

The Changing Face of Engineering

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Abstract: *Engineering and engineers should make a critical difference in tackling the big issues facing the UK economy and its future wellbeing. Science and engineering continue to be at the heart of government policies in education and in industry (DFES / DTI 2006). One aspect of the workforce supply to the UK engineering sector could contribute significantly in supporting our future. Measures to break the cycle of under representation of women in engineering education and industry have been developed and supported in isolated pockets for a number of years. There have been many interventions in the past that have been targeted mainly at recruitment, and whilst many have not made significant progress on numbers, they have made some difference to individuals who may not have otherwise chosen engineering as a career. The recently recognised challenges of climate change may also offer engineering a significant opportunity to draw in more women (UKRC/EPC Global, 2007). This paper will highlight a range of current interventions working to improve the diversity of engineering. The paper will outline interventions that could impact at different life stages of girls and women - university outreach with schools, university education and employment. The paper will explore the challenges still faced, measures of success of interventions to date, as well as lessons learned to enable engineering to change its face for the wellbeing of the UK in the future, drawing on initiatives across the UK.*

Introduction

This paper seeks to raise the profile of an issue in engineering education that continues to remain on the periphery of the sector. Mainstream engineering education is much as Greed (2000) describes the construction industry i.e. as a planet with satellites of equality and diversity orbiting without having a lasting impact. Engineering is viewed as a significant UK industrial sector for the future of the economy (Sainsbury, 2007) that continues to experience an imbalance in the gender split of its workforce. Why is it that this imbalance and shortfall of women is a low priority? The recent Sainsbury Report (2007) barely included mention of the under-representation of girls and women entering engineering. Since 2004 the UK Government funded UK Resource Centre for Women in SET (UKRC) has been working as an agent for change and the Women's Engineering Society (WES) has worked tirelessly since its inception in 1919 to support women already in as well as those women seeking entry into engineering. The Engineering Technology Board highlight the need for more girls and women in engineering careers (ETB, 2007), but within mainstream engineering higher education there is little evidence that the community is 'grasping the nettle.' Those in Engineering Education need to raise

their awareness and draw on the expertise and knowledge from the various 'satellites' to take this issue seriously and finally bring about lasting change.

Context and Issues

Sainsbury (2007) and Leitch (2007) are championing the call for a UK workforce that leads the world in its skills and innovation. Engineering has a significant role in all of the major challenges such as climate change and security that the UK and indeed the world need to tackle. The concerns about the supply of students into the sector has grown to become a now significant part of the government education agenda (DfES and DTI, 2006; DCSF, 2008) and initiatives such as the new 14-19 Diplomas should also serve to improve the supply chain. However the recent review undertaken by the Engineering Technology Board (2007) points out the continued low proportion of female participation at all levels.

- The proportion of female engineering apprentices in learning is as low as 3% (p6)
- In recent years the proportion of female students reading engineering and technology subjects has remained stable at about one-in-six, with no improvement in the gender balance. (p7)
- The proportion of female registered engineers is growing, but very slowly, so that they account for only just over 3% of the total. (p8)

Sir Anthony Cleaver, Chairman of ETB at the Engineering UK Launch event called it a (Cleaver, 2007, p2) "highly significant challenge."

A search of the Engineering Subject Centre website for resources in teaching gives signposts to outside groups such as UKRC, mentions the Balance Project (<http://www.balance.ac.uk/> ran at Loughborough between 2000 and 2002) and finally "a tongue in cheek" view of the differences between the way women and men learn (<http://www.engsc.ac.uk/er/wp/pitt.asp>). It has to be asked what positive contribution is being made with this last piece. Should there not be a dedicated part of the site that focuses on this aspect of engineering education? Researchers in this area (Faulkner, 2006; Bagilhole et al, 2007) have clearly identified continuing issues of concern for women in engineering higher education. Faulkner (2006) discusses the severe lack of confidence that women experience when they enter engineering education. Because there are so few women in engineering education, women students are very conscious that they have chosen a career counter to the norm. Faulkner (2006, p4) recommends that "Engineering faculty need to be enlisted in efforts to normalise the woman engineer amongst staff and students. They also need to be sensitised to the confidence loss some women engineering students feel on entering engineering education."

