attracting and retaining more women. Why is this? Is it because we are treating the symptoms rather than the cause? Should we look to prevention strategies rather than the current intervention strategies? The reasons why girls and young women in most parts of the world show little interest in engineering haven't changed, despite all the efforts to address them. This paper examines the proposition that leadership in engineering education may be the elixir for enriching the motivation of many young women to pursue an engineering career. Leadership in the interaction between teacher-student relationships, leadership in educational pedagogies, leadership in curriculum development, leadership in professional development for teachers and academics, and so on. Leadership, stripped of its various definitions, is basically the perceived ability to influence outcomes via people. In this case, the outcome is a sustained and exciting career in engineering. Hence, developing leadership at these coal-face activities in engineering education in encouraging diversity will influence young women to pursue such an outcome. In conclusion, we need to develop leadership in engineering education to improve diversity in the engineering profession.

INTRODUCTION

Despite the effects of the global financial crisis, engineering labour shortages in Australia still persist into 2011. There is clear evidence that the labour market is consolidating and that chronic shortages are re-emerging at a frantic rate (Consult Australia 2010; AiGroup and Deloitte 2010; BIS Shrapnel 2009; Garvey et al 2009). The engineering profession is integrally involved in the economic growth and development of Australia.

During the past decade, the demand for engineering skills has increased by 52% compared to 20% for the overall Australia economy (Kaspura 2011). Despite the intake of about 55,000 degree-qualified migrant engineers over the past decade, the skills shortage is holding back this prosperity (Kaspura 2011). One major source of supply in degree-qualified engineers is the Australian tertiary education sector. As of 2009, commencement was at an all-time high of 12,057 students with 67% of acceptances had tertiary entrance scores of over 80 compared to 51% for other disciplines (Kaspura

2011). However, this only translates to 5608 completions of bachelor degrees in 2009. The national retention rate started at 2003 is about 65% (King & Godfrey 2011). The male bias in student cohort is still evidenced. More girls are completing year 12 than boys (Kaspura 2011). In 2009, 10262 men had scores of 90 or higher with 24.3% accepted places in engineering degrees. In contrast, there were 13,515 women with tertiary entrance score of 90 or higher but only 4% accepted places in engineering degrees (Kaspura 2011). This gender imbalance cannot continue if we are serious about addressing the engineering skill shortage. Systematic intervention into the education system and graduate supply is required to support Australia's economic growth and development.

In the USA, President Obama have initiated the "Educate to Innovate" campaign to stimulate and strengthen its economy, and acknowledges that a strong and secure workforce includes sufficiently large numbers of engineers who innovate and create. Obama said that American school students needs to be inspired to pursue mathematics and sciences, and to be recognised globally as ranked 1st within the decade. He said that it is unacceptable that American 15 year old students are ranked 21st in science and 25th in mathematics. Obama goes further by introducing funding policy called "Race to the top" that will fund states for innovative science and mathematics programs in schools, and to recruit and retain outstanding teachers. Australia is on the other hand somewhat pre-occupied with the "Education Revolution" that includes ultra-expensive school halls, school computers and a consolidation of state curriculums into a national curriculum.

Recent Australian government decision to close the Australian Learning and Teaching Council (ALTC) is a set-back on the efforts on developing learning of the nation's future generations and play a part in addressing our chronic skill shortages. However, targeted work undertaken by the Australian National Engineering Taskforce (ANET) looks to rebuild overall engineering capability is a step forward. In the short term, the future does not look bright in addressing the chronic engineering skill shortages. Despite this, the profession needs to persist and persevere with our effort in attracting and retaining more women, an under-represented cohort, in the engineering profession. This paper argues for a collaborative approach by educators from K12 (kindergarten to year 12) to Universities to tackle this challenge.

