Chapter 10

Diversity in Engineering: tinkering, tailoring, transforming

Jane Grimson & Caroline Roughneen

Abstract: Diversity is essential for creativity and innovation, which are at the heart of engineering. Thus engineering can benefit from the richness and varied perspectives and expertise which individuals from different ethnicity, culture and gender can bring to problem-solving. Furthermore promoting diversity in the workforce provides greater access to talent by increasing the pool of qualified and skilled professionals. This chapter focuses on gender diversity as an area which has received considerable attention for many years from both the research community and policy makers. Researchers seek to explore the reasons for the continued under-representation of women in engineering in spite of numerous policies, initiatives and interventions. The subject will be explored through the role of female engineers in academia as it is the education sector which has the most critical influence on recruitment and retention, not just in academia itself but in the public and private sector generally. Using the "tinkering, tailoring, transforming" model developed by Rees (1995), the chapter will explore the history of women in engineering, highlighting those interventions which appear to be having the greatest positive impact. In spite of the dearth of rigorous evaluation in terms of sustainability and scaleability, there is a growing body of evidence pointing to best practice in this area. This indicates that a significant shift in attitudes and culture is required in order to reach the critical mass of 30% when the process becomes embedded and sustainable.

Keywords: diversity in engineering, women in engineering

Introduction

Engineering is concerned with the application of scientific and mathematical principles towards practical ends. It seeks to create cost-effective solutions to practical problems by applying scientific knowledge to building "things" or systems. It is about solving problems using a systematic approach, subject to economic, environmental, social and other constraints. It deals with

problems – whether it is concerned with building a bridge or designing a heart pace-maker – whose solutions matter to ordinary people. Thus engineering lies at the interface between science on the one hand and society on the other. Traditionally engineers have concentrated on the interface with science and in the rapidly accelerating speed of scientific advancement this continues to be a fundamental part of the engineer's approach to problem-solving. And this is challenging as in the past decade more scientific knowledge has been created than in all of human history (Kaku 1998). Almost daily, the headlines herald new advances in computers, telecommunications and biotechnology. However, while applying engineering and scientific principles can solve the technical problems of, say, designing a new road, the real challenges for engineering are increasingly non-technical. Rather they are concerned with the broader context in which the road is being built and its impact on the environment and people. It is the engineer who has the knowledge and skills to address the environmental, regulatory, economic and human constraints and to put forward creative and innovative solutions which take account of these wider issues within the context of what is technically feasible. Thus engineers must address increasingly the other side of the interface – the interface with society – and gain an understanding of the language and principles of the so-called "softer" sciences.

This new climate of engineering practice, together with evidence of a threatening skills shortage, requires us to look beyond our traditional pool of talent in order to capture new perspectives and build a stronger, more diverse, but nevertheless synergistic workforce. Promoting diversity in the workforce, that is, promoting a workforce which includes diversity of ethnicity, gender and culture, is seen as providing both the public and private sector with greater access to talent by increasing the pool of qualified and skilled professionals. Furthermore, it increases innovation in research, provides a better match with clients and the market-place and the private sector, and encourages a wider range of approaches, problem definitions and strategies, all of which can only improve the quality of outputs.

The twentieth century showed great variation in respect of women's participation and acceptance into the engineering profession. Prior to the World Wars, women were generally excluded from becoming engineers yet were actively encouraged, applauded and accepted into the engineering profession and activities during both wars when male labour was unavailable. Subsequently, in the UK for example, a policy was adopted which once again excluded women from engineering activities so the returning men would have jobs to go to (Wightman 1999). As Katherine Parsons, wife of Charles Parsons, inventor of the steam turbine, so eloquently put it: *"It has been a strange perversion of women's sphere – to make them work at producing the implements of war and destruction, and to deny them the privilege of fashioning munitions of peace...women are merely*

told to go back to doing what they were doing before" (Scaife 2000: 462). CP Snow, the English physicist and novelist observed in his book "The Two Cultures" that *"It is one of our major follies that, whatever we may say, we don't really regard women as suitable for scientific careers. We thus neatly divide our pool of potential talent by two"* (Snow 1959: 103).

It was not until the 1970's that women began to pursue engineering careers to any significant degree. Numbers have slowly increased since then though there has been evidence of plateauing and even a reduction in recent years. Internationally the proportion of women graduating with an engineering degree is approximately 20% (European Commission 2006*)* with very few countries attracting women to the critical mass level of at least 30% as suggested by Byrne (1991).

In the 25 member states of the European Union (EU-25) in 2004, women accounted for 44% of the total labour force. Between 1998 and 2004 their participation rate rose faster than that of men (1.5% for women; 0.4% for men). Yet, for scientists and engineers, female participation was markedly lower, at 29%, with the participation rate between 1998 and 2004 increasing much more slowly than that of men (0.3% for women; 2.0% for men). This is a worrying trend since, if it persists, women's participation in the field of science and engineering will decrease in relative terms (European Commission 2006). Critically, these figures indicate that there will never be sufficient numbers of women engineers to reach the critical mass. Below the critical mass *"a minority group within a population (especially one that has traditionally been discriminated against) is easily marginalized; its continued presence and survival is in constant jeopardy often requiring outside intervention and assistance to prevent extinction*" (Etzkowitz et al. 1994). As the level of participation increases, a tipping point is reached, generally regarded as being between 25-30%, at which the perspectives of members of both groups change and the character of the relations between the groups begins to change qualitatively.

Turning to academia, the percentage of women in tenured academic positions in the EU-25 is 35% (European Commission 2008a). Figures for the numbers applying for positions and the numbers being promoted are difficult to obtain. Anecdotal evidence would indicate that especially for senior positions in engineering (full professorships) there are often few if any female applicants. Valian (1998) describes many studies that illustrate that women candidates will be more fairly evaluated when they become more than 25% of the applicant pool, which is consistent with the overall effect on culture within an organisation when the percentage of women reaches a critical mass. Similarly more women will be granted tenure in faculties where there is already a high proportion of tenured women. The contention is that where there is a better balance of numbers, female applicants are no longer identified as women applying for traditionally men's positions.