Bagilhole et al (2007) carried out research for the ESRC with women students and make recommendations for change and include three issues that are specifically relevant for teaching and learning in this paper.

- A one-size fits all solution is inappropriate. Students attend diverse institutions and are from diverse backgrounds.
- The structure of engineering education (teaching and learning methods) should be modified to attract and stimulate interest of students.
- Support mechanisms need to be in place for women students, particular those in industrial placements experiencing problems.

This is clearly not a new issue, but it is an enduring one. Where is the evidence that engineering higher education has learned from previous interventions? Some of the criticism of earlier interventions relates to their tendency to offer a deficit view of women (Cronin et al, 1999) where they worked to help women 'fit in' to the existing culture. More recent initiatives have worked to tackle culture and examine the learning environment and curriculum (CUWAT, 1998; Williams et al, 2000). Yet as long as these initiatives remain on the edge of mainstream engineering higher education they will fail to make the impact that is needed. The CuWat project (1998) attempted to set out a framework for a technological curriculum that would widen access to women. They identified a range of issues that they wanted tackling within three themes: pedagogical approaches to teaching, curriculum content and culture. They identified the 'chilly' classroom climate (p4) that puts women off, the need to contextualize technology in order to make it relevant to women. The culture in technology was identified as "abstracted, impersonal, hard, cold and disconnected with real life" (p5) and this culture contributed to the exclusion of a number of students, women more than men. They called for teaching methods that recognized and could respond to a diverse student group with diverse learning styles, that encouraged reflection in students and that recognized the situation of being a minority in the classroom.

The Let's TWIST Project (Williams et al, 2000) was instrumental in developing staff development package for lecturers that focused on how they could make a difference to the women in their classroom. The main focus of the training is on inclusive learning and how to attract and retain women on courses, based on good practice from various initiatives and sectors of education and training. Those taking part in the training

- Hear what women say they want from education and training and how best those needs can be met
- Explore the issues which can prevent women from entering education / training
- Discuss the role lecturers play in enhancing the learning experience for women
- Share good practice with the trainers and delegates
- Discuss the best ways of tackling real problems in day to day teaching covering issues such as harassment and stereotyping
- Develop action plans to take forward the work into their own institutions

The training package has been developed since the Let's TWIST Project and now forms part of the UKRC package of Gender Equality Training. The UKRC conference theme in 2007 was Climate Change and they commissioned a survey to explore the views of those working in SET of the challenges faced (UKRC/ EPC Global, 2007). The findings indicated that more women could be engaged with a focus on environmental challenges faced. Women wanted to address the compelling changes that face humanity (p2). This reinforces other research on women and engineering (CUWAT, 1998; Williams et al, 2000; Prendergast and Read, 2007) that indicates that context of learning and teaching is more important to women.

Greed (2000) in her study of construction culture, examined the range of initiatives and policy groups that were working in the built environment sector. She used the term 'planet construction' with a range of 'satellites' circling the planet but failing to change the orbit. She called for the satellites to become more involved with the mainstream cultures and communities in construction, and for 'top down' change agents to link with 'bottom up' change agents to make the breakthrough needed for lasting change. It is now time for the engineering higher education sector to take

some responsibility for drawing the various research projects and the initiatives involved in change together, so that a positive change can take place that will finally and sustainably include women in engineering.

Interventions

The following interventions are outlined as examples of practice that has been developed by those with experience and interest in this area of work. Evaluations of the interventions support the benefit of the practice and they comply with the recommendations of research projects summarised above as well as within the descriptions below.

1. Work with school girls to promote engineering as a career by delivering work experience programmes with good employers and allied work in university outreach and widening participation.