MATHEMATICS AND SCIENCES EDUCATION

Australia is performing slightly better than the USA according to the latest PISA assessment on middle secondary student performance in reading, mathematics and sciences (OECD 2010). However, Australia was again outperformed by all of the Asian countries as well as England and the United States at the year 4 primary level in the 2007 TIMSS assessment (ACER 2009), a similar position to that obtained in 2003. This is despite Australian students' average scores in Year 4 mathematics have increased significantly by 17 points since 2003. Similarly, for Year 8 mathematics, the result for Australia is similar to 2003 but achievement scores have decreased since the first administration of TIMSS in 1995. Increases in scores achieved by students from England, the United States and Lithuania, in combination with a decrease in Australia's score, resulted in those countries significantly outperforming Australia in 2007. Overall, Australian students performed poorly in the areas of geometry and algebra. A similar trend is visible for the respective cohorts in the science assessments.

Interestingly from the 2007 TIMSS assessment, both internationally and within Australia, Year 4 students tended to have a more favourable opinion of mathematics and science than Year 8 students. However, far fewer Australian Year 8 students had high positive affect toward mathematics and science than was the case internationally. At both Year 4 and Year 8 the percentage of Australian students with high positive affect toward mathematics decreased significantly from 1995, while there was a slight increase in positive affect toward science at Year 4. At both year levels, higher positive affect toward mathematics and science was associated with higher achievement.

In terms of results for males and females:

- Year 4 mathematics – There was no significant gender difference in the Year 4 mathematics performance of Australian students. This was similar to the results internationally, in which males and females performed equally well at this level. In Australia, a slightly higher proportion of males achieved at the advanced benchmark, while a similar proportion of males and females achieved at the low benchmark. With respect to performance within the Australian states, there were no gender differences.
- Year 8 mathematics – At Year 8 nationally, there was a substantial and significant gender difference in favour of males. More males than females achieved the higher benchmark levels, while similar proportions of females and males failed to achieve at the low benchmark level. The gender difference in favour of males was only significant in Queensland.
- Year 4 science – At Year 4, there was no significant difference between the average performance of males and females in Australia. This is different to the results internationally where females outperformed males on average. In Australia, a higher proportion of males achieved at the advanced benchmark, while a similar proportion of males and females achieved at the low benchmark. There was no difference across the states in terms of the performance of male and female students.
- Year 8 science – At Year 8, there was a substantial and significant gender difference in favour of males in Australia, while internationally it was female students, on average, who outperformed males. In Australia, the better performance of males is apparent mainly at the higher benchmarks – there was little difference in the proportion of females and males achieving at the low benchmark. At the state level, the only significant gender difference (in favour of males) was found in Queensland.
- Trends – The increased score for Australia overall for Year 4 mathematics was the result of a significant increase in the scores of both males and females. In contrast, the significant gender difference in favour of males found in Year 8 mathematics (not previously seen in 2003 or 1995) appears to be due to a significant decline in the average score for females over the 1995 – 2007 time span.

The 2007 TIMSS report also indicated that more males than females had high self-confidence in learning mathematics, both within Australia and internationally, and at both year levels. For science, however, there was no gender difference in self-confidence at Year 4, contrasting with a gender difference in favour of males at Year 8. Within Australia, the gender difference in self-confidence in learning mathematics and science could help to explain the gender difference in achievement at Year 8. Approximately one-third of Year 8 students intended to study at least an undergraduate degree, while 13 per cent expected only to finish secondary school. A clear positive relationship was found between mathematics and science achievement and students' educational aspirations.

The report also provided information about the Australian teachers and their preparation for teaching:

- Across Australia, a majority of Year 4 teachers were female and about one half of Year 8 students were taught mathematics by female teachers. Internationally, more Year 8 students are taught by females than males. Nationally, in Year 8 science classes, there were equal proportions of male and female teachers. Internationally, however, Year 8 students were taught science more often by females than males.
- The Australian teaching workforce was well-educated in terms of completion of university and postgraduate university degrees. The majority of Year 4 and Year 8 students had teachers with a university or postgraduate university degree.
- Internationally, about one-quarter of Year 4 students were taught by teachers with a qualification in primary education and a specialisation in either mathematics or science (or both). However, in Australia, most year 4 students have teachers with a specialisation in primary education without a major or specialisation in science or mathematics. In Australia, at Year 8, about one half of students had teachers with a mathematics education qualification or mathematics qualification. Over two-thirds of students had science teachers that had studied biology, physics, chemistry or Earth science.
- At Year 4 and Year 8, across all mathematics topics, Australian students generally had teachers who reported feeling 'very well' prepared to teach all topics. Teachers of science at Year 4 were less well-prepared to teach all topics. At Year 8, more students had science teachers who reported being well prepared than was the case for Year 4 science; however, Year 8 mathematics teachers reported a higher level of preparedness to teach than Year 8 science teachers.
- For Year 4 mathematics, the percentage of students with teachers who reported feeling 'very well' prepared to teach geometric shapes and measures was lowest both internationally and in Australia. For Year 4 science, physical science was the weakest area both in Australia and internationally. For Year 8 mathematics, data and chance was strongest and geometry and algebra were the weakest areas in Australia. For Year 8 science, the percentage of students whose teachers reported feeling 'very well' prepared for chemistry was highest and physics and Earth science were the lowest areas in Australia.