This chapter examines the issues surrounding the under-representation of women in academic engineering. The recruitment and retention of women in academia is of crucial importance for the entire engineering sector. Universities determine who has access to engineering programmes and hence to engineering careers. They provide role models not just for engineering students but also for students training to be teachers who in turn will influence the career choices of the next generation. The chapter begins by looking at the number of women entering engineering, examining the extent to which girls have traditionally been excluded from engineering. Current data on the position of women in engineering in academia is presented followed by a discussion of a number of key reports and policy studies which have sought to understand and propose solutions to the problem of the under-representation of women in engineering. The central section of the chapter provides a detailed analysis and examples of a variety of interventions across many different countries under the 'tinkering, tailoring, transforming' model proposed by Rees (1995). The chapter concludes with a set of recommendations in relation to best practice based on those interventions which appear to have the greatest impact.

Entering engineering

The metaphor of the "leaky pipeline" (Alper, 1993) has been used for many years to describe the progressive loss of women on the career ladder. The phenomenon is clearly visible in the higher education sector with women accounting for 20% of engineering graduates but 6% of professors in engineering and technology (European Commission 2006: 60). The pipeline metaphor has been increasingly criticised for being too simplistic and encourages solutions which are based solely on plugging the leaks. It ignores the numbers entering the pipeline which is an important factor in engineering and also ignores those factors which might draw men and women out of the pipe. These "pull" factors can be just as important as the "push" factors which propel people along the pipe. A study by the economist Anne Preston (Preston 2004) showed that the primary reason (35%) women left science was that they preferred other positions (pull), closely followed (34%) by the lack of career opportunities (push) and better pay (33%) in non-science positions (pull). By contrast, the main reason why men left science was overwhelming (68%) due to the better pay offered outside science (pull) closely followed (64%) by the lack of career opportunities (push). Nevertheless, the leaky pipeline metaphor has proved useful in highlighting the problem provided that it is not the exclusive driver of solutions.

In most developed countries today, a career in engineering is equally accessible in principle at least to both men and women provided a reasonable level of mathematics has been reached in high school. This was not always the case. For example, in Ireland between the 1930s and 1968, special

mathematics examinations were provided – "Arithmetic—girls only" and later "Elementary mathematics (for girls only)". The rationale was presumably based on the assumption that girls were either less mathematically capable than boys or that the subject was less relevant to their subsequent careers (O'Connor 2007). It is worth noting that at that time the majority of students attended single sex schools, thus helping to reinforce the gender stereotyping of subjects.

In Ireland the proportion of girls sitting the higher-level mathematics examination required for entry to engineering programmes remained very low up until the 1960s (e.g. 1% of girls in 1952 compared to 26% of boys). For most female pupils at that time, higher-level mathematics was simply not an option that they were offered (O'Connor 2007). The gender imbalance in the proportions taking higher-level mathematics has persisted over time. In 1991 boys were still twice as likely as girls to sit the higher-level paper (16.1% versus 8.2%). However, the gap has narrowed significantly in recent years where in 2008, 22% of boys and 15% of girls took higher level mathematics (Department of Education and Science 2008). This historical gender segregation of the subject has reduced access to engineering by girls and reinforced the stereotype that mathematics and engineering are for boys. Drew & Roughneen (2004) noted that mothers can have a negative influence on girls' decisions to study engineering, which may in part exist because of the social stereotypes and expectations relating to girls being passed from generation to generation. While the Irish educational system may be unusual compared to those of other countries in that there remains a significant number of single sex schools, the overall figures for those entering engineering programmes at third level are comparable. Girls are consistently over-represented in the highly competitive programmes such as medicine and law and under-represented in less competitive programmes such as engineering and the physical sciences. Girls with good performance in mathematics are proportionately less likely than boys with the same performance level to enter mathematically oriented programmes (Department of Education and Science 2008).

Current Position of Women in Engineering in Academia

The leaky pipeline referred to above is a feature of the career path of women in many domains, not just engineering in academia. Figure 1 - the so-called 'scissors diagram' - illustrates the way in which the gender gap changes throughout the stages of an academic career, beginning with undergraduate level (ISCED 5A) through to senior grades. The slope of the graph may vary from country to country and from discipline to discipline, but the overall shape is the same. Engineering disciplines are slightly different in that there are never more female than male undergraduate students and therefore the two lines never intersect.

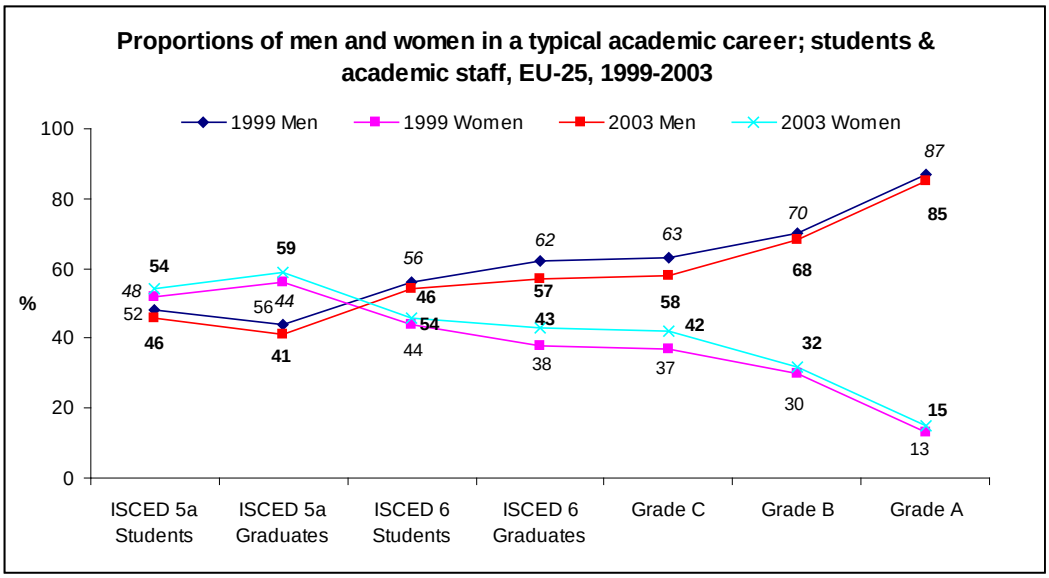

Figure 1 Scissors Diagram: Percentage of men and women in a typical academic career in science and engineering, students and academic staff, EU-25, 1999-2003
(European Commission 2006: 55)

Figure 2 illustrates the Europe-wide percentage representation of women and men in science and engineering in 1999 and 2003 from undergraduate students (ISCED 5A) though to grade A - full professorship or equivalent.