The Wider Horizons work experience placement scheme was created as a direct response to current difficulties present in stereotypical work experience choices. Wider Horizons was funded by a European Social Fund Equal project (JIVE Partners) and built its development on research evidence from an Equal Opportunities Commission funded report (Hamilton, 2003) that found that work experience choices were reinforcing stereotypical choices rather than challenging them. Wider Horizons was developed in South Yorkshire by a member of the WiSET team at Sheffield Hallam University and provided 2/3 week long placements for girls undertaking work experience as part of their normal school delivered programme in Y10 and / or Y11. The scheme encouraged girls who had chosen clerical / admin jobs for work experience to investigate alternative careers whilst on placement in science, engineering and technology based companies. In working closely with all stakeholders involved the scheme was able to draw out the key factors that would make an impact and create some change. The scheme worked closely with employers, the Business and Education partnership, school teachers, work experience coordinators and careers advisers, pupils and their parents to ensure awareness was raised about the opportunities in careers such as engineering, but also tackling some of the issues such as being a female in a male dominated workplace, culture and employer concerns including health and safety. The impact of this work will only become clear over the long term. Ongoing links with schools and their pupils is part of the strategy followed by the WiSET team and staff in the university and this addresses some of the concerns about one off initiatives that have no lasting impact (Sian and Callaghan, 2001). However it is worth referring to a Powerpoint presentation given by one of the students (as part of the scheme on her return to school). Her original career interests before the placement were design or photography.

During my work experience

- *I learnt how Rockware Glass works*
- *I learnt about the different roles of the different employees*
- *I learnt that I don't want to be an Electrical Engineer*
- *I learnt that I don't mind the heat, grime and dirt of the shopfloor*
- *I learnt that there are very few females in engineering jobs*
 - *I learnt that I would consider becoming an engineer as one of my possible career options.*

She has now set her sights on a career in biomedical engineering (Collins, 2007; Brodie, 2006).

The project received an award from the Institute of Careers Guidance in 2007 and is being mainstreamed as part of the UK government's support for STEM Careers.

2. The building of networks to support female students at university and to support progression to engineering careers beyond university.

Researchers (Jensen et al, 2005; Faulkner, 2006; Powell et al, 2006; have all established a need for support networks for women students in engineering education. The Balance Project was a key HEFCE (<http://www.balance.ac.uk/>) funded project that had a strong thread of mentoring development and dissemination. Unfortunately the project's life did not continue beyond the initial phase and the materials. Although the original materials are still available on the website they have not had any funding to grow and incorporate other schemes developed more recently e.g. the SET for Work scheme funded by the DfES and run by UKRC (UKRC, 2005).

The Balance project did however refer to a much older scheme to support women in engineering – the Women's Engineering Society (WES). WES was formed in 1919 when women really were a rarity in a male dominated environment. Because of their own sense of isolation, women engineers came together to provide a forum to meet and exchange ideas on common interests, training and employment (<http://www.wes.org.uk/whoweare.shtml>). WES today offers far more than just an opportunity to share ideas. They are the largest women in SET professional group and they have the only engineering group that is truly inclusive across all levels and areas of the engineering community. WES also runs MentorSET which is the largest national SET mentoring network for women.

There are also a number of individual student networks that develop, some within WES and some with the support of WES and others with the support of universities who have recognised the need. Two recent examples include

- Student Support Forum for Females at Napier University – the scheme includes a web-based forum to link students with role models, including WES members. It is hoped this forum can develop to support female students across Scotland subject to funding. The strength of such schemes often comes from students themselves. In this case students carried out research in 2006/7 and they have since developed the website (<http://www.napier.ac.uk/fecci/ssf4f/Pages/index.aspx>).
- Student Network for Women Engineers at Sheffield Hallam University – the network was developed by a female engineering academic with support from the Faculty and its Widening Participation team as well as from the WiSET team. The network started as an opportunity for students to come together and meet role models in industry and academia, but has also provided students themselves with opportunities to be role models for schoolgirls and has linked with the Wider Horizons scheme. The network is now receiving support from female role models outside the university wanting to become involved. There is clear potential for working closely with the WES cluster in Yorkshire and Humber.

3. Work with employers to assist in culture change and to support women who have taken a career break to return to engineering.

