



Gender equality and representation
within and beyond the University
of the Highlands and Islands

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Attracting women into engineering – a personal reflection

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Abstract

It is well known that engineering fails to attract sufficient women: in the United Kingdom (UK) 2018-19 academic year, only 21% of all higher education (HE) engineering and technology entrants, and only 12% of the engineering workforce, were women, which reduces to 9% for occupations exclusively within the engineering sector (Engineering UK 2020).

This chapter reviews the literature which supports my observation, over more than 3 decades as a female engineer, that predominantly male workforces value masculine traits: assertiveness, objective rationality, technical capability and direct problem solving. These same

traits are, indeed, the gateway to higher engineering education and the cornerstones of success in engineering degrees. This chapter discusses, from both personal and established viewpoints, why women are still not attracted to engineering careers, despite considerable global efforts to remove the patriarchy. It highlights, by examining published case studies, how failing to attract women into engineering careers is detrimental to the whole profession. Negative effects include insufficient engineering graduates available, abysmally poor retainment of female engineers, products badly designed without female input, and ignorance of the benefits feminine attributes bring to engineering teams.

Critiquing, through research, potential solutions to this worldwide problem, this chapter goes on to recommend realistic and implementable changes which can be made to the University of the Highlands and Islands' HE curriculum to improve gender diversity in engineering, thus supporting the post-COVID-19 engineering environment, where drastic

change is imminent. Industry 4.0¹, the fourth industrial revolution, heralds the start of a Smart Factory era when many traditional engineering jobs will be taken by robots – no longer will engineers ‘fix engines’. Going forward into this automated era, creative multi-tasking and empathetic collaboration are likely to become the dominant skills required for the engineer of the future, and these skills are particularly prevalent in women.

Keywords: Engineering, women in engineering, skills shortages, STEM gender gap, gender equality, higher education, further education

Introduction

Engineering was not an obvious career choice for a girl educated at a single-sex school but during the lean

¹ The Fourth Industrial revolution, also referred to as Industry 4.0, is a technological revolution which is impacting how we live and work, as did the First, Second and Third. It is a digital revolution predominantly driven by the advent and rapid expansion of Artificial Intelligence, Robotics, and the Internet of Things (Schwab 2015).

'Thatcher' years of the early 1980's, it did guarantee employment opportunities, with the newly launched space shuttle, the introduction of desktop computing, and a prediction of engineering jobs increasing by 38% (Marcus 1983: 20). So, I chose to study Electronic Engineering at Dundee University. From day one I was in a gender minority, with less than 5% of my class being women (Baker 2005), however that did not hinder us from all achieving Honours awards in 1985. Within a month of graduating, I was working in a small radar research establishment, Racal, in Linlithgow, Scotland. Here I designed circuits for multi-million-pound, cutting-edge defence equipment. I remained in this fulfilling career for eighteen years, learning and practicing the engineering skills which eventually led to my becoming a Chartered Engineer and leading teams of my own. When the company was acquired by Thales, and our site closed in 2003, I moved to Denchi Power in Thurso, Scotland. This was a similar company making military batteries and chargers. For most of these industry years, I was the sole female engineer on the project team and always reported to a male boss. In 2006, I felt old enough

and wise enough to disseminate my knowledge and experience, so I took the difficult decision to leave, at the pinnacle of a rewarding career, for a Further Education (FE) contract with North Highland College in Thurso, Scotland. Here I progressed from Lecturer to Programme Leader and eventually Curriculum Leader. In 2019, I moved to the University of the Highlands and Islands (UHI) to become an Academic Lead Developer, whilst still lecturing part time at North Highland College UHI. I was, for many years, the only female Lecturer in my department, teaching almost exclusively male classes and managing an all-male team. Most of the College workforce are, however, women. This was a novel experience for me and one where I began to realise that I had feminine qualities which could enhance my impact as a designer, teacher and leader, and could help encourage more women to study engineering. With the advent of the fourth industrial revolution, Industry 4.0, and the rapidly changing engineering roles this entails, I believe that attracting women to train for this evolving, multi-disciplinary, multi-tasking work-force, is imperative and urgent.

Background

Throughout my working life I have never experienced any explicit gender discrimination – I guess I am one of the lucky ones. I did, however, often feel I had to behave like “one of the lads”. One particular example I remember well, was having to eat disgusting Tabasco© sandwiches whilst field-trialling a radar, because this was the only food the ‘guys’ ate. I also remember having to lift heavy and awkward equipment, clearly designed exclusively for male physiques. I surmised this was because of, mostly unconscious, male bias in the working environment. It is well known that engineering fails to attract sufficient women: in the 2018-19 academic year, only 21% of all engineering and technology entrants were women (Engineering UK 2020: 5) and only 12% of the UK’s engineering workforce are female (Engineering UK 2018: 13), which reduces to 9% for occupations exclusively within the engineering sector. This suggests an abysmal retention rate. Coincidentally, 21% is the proportion of female higher education academics in this sector (HESA 2017), so, in

common with most female engineers, I still feel rather an outsider and a pioneer. The problem is self-propagating: the existing patriarchy discourages women from entering the profession, resulting in insufficient prominent female engineers to challenge the situation and too few role models to motivate aspiring girls.