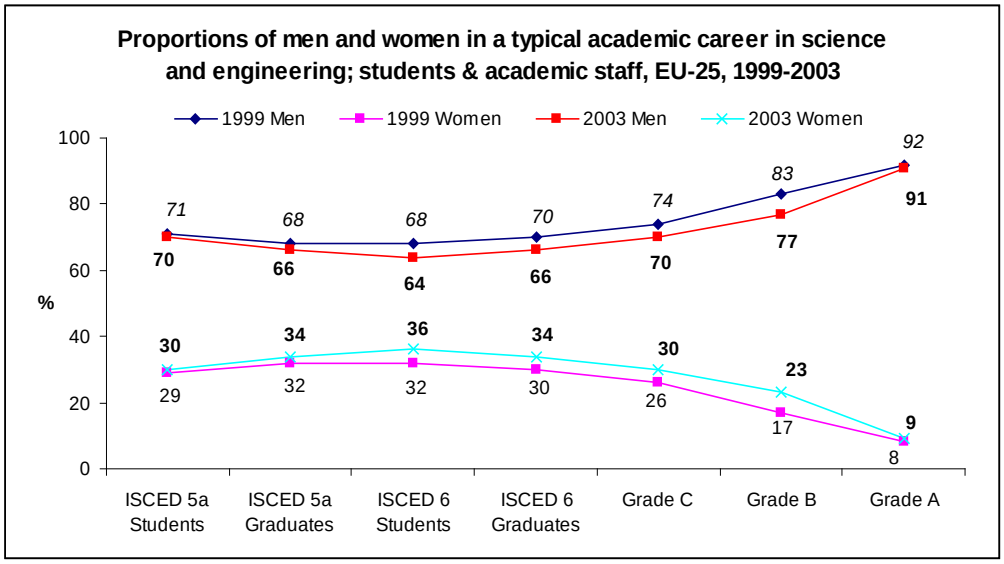

Figure 2 Percentage of men and women in a typical academic career in science and engineering, students and academic staff, EU-25, 1999-2003
(European Commission 2006: 56)

The vertical dimensions of patterns of employment – relative distribution of women and men at different levels of seniority within the engineering hierarchy – are vital as it is at these senior levels that decisions are made and leadership is defined and carried forward into the research agenda. Those in senior positions also act as role models for future leaders. In the EU in higher education, only 15% of those at the highest academic grade (grade A, equivalent to professor) are women yet the gender imbalance at this senior grade is even greater in engineering and science where the proportion of women is just 9% (European Commission 2006).

History of research informing policy: Key studies

The under-representation of women in science and engineering has been extensively studied in the research literature and the realisation has grown that the waste of talent involved in this "leaky pipeline" has to be addressed and not simply for reasons of equity and social justice. Rather the matter is being increasingly viewed as an economic imperative. This economic imperative to increase the participation and retention of women in Science, Engineering and Technology (SET) is not only about increasing the pool of available labour, although this is clearly important in the context of the skills shortage in engineering, it is also a question of increased diversity fuelling creativity and innovation. It is not simply a matter of attracting more women

into careers in SET. It is also a matter of retention and advancement. Furthermore, enriching the research agenda of an institution through greater diversity is of critical strategic importance. Women often ask different questions in research, use alternative approaches, and may take a more interdisciplinary approach (Mitchell 1999). The European Technology Assessment Network - ETAN - Report (2000) highlighted the fact that the principal determinant of academic success, namely peer review, can disadvantage women in subtle ways. A key paper published by Wennerås & Wold (1997) demonstrated that women had to be 2.2 more productive than their male counterparts in order to be successful in the competition for research fellowships offered by the Medical Research Council in Sweden. These findings attracted considerable attention across the world and triggered a series of similar studies including the UK's Research Councils and Wellcome Trust study on gender equality in UK grant applications (Blake & La Valle 2000), Denmark (Vestergaard et al 1998), and Finland (Peltonen 1999).

While not all these studies were conclusive, they did bring about a number of changes in the review process. However, there still appear to be some subtle effects at work which are difficult to explain and therefore difficult to address. A recent study by the European Molecular Biology Organization (Ledin et al. 2007) tested whether unconscious gender bias influences the decisions made by the selection committee for fellowships, where women had lower than average success rates. The application process was gender blind, including external sources such as letters of recommendations. A review of citations noted that women had a lower average number of publications, lower impact factors and lower citation counts (for first and last author publications). Further results showed that when investigating the cohort of researchers, they found that women, on average, have less time available at work and have a greater burden to carry outside the laboratory; they tended to receive less professional support than men; and felt, more so than their male counterparts, discriminated against because of their gender.

Another important study conducted at the Massachussetts Institute of Technology (MIT) by the Committee on Women Faculty in the School of Science (1999) showed that women faculty appeared to be marginally discriminated against in many different often minor ways which on their own could not explain why so few women made it to the top as full professors but which together had a significantly detrimental effect on their careers. As a result of this report, several policies were put in place and the number of women appointed increased significantly. However, there is evidence of a plateauing in recent years suggesting that the interventions have not yet been fully absorbed into the culture of the organisation (Figure 3). Hopkins (2006) deduced that the first sharp rise in the number of women faculty in Science beginning in 1972, was the result of pressures associated

with the Civil Rights Act and affirmative action regulations in the United States. The second sharp rise, between 1997-2000, directly resulted from MIT's response to the 1996 Report on Women Faculty. However, the progress was not sustained and a number of women faculty in SET have left after failing to get tenure.