DIVERSITY & WOMEN IN ENGINEERING

One statistic suggest that women make up only 16% of commencing undergraduate students in engineering, and 9.5% of those with tertiary qualifications in engineering or related occupations (Engineers Australia 2008). This figure remains unacceptable low, and is one aspect of a broader problem with participation of women in highly-paid engineering professions and technical trades.

While women's involvement in engineering has increased somewhat over the past three decades, beginning from an extraordinarily low base, female participation remains very low compared to overall female workforce participation rates. Cultural and workplace flexibility issues have caused the exodus of women from the profession. In a APESMA's (2010) *Women in the Profession* survey, 78% of respondents indicated that they worked in a male-dominated industry. Of engineering respondents, 75% felt that working part-time in their current job has had or would have detrimental impacts on their career. And disturbingly, around 70% of engineering respondents thought that taking maternity leave would be detrimental to their career. Most respondents noted that a lack of access to senior roles for women, and found difficult to juggle work-life balance. This “outdated” workplace trend is well supported by other studies (D’Angelo Fisher 2011) and increasingly applicable to the male workforce as well.

Attracting and retaining women students and engineers is an issue of both equity and practical supply. Though addressing systemic workplace and cultural issues in the engineering profession is of urgency, the profession needs to consider strategies to improve the pipeline for supplying female engineering graduates. Hence the K-12 (kindergarten to year 12) sector is critical in the equation for successful participation.

Graduations from university engineering courses are limited primarily by the number of enrolments from qualified and motivated school leavers. In a student-demand driven educational system post Bradley Review, Australia cannot rely on market forces and student preferences to ensure the flow of engineering graduates that the nation requires. Given that in many cases, the problem stems back to declining levels of engagement with mathematics and the sciences at the primary and secondary level education.

MENTALITY & SELF-LIMITATIONS

Although women make up roughly half the workforce, far fewer women than men reach senior management and leadership positions. While the business case for gender diversity at all levels is compelling, progress has been glacial. In a survey of 3000 members of the Institute of Leadership and Management, it was found 73% of female respondents felt barriers still existed for women seeking senior management and board-level positions in Britain. In contrast, only 38% of men believed there is a glass ceiling. The report, *Ambition and Gender at work* (2011), suggests women’s managerial career aspirations lag behind men’s at every stage of their working lives and that they have less clarity over traditional career direction than men. The engineering profession wants to nurture the talent of their best female employees; it needs to start challenging some of the unwritten rules of what senior engineering management roles looked like.

According to the research, the glass ceiling facing the female engineering workforce may be all in the mind. A lack of ambition and self-confidence, and not the perceived overt male sexism, is holding women back from senior management roles. Women of all ages are likely to set their career goals lower than men, are more hesitant about putting themselves forward for promotions and more frequently admit to self-doubt, according to the study. Some women may also have their ambition limited by worries about whether they can succeed in a male-dominated workplace, and by a greater innate aversion to risk taking.

From this research, there is still a fundamental confidence issue about what women think they will be able to do. One can argue that this confidence issue initiates at the primary education level. Up to 40% of first year undergraduate students first consider university in primary schools, and another 23% at lower secondary schools; with 79% decided to study an area of interest (Hare 2010). The finding, as part of a large-scale survey of 55,000 students in 55 institutions, has given universities quantitative evidence for the first time that young students are highly receptive to the notion of attending university. Prof Trevor Gale, director of the National Centre for Student Equity in Higher Education, said even though it was the first time that age at which students first considered university had been quantified, it "didn't really surprise". He said the survey raised several interesting questions, such as the role of schooling in aspiring for university and achievement once there, and the relationship of that to having degree-holding parents as well as the influence of teachers. Professor Gale said "For some children it is a given that they will attend university. They never consider otherwise. It's part of who they are" (Hare 2010).