The UKRC established in 2004 as a result of the Greenfield Report (2002) has a very wide remit, but work with employers to bring about

culture change as well as interventions to improve the access of women returning to SET have been key strands of its work. The Culture Analysis Tool (CAT) has been developed to support employers in SET to identify and understand the issues in the workplace with regard to gender equality and following this to work to improve the culture. To build on the work that employers are doing to promote gender equality the UKRC has worked in partnership to develop awards recognising good practice. It is noteworthy to mention that the Institute for Mechanical Engineers Manufacturing Excellence (MX) Award for Gender and Diversity had no clear winners until DuPont (UK) Ltd received the first MX Award under this heading in 2007 and Jaguar Cars Landrover Ltd. Received the UKRC Quality Mark also in 2007 (www.ukrc4setwomen.org.uk).

The Women and Work Commission Report (2006) has focused attention on concerns about the disadvantages still faced by women in the workplace that, if tackled could contribute around 2% to GDP. However the report found that women who were out of the labour market rarely had access to information about education and training opportunities, and women with caring responsibilities found it very difficult to participate in education and training (p54). Women often end up in occupations working below their potential (Olsen et al, 2005) with returners under utilizing their past training. After taking an extended period out of work women face many barriers to returning, often compounded with lack of confidence in their own ability (Women in Work Commission, 2006). Maximising Returns (2002) explored ways in which the UK could make the most of the investment in SET graduates and address skill shortages. The research found that women with SET degrees are less economically active than SET men or non SET women. The UKRC working with its partners has developed a Return Strategy that includes career development courses, networks of support and placements and focused careers advice for women returners, but there is much still to do to tackle the barriers.

4. Development of pedagogy and curriculum that will result in an inclusive approach to engineering education.

Work to intervene to change the curriculum and pedagogy present in engineering higher education has been less well developed, but there have been signs of some innovative projects that could make a difference if they could be more widely discussed and taken on board. The CUWAT project (1998), The Let's TWIST project (1998) and JIVE project (2002 and 2004) as well as SHEFCE Winning Women project (1997) are examples of initiatives that have tried to introduce debate about pedagogy and curriculum. The London Engineering Project (LEP) (<http://www.thelep.org.uk/>) led by the Royal Academy of Engineering (RAEng) and funded by HEFCE is currently working through a partnership of schools, universities, STEM organisations and industry to broaden participation in engineering higher education. The project has worked closely with UKRC, and supported by an HE working group to enhance Foundation, BEng and MEng courses with a common theme of widening participation, not just to women but to other under-represented groups. A checklist has been developed to support change to current pedagogical practice in the universities involved allowing scope to concentrate on areas that are relevant to each institution (Prendergast and Read, 2007). The check list has the following headings:

- Place engineering theory within its practical context
- Provide opportunities for problem-based learning
- Discuss engineering practice in society
- Equip students with the full range of skills to become professional engineers
- Support the transition from education to employment
- Develop delivery strategies to include all students
- Develop a positive learning environment and culture that is inclusive to all students
- Offer support and networking opportunities
- Emphasise links between students and lecturers
- Promote co-operative working amongst students
- Use a range of assessment methods
- Develop mechanisms to make use of student feedback.

The QAA Subject Benchmark for Engineering (2006) includes similar requirements to the checklist including the ability to problem solve, awareness of the practical context and knowledge of application of engineering in society. This may have indicated that engineering higher education should already be delivering these aspects, but recent research findings from Bagilhole (2007) and Faulkner (2006) suggest that there is still considerable scope for improvement..

Impact and Challenge

There have been a number of studies that have explored the elements of bringing about change in higher education. The drive for change within higher education from a wide range of influencers and policy drivers has brought forth a range of views on how best to bring about lasting change from top and bottom. According to Hannan (2001) who looked at innovation in learning and teaching there are three themes – “individual innovation, guided innovation and directed innovation” (p5). He found that innovation is most likely to take place when:

- the innovator feels secure within the community to bring about change
- the institution encourages parity between research and teaching
- colleagues are interested in the dissemination of outcomes
- resources are available to innovate.