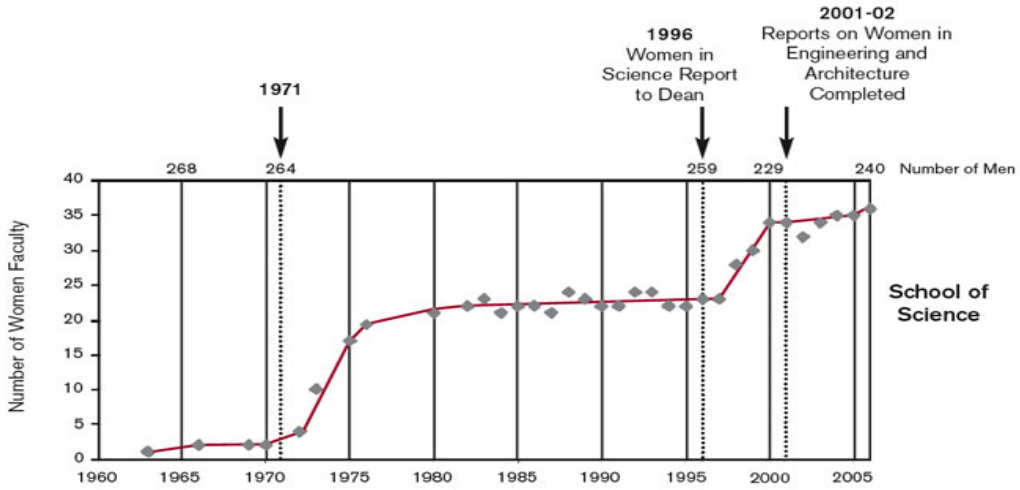

Figure 3 Number of Women faculty in the School of Science (1963-2006) at the Massachusetts Institute of Technology (Hopkins 2006)

At European level, two influential groups were supported by the European Commission to undertake studies on women's under-representation in science, including engineering, namely the Helsinki Group on Women in Science and the ETAN Expert Working Group (European Commission 2000). The Helsinki group reviewed policies established in 30 countries (Rees 2002). While the report acknowledges that there is considerable diversity in terms of infrastructure surrounding women in science among the countries examined, it concludes that a gender imbalance in decision-making about science policy is a common factor. It calls for the integration of gender mainstreaming into policy and decision making in all areas.

The ETAN Expert Working Group on Women in Science identified numerous barriers which contribute to the relative absence of women from academic careers in science, particularly at higher levels. The report highlighted the need for close gender monitoring and readily available statistics, as well as the provision of grants and networks specifically for women researchers. The report concludes that *"the under-representation of women threatens the goals of science in achieving excellence, as well as being wasteful and unjust"* (European Commission 2000).

From these reports, key initiatives have been born at a European level. A subgroup of statistical correspondents was formed within the Helsinki Group with the aim of gathering extensive and internationally comparable statistics on women in SET across Europe. The results of this group are the production of statistical reports: She Figures 2003 and 2006 (European Commission 2003, European Commission 2006). Interestingly the 2003 Report suggests that countries such as Portugal, Ireland, Greece and Finland which have a higher (>40%) than the average (33%)of female public researchers are countries in which "*scientific professions are less developed and where the institutions are relatively new… In other words, countries where traditions run less deep"* (European Commission 2003).

Intervention Programmes

Over the past two to three decades there have been many initiatives addressing the under-representation of women in science and engineering – some operating at departmental level, others at institutional level and a growing number at national level. Very few have been subjected to rigorous evaluation which makes the identification of best practice at best difficult and at worst impossible. Many of the initiatives are neither sustainable nor scaleable. In order to try to understand the history of these programmes and their targets, Rees (1995) developed a useful taxonomy through which to analyse these programmes for equal opportunities under the headings of 'tinkering, tailoring and transforming'.

The 'tinkering' (legislative approach) argues that everyone should be treated the same and aims to remove any direct form of gender discrimination which leads to the unequal treatment of men and women. The 'tinkering' approach is enshrined in law while the 'tailoring' (or positive action) equal opportunity approach recognises that the differences between men and women which exist are due to a complex range of social, historical and economic reasons and have led to unequal choices of and access to careers. The tailoring approach seeks to address these differences by ensuring a 'level playing field' in the competition for jobs, promotions and career advancement. Underpinning the 'transforming' (gender mainstreaming) approach is the idea that existing structures and institutions are not gender-neutral but favour one sex over another, usually men, in a variety of subtle and often invisible ways such as those identified in the MIT study (Committee on Women Faculty in the School of Science 1999). The 'transforming' approach also recognises that differences exist between the sexes yet embraces these differences as bringing added value to the engineering environment and also recognises the vital contribution that women, as women, can make to engineering.

In short, while equal treatment is about addressing individuals' rights to equality, and positive action addresses group disadvantage, mainstreaming focuses on systems and structures themselves — those much institutionalised practices that cause both individual and group disadvantage in the first place (Rees 2000). The next sections of this paper will examine the history of the development of programmes to support diversity by examining equal opportunity measures that have been identified to tackle gender imbalance in the workplace according to the "tinkering, tailoring, transforming" taxonomy.

Tinkering: a legislative approach

The strategy of equal opportunities is pursuing "equal rights and equal treatment". The aim is to establish formal equality between the sexes with a focus on legislation, rules and procedures in order to ensure that men and women are treated equally and includes mechanisms to ban all forms of discrimination. This approach is enshrined in legal terms and is designed to emancipate all subordinate groups in society, providing them with grounds to appeal in cases of direct discrimination. The key actors for the tinkering strategy are legislative authorities and all persons responsible for establishing official rules and procedures (Stevens & Van Lamoen 2001).