The evidence suggests that the most potential for influence and setting career expectations in students are not currently been successful exploited. The best candidate for channelling this influence is the teachers and career advisors. However, in recent times, the K-12 sector has been struggling with some segment of the teaching profession in leading classrooms to influence decisions to pursue higher education, and in particular, an interest in the engineering profession. In the absent of inspiration, directions and role models, this confidence issue becomes endemic at the primary and secondary education levels where growing minds form and adjust their expectations for their future career paths, and they become self-limiting. Even if they persist through this doubt and progress to graduation at the tertiary level, female engineers may be acculturated with this self-limiting mentality if the confidence issue is not addressed at earlier stages of learning development. This problem is perhaps one of the main reasons behind the declining levels of engagement with mathematics and the sciences at the primary and secondary level education.

LEADERSHIP IN THE CLASSROOMS

The core issue of graduate supply to the engineering profession comes down to the need for confident teachers at all educational levels, and those that are well supported by professional development and training. Leadership plays a major role in developing confident teachers. This classroom leadership should begin at the primary and secondary levels, and further reinforced at the tertiary levels. There have been many initiatives from the engineering profession and engineering faculties in addressing the supply of quality engineering graduates (King 2008). Refer to ALTC projects within the engineering and related disciplines for details of these initiatives (ALTC n.a) as well as current and forthcoming ANET reports (ANET n.a).

Southwell & Morgan (2009) provides a comprehensive literature review of the leadership topic for the K-12 as well as the tertiary sectors. In their work, teacher leadership is defined as the process by which teachers, individually or collectively, influence their colleagues, principals, and other members of school communities to improve teaching and learning practices with the aim of increased student learning and achievement. Such leadership work involves three intentional development foci: individual development, collaboration or team development, and organisational development. Based on the empirical research into successful examples of teacher leadership, one may speculate that improvement in student outcomes is more likely when there is a sustained, intensive focus on the nexus between how teachers teach and what students learn. Required are effective professional communities that contribute to enhanced student learning outcomes by fostering positive change in the professional culture of primary and secondary education sectors.

This intensive focus on this nexus should contribute to developing leadership in the interaction between teacher-student relationships, leadership in educational pedagogies, leadership in curriculum development, leadership in professional development for teachers and academics, and so on. The potency of teacher leadership for increasing student learning hinges on the specific classroom practices that leaders stimulate, encourage and promote. Highly qualified, well resourced and supported teachers will have a leading impact in delivering a highly exciting and motivating STEM (Science, Technology, Engineering and Mathematics) experience at the primary and secondary levels. Indirectly, a consequence of this leadership is that a proportion of these inspired students will ultimately choose a career in STEM education as a primary, secondary or tertiary educator.

In many ways, science and mathematics teachers play a "leading" role in motivating students (or the lack of). And in some cases, are often not the best role models for STEM occupations. There are still prevailing belief in the community that male cohort are stereotyped as being better at science and mathematics. School career advisors somewhat encourage this belief system. They are often very influential in the negative sense in that the advice given often eliminates STEM careers, and in particular, the engineering profession from the list of potential career choices for the aspiring female students. It is often the case of perceptions become reality.

Professional teachers needs to be trained to be sensitive to gender differences when teaching all subjects but especially mathematics and sciences. Teacher's profession development needs to include ways to engage students in the face of gender-based peer pressures and parental expectations (or the lack of). The importance of science and mathematics teachers is crucial in ensuring student engage and do well in STEM subjects, hence increasing the likely of students pursue a career in STEM occupations.