Bailey et al (1998) describe the impact of an equal opportunities change programme at the Open University and suggest four key points (p62):

- policy needs to be congruent with institutional culture
- change must be multi-layered
- a long term approach is needed
- a wide range of tools to be used to evaluate...not just quantitative.

Knight and Trowler (2000) express concern that the changing nature of higher education has inhibited an improvement in learning and teaching: Intensification and long hours working.

- Hard managerialism means staff are less trusted and given more administration.
- A loss of collegiality with no time to socialize and opportunity to discuss practice.

- Greedy institutions, where particularly women and ethnic minority staff find they get called on for a disproportionate amount of service work.
- Ageing, malaise and marginality with reduced self esteem and self confidence that reduces the confidence to take risks.

These issues can limit the impact of individual initiatives that are trying to improve the participation and progression of women in engineering. The individual initiatives can achieve change in a limited way, but the difficulties in achieving lasting change should not be misunderstood. It is relevant to draw on Greed's study of the Construction Professions (2000) mentioned earlier in this paper. The numbers of women entering engineering is still well below the percentage (around 30%) that is used to argue the case for critical mass. Yet even achieving critical mass will not alone achieve change and as Greed proposes (p183) this concept is "highly optimistic and over simplistic...without acknowledging the immense cultural and structural obstacles present."

What is clear is that there are a number of very active and motivated forces for change within engineering that are currently working to improve the participation and progression of women. The challenge to the main influencers in the field of engineering higher education is to bring the individual projects and forces together to achieve a much bigger impact and to overcome resistance to change.

Conclusions and recommendation

The paper has attempted to highlight the need for engineering higher education to address a longstanding and important problem – that of the under representation of women in engineering. Engineering higher education acts as gatekeeper to the industry and while there have been a range of individual interventions to try and improve the participation of women there is no central champion co-ordinator within engineering higher education to ensure the sustainability of them. Research in the area of the under-representation of women in engineering (CUWAT, 1998; Williams et al, 2000; Bagilhole et al, 2007) confirms that changes need to be made to the existing learning experience as well as the provision of measures to support women students. Promotional activity to girls to improve entry will not resolve the problem on its own. The paper has described some of the interventions that have worked and are working with those organisations engaged in a range of innovative as well as some enduring and longstanding institutions supporting women, Women's Engineering Society. The initiatives described are examples that have been designed by those with significant experience in gender and occupational segregation as well as those that have experienced the culture of engineering first hand.

- Promotion to young women in their school based work experience, which is recognised as a significant time of influence, in a scheme that also works with employers, schoolteachers and parents as well as career professionals to ensure all influencers work together.
- Networks of support for women students to ensure they have access to role models in engineering employment, as well as the opportunity to socialise with other women engineers, in schemes that link to the largest network for women engineers in the UK (WES).
- Interventions to ensure that engineering can be a life long career for any woman by supporting culture change in engineering work environments that discourage women at entry, from returning from a career break, and from progressing to the highest level.

- Development of the engineering curriculum and pedagogy to ensure that engineering higher education is inclusive, attractive and meaningful to all.

So while individual initiatives are making a small difference to the participation of women in engineering, their success continues to be limited without a coherent and central voice from within engineering education promoting change. The research on change in higher education in the area of equal opportunities (Bailey et al, 1998) suggests that related interventions need to link to culture and be multi-layered as well as being long term. There is now an urgent need for a concerted effort to embed inclusive practice in engineering higher education across the breadth of engineering. The researcher suggests that the Engineering Subject Centre as "provider of support for learning and teaching to the UK higher education community" and with a mission "to improve the student learning experience in partnership with the UK engineering community" (<http://www.engsc.ac.uk/>) should take on the role of champion and co-ordinator with the backing of and contributions from the engineering higher education community. The organisations involved in delivering interventions such as those outlined in this paper are ready to work alongside the UK engineering higher education community and support the campaign for lasting change. With a concerted effort from all, a significant improvement in the representation of girls and women in engineering could be achievable for the benefit of the UK economy and engineering.

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