Anti-discrimination legislation in the context of gender was introduced in many countries including Canada (Canadian Human Rights Act 1977); Germany (General Equal Treatment 2006); United Kingdom (Equal Pay Act 1970, Sex Discrimination Act 1975); United States (Civil Rights Act 1964, Pregnancy Discrimination Act 1978); and Ireland (Employment Equality Act 1998 & 2004, Equal Status Act 2000 & 2004). In the European Union, the Equal Treatment Directive (1976) established the principle of equal treatment for men and women with regard to access to employment, vocational training and promotion, and working conditions. This was followed by the Council Directive in 2006 (2006/54/EC) which adopted the "implementation of the principle of equal opportunities and equal treatment of men and women in matters of employment and occupation".

All good employment policies benefit women in engineering. The 'tinkering' approach provides open advertising for all jobs (such as including the statement that the company is 'an equal opportunities employer' in advertisements), fair and effective recruitment and promotion procedures, and good work/life balance policies to ensure that women are treated equally (Rees 2000). Ensuring the operation of the highest standards in appointments, promotion and in peer review procedures is an essential element of equal treatment. The development and use of the concept of 'academic' rather than chronological age has been helpful in this regard. Thus, for example, the clock stops ticking during periods of maternity leave.

The tinkering, or legislative, approach seeks to ensure equal rights and equal treatment for both sexes but does not guarantee that there is actual equality between the sexes as it does not take into account any real differences that exist due to historical, social and cultural behaviours. Some countries have recognised this and enacted further legislation in order to recognise the differences. Equal treatment legislation in some countries has been reformed to broaden the concept of discrimination and the sphere of application – such as public services and facilities, education and the workplace (Daly 2005). For example, the Gender Equality Duty introduced in the UK in 2007 requires public authorities, including education providers and all other statutory services, to promote gender equality and eliminate sex discrimination. They are required to consult their service users and have a gender action plan. Previous legislation in the UK relied on individuals to complain about discrimination. The new law imposes a duty on all public sector managers to make their sector more efficient, effective and responsive to the realities of how we live our lives.

However, the crucial flaw in 'tinkering' (equal treatment) is that it takes the male as the norm. Women are legally entitled, in effect, to be treated not as equal to, but as the same as a man. There is a need for a more sophisticated understanding of the issues in the 'sameness' and difference' debate, whereby the principle of the legal right to equal treatment is upheld, but that differences are accommodated (Liff & Wacjman 1996). Sometimes treating men and women equally does not necessarily mean treating them the same. Hence, the law on equal treatment is a vital principle and an effective tool in combating overt discrimination, but it is not a sufficient measure to ensure equality (Rees 2000). This realisation has led to the development of tailoring strategies.

Tailoring: a positive action approach

Tailoring strategies seek to address the persistent inequalities by establishing specific measures and actions for women. The main focus of this approach is to target women who are under-represented or those who occupy disadvantaged positions. Strategies include positive action (providing support for women to compensate for their unequal starting positions due to historical, cultural and social reasons) and positive discrimination where preferential treatment for women exists to ensure not only equality of access but also equality of outcomes.

Positive action measures are effective if they tackle blockages in the system and/or focus on the development of good practice that can then be mainstreamed (Rees 2000). In this context, there are examples in the EU member states of measures to assist women scientists who have had career breaks (Germany); the funding of chairs directed at women (Sweden); and fellowships designed to suit women (UK), in particular on their return from a

career break. Table 1 presents a summary of number of key positive action initiatives in a number of countries.

Table 1 Some recent key positive actions by selected countries to promote women in science (European Commission 2008b).

Country	**Key Actions**
Belgium	Creation of the Institute for the Equality of Women and Men in 2002.
Canada	Council for Research in the National Sciences and Engineering created a number of chairs for women in science and engineering from 1989
Denmark	Female Researchers in Joint Action programmes to finance specific research projects conducted by highly qualified women in 1998.
Estonia	Parental leave (and military service) is now taken into account in the evaluation of eligibility of applicants for Estonian Science Foundation grants since 2006 and targeted research funding grants since 2007.
Finland	Gender quota principle where all government committees, advisory boards and Research Councils, must by law comprise at least 40% women (currently 43%). Since 2002 research councils are required to make every effort to ensure that the under-represented gender occupies at least 40% of research positions.
Germany	There is a university ranking based on gender justice criteria. There are grants and awards that can be used in part to pay for childcare or to support part-time research (Christiane Nusselein Foundation).
Greece	Creation of the PERIKTIONI network of women scientists through EU funding. The Ministry of Education allocated €4.475m for research on gender related topics (37 projects).
Ireland	Science Foundation Ireland established the Women in Science and Engineering Programme (2005). This included research grants for women who had taken a career break (generally maternity leave); 3 University led projects (including the Centre for Women in Science and Engineering Research, Trinity College); and scholarships for girls studying engineering. A returners' scheme for women in science and engineering as recently been introduced by Women in Technology and Science (WITS).
Norway	The Norwegian Ministry for Education and Research founded the Committee for Mainstreaming – Women in Science in 2004. In the University of Oslo activities include: headhunting female candidates for a post; affirmative action where if 2 candidates are equally qualified, the less represented sex may be favoured; gender-budgeting to ensure fair and effective uses of resources, and economic incentives to departments. The Minister for Education and Research has committed funding for earmarking of posts for women in academia which will be included in the National Budget for 2009.
Slovenia	A Women in Science section has been established within the Ministry of Higher Education, Science and Technology. One year maternity leave (paid); 'freezing' the contracted period for young researchers when they take maternity or paternity leave; rules on academic promotion including the 'freezing' period.