These primary and secondary education objectives are also applicable to the tertiary sector for engineering educators but somewhat complicated by contrasting priorities in the form of academic research (versus scholarship of learning and teaching). Academic leadership in learning and teaching needs to be a focal interest to improve student engagement with the engineering profession by proactively engage the profession as engineering educators, and having appropriate role models (eg. female professional engineers as part of the teaching team) for engineering students. However, these activities at the tertiary level would not be effective without first addressing teacher leadership at the early stages of development in primary and secondary levels.

THE MISSING "E" IN STEM EDUCATION

The core hypothesis of the current education system is that it imparts the students a thirst for knowledge and the motivation to pursue STEM studies and provides highly motivated students to universities to develop them into highly competent STEM professionals. What if this hypothesis isn't quite true and the system is somewhat broken? The consequence of a broken educational system is a deficiency in the quantity, and most important, quality of graduate supply into the engineering profession.

According to 2007 TIMSS, Australian primary school teachers at Year 4 believe they are less prepared to teach science and mathematics. Internationally, about one-quarter of Year 4 students were taught by teachers with a qualification in primary education and a specialisation in either mathematics or science (or both). However, in Australia, most year 4 students have teachers with a specialisation in primary education without a major or specialisation in science or mathematics. The statistics on qualifications of teachers tasked with teaching mathematics and sciences are somewhat concerning. At Year 8, about one half of students had teachers with a mathematics education qualification or mathematics qualification. Over two-thirds of students had science teachers that had studied biology, physics, chemistry or Earth science.

The hypothesis here is that lower level teachers who may be struggling to encapsulate complex technical concepts may be less able to introduce, contextualise, and inspire such STEM materials to students, and thus limiting the supply of future students to further STEM studies in year 11 and 12. A question worth asking is, "Wouldn't it make more sense to have the best qualified and performing teachers at the threshold of student career decisions?" With the declining interests of future teacher graduates in professional degrees in preference for education degrees for teachers, this trend will worsen as each generation of teachers leave the profession.

The engineering profession and Australian engineering faculties needs to collaborate extensively with the primary and secondary education sector to provide an input and put the "E" back into STEM education. This should manifest as we speak by providing input on the development of the Australian National Curriculum, and working with the government agencies to providing continuous professional development (CPD) opportunities for teacher development in STEM education, and specifically engineering education. Highly qualified teachers supported with teaching resources and CPD will deliver a better and motivated experience for aspiring female engineering students. There are some successful models being developed in the UK via the "Engineering Engagement Project" (Royal Academy of Engineering). It aims to widen STEM participation by supporting teaching and learning through CPD for teachers, curriculum resources and support, and guidance and access to grants for after-school science and engineering club. This initiative can be duplicated here in Australia; however, it does require leadership not just from the government in terms of policy, but from the engineering profession, engineering faculties, and the education faculties.

CONCLUSIONS

The engineering profession within Australia has failed to attract young women for the last decade despite all the effort that have gone into promoting engineering as a preferred career choice for girls. It is a missed opportunity for the profession to flourish as a heterogeneous team. Many traditional initiatives and programs have failed to make much impact or at best incremental improvement into attracting and retaining more women.

The reasons why girls and young women (in most parts of the world) show little interest in engineering haven't changed, despite all the efforts to address them. This paper examined the proposition that leadership in engineering education may be the elixir for enriching the motivation of many young women to pursue an engineering career. And this process starts at primary and secondary education.

There needs to be leadership in the interaction between teacher-student relationships, leadership in educational pedagogies, leadership in curriculum development, leadership in professional development for teachers and academics, and so on. The national curriculum is a great opportunity gone begging. Of the many recommendations adopted, engineering or rather the "E" in STEM education is still "missing". The deficiencies in the "E" in STEM and teacher leadership may be the reasons for the current low female participation in the engineering profession.

In saying this, the engineering profession and engineering faculties in Australia need to collaborate, take an active role in addressing concerns in the education sector by providing industry support to primary and secondary school teachers and provide input into the Australian National Curriculum and CPD opportunities for teachers.

A renewed focus on teacher leadership and the "E" in STEM education, the outcome is a sustained and exciting career in the engineering profession (for both male and female cohorts). Hence, developing leadership at these coal-face activities in engineering education at the primary, secondary and tertiary levels will influence young women to pursue such an outcome. In conclusion, we need to develop leadership in engineering education to improve diversity in the engineering profession.

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