Spain	Gender Equality Units must be created in universities; reports on the application of the principle of equality must be produced; boards for hiring and promotion must have a balanced representation of women and men, by law. Research fellowships allow one year maternity leave.
Sweden	The Minister for Integration and Gender Equality coordinates the government's gender equality policy as gender equality is seen as a policy area affecting all citizens.
Switzer-land	Program for Gender Equality at Swiss Universities supports positive actions such as mentoring, childcare and incentive system for newly hired female professors.
United Kingdom	Establishment of the UK Resource Centre for Women in Science, Engineering and Technology (UKRC) as part of the government's Strategy for Women in SET in 2003. Positive action activities include good practice guides, funding opportunities; dissemination of activities by networks and collection of statistics. The Athena Swan charter was signed by 34 universities under which they committed to advancing women in SET in academia. Positive actions include collection of statistics and data; mentoring programmes; personal and career development programmes; role model exposure; networking opportunities and return-to-work schemes. Since 2007, a Gender Equality Duty has been introduced in the UK shifting the focus of gender equality from the individual to the institution.
United States	The National Science Foundation funds the ADVANCE programme-Increasing the Advancement of Women in Academic Science and Engineering Careers. Since 2001, 41 universities and higher education institutions have been funded. Positive action activities also include collection of statistics and data; mentoring programmes; personal and career development programmes; role model exposure; networking opportunities; return-to-work schemes; and quotas,

Table 1 gives examples of a wide range of interventions, details of which can be found in a report by the European Commission (20008b). Typical of the type of positive actions at individual institutional level is WiSER at Trinity College Dublin and at national level the Tham professorship scheme in Sweden. WiSER is the Centre for Women in Science and Engineering Research, Trinity College Dublin (http://www.tcd.ie/wiser/) supported and financed by government, through Science Foundation Ireland. The centre supports women directly through a personal and professional career development programme; a mentoring scheme for junior female staff and researchers; a specific fund for women researchers who are trying to establish their research career; role model speakers; and networking opportunities. In Sweden, the proportion of women among new professors was 7% in 1985-92 and 12% in 1993-95. This led to the Tham Initiative by the Government (Margolis & Fisher 2002) which established a number of professorships (32) ear-marked for women. Also, the goals set for each university added up to a national goal of 19% of women among new professors for the period 1997-1999. In actuality, the proportion of women

among new professors for all universities together was 21% in this period as well as in the next period for which goals were set (2001-04). A number of factors may have influenced this outcome but the goals set by the government are generally seen as having played a major role (European Commission 2008a). However, after complaints in 2000, the European court ruled these professorships to be unlawful.

The criticism of the tailoring strategies is that they target women specifically and encourage women to make changes, improve themselves and address what could be considered 'their deficiencies' in order to fit the organisation. Women are expected to assimilate into the status quo of that organisation without addressing the working practices and culture of the organisation. These strategies work on the assumption that gender under-representation in engineering is a woman's issue rather than an issue that concerns the organisation as a whole i.e. they are concerned with "fixing" the women rather than fixing the system. Measures are put in place to facilitate the lack of opportunity women face due to gender differences. As they are directed specifically at women, they do not usually address the culture or masculine social construct of the engineering profession.

Transforming, a Gender Mainstreaming approach

The Group of Specialists of the Council of Europe defines gender mainstreaming as the *"(re)organisation, improvement, development and evaluation of policy processes, so that a gender equality perspective is incorporated in all policies, at all levels and at all stages, by the actors normally involved in policy-making"* (Council of Europe, 1998: 18). Gender mainstreaming recognises that differences exist between the sexes yet embraces these differences as bringing added value to the engineering environment, and recognises the vital contribution which women, as women, can make to engineering. Rather than seeking to 'fit women' into the systems and structures as they are, the transformative approach of gender mainstreaming pursues a restructuring of an organisation in such a way that the demands and expectations of women and men are heard and respected equally. All policies and practices are informed by the knowledge of the diverse needs and perspectives of their beneficiaries, both male and female. The main focus is the organisation as a whole with all its structures, values, customs, policies and practices.

The aim in 'transforming' is to develop systems and structures which not only value difference but which no longer underpin hierarchies and power relations based on gender (Rees 2005). Mainstreaming gender equality in universities and research institutes entails a wholesale programme of assessment of the gender impact of existing and new policies. Monitoring and evaluation mechanisms of new procedures need to be instigated.

Awareness raising and training for staff is a prerequisite. Building ownership through performance review and line management systems is a requirement. Targets are needed for moving towards a gender balance in decision-making throughout the organisation. These tools need to be animated by the 'visioning' of gender mainstreaming, the development of ways of seeing and doing things differently, challenging and changing the organisation and its culture. This needs expertise that can be brought in to assist organisations to change (Rees 2000).

Daly's (2005) findings of an eight-country (Sweden, Ireland, Belgium, United Kingdom, France, Greece, Spain, and Lithuania) review of gender mainstreaming approaches noted three varieties of gender mainstreaming. Sweden takes an 'integrated' approach where gender mainstreaming is employed in a global fashion and is embedded across institutions in society. Ireland and Belgium take a 'mainstreaming light' indicating little more than the involvement of different government departments in the implementation of a plan or programme around gender equality. In the remaining countries, gender mainstreaming is highly fragmented, confined to either a small number of policy domains or to a specific programme within a domain and disconnected from general governmental policy on gender.

A potentially useful framework for applying gender mainstreaming in the university setting was proposed by Stevens & Van Lamoen (2001). They developed a Manual on Gender Mainstreaming at Universities which provided four toolkits or sets of instruments:

1. measurement and monitoring;
2. gender proofing and evaluation;
3. implementation and organisation; and
4. building awareness and ownership.

Measurement and monitoring is the systematic collection and dissemination of data on the position and opportunities of women and men and is indispensable to the identification of those areas which need to be addressed most urgently and to check the impact of policies, measures and processes that have been implemented. Gender proofing tools are designed to trace the causes of existing gender biases (research studies, feminist theory) and provide guidelines for changing structures and procedures aiming at promoting gender diversity. Specific individuals must be assigned with responsibility and accountability for gender mainstreaming. The fourth toolkit requires academic leaders and managers and those who will have been assigned responsibility for gender mainstreaming to be trained in order to reach a degree of gender awareness and gender expertise. Monitoring statistics, can form the basis for setting equality targets.

From 2001 to 2004 the European Social Fund supported the EQUAL project 'Bridging the Gender Gap at Universities' in the Netherlands. The main objective of this project was to systematically introduce the principles of gender mainstreaming into Dutch universities. The idea was that by

introducing a new framework for policy-making, namely gender mainstreaming, not only would the number of women in higher scientific positions increase, but that it would become possible to change the (masculine) university culture and increase the diversity of academic leadership and the quality of the management and policy making as a whole. The project was based on Stevens & Van Lamoen's Manual and they followed the four toolkits. Their findings concluded that gender mainstreaming as a concept and as a practice turned out to be too difficult to grasp for most of the policy- and decision-makers. The project was successful in putting the issue of women's under representation on the agenda of the universities, but the result was a renewed call for positive action and measures that were visible and would lead to quick results (Van der Horst & Visser 2006).

Central to any gender mainstreaming policy is the ability to measure and monitor progress. Data must be gathered on a regular basis which reveals those factors that prevent men and women from accessing and advancing in all domains of academic life on an equal basis. Data on equality of participation can show whether resources are divided equally and whether decision making bodies are gender-balanced. Data on the equality of outcome can reveal the overall equality between different groups in the university e.g. do women stand equal chances to men when applying for research funds. Data on employment conditions can show the extent to which men and women are paid equally and have the same access to career breaks. An example of the importance of measuring data was the MIT study whose findings showed that men had access to larger working spaces and better resources than their female counterparts (Massachussetts Institute of Technology 1999). The She Figures 2003 and 2006 reports represent another example of good practice of measuring data (European Commission 2003, 2006).

Gender impact assessment is another measurement tool which is designed to check whether or not specific practices affect women and men differently, with a view to adapting them to make sure that potential biases are eliminated. Gender impact assessments can be applied to all kinds of practices and processes including selection and recruitment procedures, financial resources and to the organisation's culture.

There are a number of specific issues that departments in universities have to address surrounding 'openness and inclusivity' in order to transform the culture to the benefit of women – and men. These include, for example, how part-timers, those on maternity leave, career breaks and sabbatical are included in the ongoing life of the institution/department; identifying how departmental processes, procedures and practices impact on staff with caring responsibilities and part-time workers; ensuring senior staff are accessible to junior staff; and identifying social activities are inclusive. The Athena SWAN Charter for Women in Science (www.athenaswan.org.uk) is an

example of a national initiative which celebrates and rewards best practice for women working in SET in higher education and research. The Athena SWAN gold, silver and bronze awards are widely recognised and celebrated. Good initiatives include scheduling departmental meetings at times when staff with caring responsibilities can attend (Bristol Physiology and Pharmacology Department: Silver award); allowing part-time academics to supervise PhD students (Manchester University: bronze award); reducing workloads for maternity returners, giving them fewer projects, lower student allocations and lighter administration loads (Psychology School at Nottingham University: silver award) and introducing a range of part-time working strategies to support their staff, for example, extended lunch breaks to enable care of elderly relatives, variable hours to enable the staff to complete school pickup, and gradual changes in hours to facilitate the return to full-time working for new parents (Department of Mechanical, Materials and Manufacturing Engineering at Nottingham University: silver award).

Issues surrounding departmental roles and responsibilities can include whether committees are reviewed for gender balance, whether membership is reviewed and renewed, how to avoid 'committee overload' on the small numbers of women available in SET, and identifying how committee decisions are communicated widely to all staff and researchers. Examples of good practice include publishing gender balance of committees (Reading University: bronze award).

Other areas of change at departmental level include improving the visibility of women in engineering. Increasing both the visibility of women in engineering and the work women contribute to engineering challenges 'taken for granted beliefs' that men generally are engineers, not women. Areas to address include encouraging women at all levels to raise their profile externally and internally monitoring the gender balance of speakers at conferences, seminars and events (York Chemistry department: gold medal), and also identifying whether the proportion of women applying for academic positions at all levels is representative of the recruitment pool.

The development of specific structures concerning equal opportunities (centres of expertise, networks, and responsible actors) is an important factor in sustaining the actions and measures of gender mainstreaming. It is also important to create commitment from stakeholders through activating all participatory bodies (e.g. university councils, boards) by placing gender mainstreaming on their agenda. An example which incorporates all steps to the gender mainstreaming process in education is the ADVANCE funded (NSF 2008) STRIDE (Strategies and Tactics for Recruiting to Improve Diversity and Excellence) Committee in the University of Michigan (STRIDE 2008). The STRIDE Committee provides information and advice about practices that will maximize the likelihood that diverse, well-qualified candidates for faculty positions will be identified, and, if selected for offers, recruited, retained, and promoted. The STRIDE programme appears to have

had a positive impact on the recruitment of women. In 2001 only 13% of science and engineering hires were women (6 female and 41 male hires) compared with 29% in 2005, 15 female and 37 male hires (Stewart et al 2007).

While gender mainstreaming has been developed by the EU to assess policies, practices and procedures to be implemented at a national and organisational level, an alternate view focuses directly on transforming the organisational culture. Organisational culture can be defined as '*a pattern of shared basic assumptions that the group has learned as it solved problems.....that has worked well enough to be considered valid and, therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to those problems'* (Schein 1992: 97). Under this model, the onus of change is not on an individual but on the change of culture and environment in which the individual works. There are three layers of culture that need to be addressed when 'transforming academic culture'. These are:

- Artefacts: visible structure and practices, such as policies and procedures, which can be monitored and changed if necessary;
- Espoused values: what people say they believe – these are not generally a problem; for example, most people believe that appointments and promotions should be fair and based on merit; and
- Underlying assumptions: unconscious, taken-for-granted beliefs, thoughts, and feelings, ultimate source of values and actions.

Transforming the academic culture alters the culture of the institution by changing select underlying assumptions and institutional behaviours, processes and products. In order for the culture of academic engineering to be altered, all three layers need to be addressed. Generally, universities are working at the artefact level while the remaining two levels are not consistently addressed (Trower 2004). Aspects of the transforming academic culture relevant to advancing women in engineering can include institutional and department openness and inclusivity, institutional and departmental roles and responsibilities, visibility of women in engineering, valuing staff contribution, workload allocation and induction and training.

Conclusions

There have been many programmes, initiatives, advocacy groups funded from different sources including government and philanthropic sources to recruit, retain women in engineering, and offer support services to those who wish to return to engineering after a career break or maternity leave. The findings show that while these initiatives have targeted many different career stages, and have had very clear and hopeful objectives, the statistics over the past 30 years have not shown significant increases in the number of women in engineering.

The current policy of the EU is that it is pursuing positive action and gender mainstreaming as a twin-track approach to gender equality. Given that gender mainstreaming is a paradigmatic shift in approach that takes considerable time to embed, it is essential that equal treatment (tinkering) and positive action (tailoring) measures continue to be developed alongside it. The equal opportunities approaches are not separable in practice but are intertwined with and build on one another (Daly 2005). The strategies involve removing obvious and invisible barriers by incorporating a gender perspective in all policies transforming the organisation to increase room for different lifestyles, perspectives and competences, making it less homogenous. Those involved in transforming strategies include policy makers, supported by specialised units, centres or officers with specific expertise in gender mainstreaming (Stevens & Van Lamoen 2001).

As with the leaky pipeline metaphor, the classification of "tinkering, tailoring and transforming" has been subject to some criticism. All along the transformational approach, tinkering and tailoring strategies need to be continued. The chronological aspect of the approaches does not necessarily imply that one follows another or that one should replace the other. The strategies focus on different aspects of equal opportunities which are important in themselves. Booth & Bennett (2002) interpret the trilogy of models of 'equal treatment perspective', the 'women's perspective', and the "gender perspective" are complementary rather than mutually exclusive, challenging the compartmentalising of different types of equality strategies. This suggests that they are better conceptualised as components of a 'three-legged stool' in that they are interconnected and each needs the other.

While a lot of money, time, resources and goodwill have been injected into addressing the imbalance of women in engineering, there are still critical reasons for the lack of overall success in the majority of countries. Most of the initiatives have targeted the more attainable and visible tasks such as networking, mentoring, and career development for women. Often, these areas are targeted because funding is limited and justification and evidence has to be given for continued funding.

Diversity is seen as a fringe activity. It is viewed as something to be added on to the day-to-day activities and decision making. When compared to other demands of a university, institution or company, diversity and gender generally do not reach the priority list. Other actions will always take precedence and the issue remains on the fringes. However, the leaky pipeline is a feature not simply of academia and the research system but also of the corporate world. There are signs that the corporate world is beginning to see the under-representation of women, especially in senior positions, as an issue which affects the "bottom line". Research from a number of countries has shown strong correlation between shareholder returns and the proportion of women in the higher executive echelons. Of course this does not establish a causal relationship but it does suggest that a corporate culture

which fosters women's careers can also foster profitability (Women in Business 2005). It is not clear that academia has made this transition and continues to view the under-representation of women as largely an issue of social justice and equality. In spite of years of equal opportunities in academia there is still evidence than women and men are not treated equally resulting in very few women making it to the top. The days of active, overt discrimination are gone, but as both the MIT and a similar more recent study at Harvard University (Task Force on Women in Science and Engineering 2005) reports have shown, there is often a series of minor issues which together add up to make it more difficult from women to climb the ladder of academe.

Likewise, while gender mainstreaming potentially has the capacity to transform policy making processes, positive action implemented by grass roots community organisations, can ensure a connectedness with the people and the issues that policies are seeking to address. Gender mainstreaming, as an institutionalised approach to equality can change systems, but positive action can ensure that the aspirations and needs of women on the ground are fully taken into account.

Unless gender and diversity in institutions is adopted through legislation this action will remain on the fringes. Without legislation, it is left to individual people, be it the head of a university, school, or department to understand the importance and benefit of diversity and to take action to improve the situation. This puts an onus on the individual rather than the organisation. Some of those who are in positions of authority have considered positive action as 'social re-engineering' and rebel against any actions put forward. Unless positive measures are understood, actions will simply be seen as 'paper ticking' or just 'that the university is seen to be doing the right and expected thing'.

What then is the answer to the problem of the under-representation of women in engineering? This chapter has attempted to show that the problem is a complex historical, cultural and organisational one for which there is no single solution – no silver bullet. Virtually all the interventions and initiatives presented here have had a positive impact at local level. The challenge is to develop programmes which are sustainable and scalable across all universities and beyond. There is insufficient evidence to point to a single set of solutions which if not guaranteeing total success can at least be reasonably expected to improve the situation for women. However, such evidence that there is points to a number of areas of best practice.

Firstly, there is a fundamental requirement for strong legislation, such as the UK Gender Duty, which is much more than just aspirational. The Gender Duty legislation of the UK places a legal obligation on institutions to address gender imbalance. Institutions including universities must therefore respond. If a public authority does not comply with the general duty, its actions or failure to act can also be challenged through an application to the High

Court/Court of Session for judicial review i.e. legal action from government (Equal Opportunities Commission 2007)

Secondly, in order to be able to respond, universities need professional gender expertise and support which goes beyond the token Equality Officer whose remit tends to be very broad and whose role if often very peripheral to the mainstream of academia.

Thirdly, there must be a senior individual who is responsible and accountable for the implementation of gender mainstreaming within the institution. This individual must be fully empowered to make decisions and take action. They must carry sufficient "academic weight" to command the respect of peers and to overcome the traditional resistance to change.

Fourthly, national initiatives such as Athena SWAN (www.athenaswan.org) and ADVANCE (NSF 2008) are vital to support and drive change and which focus on addressing the practical issues at departmental, faculty and institutional level. By taking a holistic or in engineering parlance a system view, they can tackle the problem in a systematic and comprehensive way.

Finally, it is vital to monitor progress. Therefore initiatives which ensure the collection of complete and accurate statistics, both quantitative and qualitative, are essential. Critically, these can then provide the foundation on which to set realistic targets for the recruitment and retention of women in engineering at all levels. Academic units and institutions which fail to meet these targets should be required to provide a detailed explanation including what direct actions they took to try to meet the targets. It is no longer acceptable to simply shrug one's shoulders and say "no women applied".

Ultimately perhaps it is only when the international rankings of universities include, as one of their criteria, the percentage of women at senior level within the institution is there likely to be a major and radical shift in attitude which will bring the problem centre stage.

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