My experience suggests that predominantly male workforces value masculine traits: assertiveness, objective rationality, technical capability and direct problem solving. McBride-Wright's (2019: 6) survey found that over 26% of respondents agreed that engineering was a masculine culture, and over 75% felt society expected men to show aggressively masculine characteristics. Indeed, these same traits are the gateway to higher engineering education and the cornerstones of success in engineering degrees. Stentiford (2019: 218) cites cases of extreme "laddism" in engineering classes, which is obviously disruptive and off-putting for otherwise enthusiastic female students, but she also notes that less overt "laddishness" is

prevalent; this is just accepted, by the girls, as something to be tolerated – mirroring my own observations.

However, there is some indication that a change is imminent: Industry 4.0 heralds the start of a Smart Factory era when many traditional engineering jobs will be taken by robots (Osterreider et al. 2020) – no longer will engineers ‘fix engines’. Cevik Onar et al. (2018: 138) intone that Universities need to adapt their engineering education to instil the skills required for new cross-functional roles, including soft skills such as “capability development, interdisciplinary collaboration, and innovation”. Skills Development Scotland (SDS 2018: 8) further define these new skills as “self-management, social intelligence and innovation”. Considering Table 1, there appears to be considerable synergy between Industry 4.0 skills and feminine attributes. Of course, this does not imply that masculine qualities will become redundant, but perhaps the focus will shift towards a better balance.

Gender equality and representation within and beyond
the University of the Highlands and Islands

Masculine Attributes	Feminine Attributes
Rational	Multi-tasking
Practical	Empathetic
Analytical	Expressive
Logical	Creative
Dependable	Supportive
Dominant	Sensitive
Decisive	Tolerant

Table 6.1: Comparison of Masculine and Feminine Attributes (Smith et al. 2018)

I have long believed that women’s contributions to engineering are unique and invaluable, not least because they constitute half a population which could help alleviate the 2020 to 2025 predicted annual shortage of 59,000 engineering graduates in the UK (IET 2019: 2). Strachan et al. (2018: 2088) note that “organisations with a more diverse workforce are more creative and innovative, and ultimately perform better and are more successful”. In Criado Perez’ (2020) book, ‘Invisible Women’, the male bias in design, even although usually unintentional, is shown not only to disadvantage women, but to endanger them. Examples include:

- Ill-fitting, infection preventing Personal Protective Equipment (PPE) resulting in female medical staff having to wear Filtering Facepiece Particle (FFP) masks designed exclusively for males. With 77% of the UK's National Health Service's workforce being women, this presents an unacceptable and unnecessary COVID risk (Fidler 2020),
- Stab vests which cause breast injuries and provide inadequate protection (TUC 2017),
- Car seat belts which are 47% more likely to cause female drivers to sustain serious injury, than male drivers in comparable crashes (Bose et al. 2011),
- Artificial hearts which are too large for many women, so prevent life-saving operations (Syncardia 2020).

Gender equality and representation within and beyond
the University of the Highlands and Islands



Figure 6.1: Image of a woman putting on a seatbelt
(Image by cfarnsworth; [Pixabay](#) / [Pixabay license](#))



Figure 6.2: Image of heavily armed soldiers
(Image by parameciorecords; [Pixabay](#) / [Pixabay license](#))

These products, and many more, would have benefitted from a women's perspectives and input. There is no reason why the designs of women would not be as good as, and from a gender neutrality viewpoint possibly better than, the designs of men. Women achieve better grades in Science, Technology, Engineering and Mathematics (STEM) subjects, both in high school and at University undergraduate level (WES 2020). Indeed, many female engineers are accredited with design excellence. Examples include (Katwala 2017):

- Stephanie Kwolek's Kevlar[®] super-strength material;
- Tabitha Babbit's circular saw;
- Mary Anderson's windscreen wipers;
- Hedy Lamarr's frequency hopping remote control technique;

There is also evidence that women are equally capable engineering leaders, with some recent, significant engineering influencers being:

- Meredith Westafer, Senior Industrial Engineer and manager of Tesla's Gigafactory;
- Yael Garten, Director of Apple's Siri Data Science and Engineering department;
- Sophia Velastegui, General Manager of Microsoft's Artificial Intelligence Product Unit.

However, gender bias is prevalent because of male domination of the engineering industry, initiated by the historical attitude that women are too weak for this work, and the post-war belief that women should stay at home (Emes 2017). Surprisingly, these attitudes persist today; less so in established economies like the UK, but still evident in men with strong religious beliefs, who are almost twice as likely to support the traditional gender role viewpoint (Emes 2017). This further undermines the determination and confidence girls need to choose engineering careers.

Possible solutions

The key question is, what can be done to solve the problem of under representation of women in FE and HE engineering education and in the engineering workforce? There are numerous high-profile initiatives focussing on this, for example:

- The Women's Engineering Society (WES 2020) host conferences and webinars, award prizes, publish a journal, and have the 'Lottie Tour' and 'She's an Engineer' projects. They also host an International Women in Engineering Day, INWED.
- The Institute of Electrical and Electronics Engineers (IEEE) have a Women In Engineering Society (WIE 2020), which offers a supportive network and hosts global conferences. I was lucky enough to obtain a volunteer position at their 2017 International Leadership Conference

where I met many inspiring and influential female engineers.

- UHI have STEM Femmes (2020a) – paid opportunities for students to help break down barriers faced by women in STEM subjects. They also offer an award to female students who exhibit engineering excellence.
- Equate Scotland (2020) provide training and opportunities for women studying or working in STEM fields. They proactively push to change attitudes and policy in education and industry.
- The Young Scot STEM campaign (2020) which is helping the Scottish Government improve gender imbalances on College and University STEM courses.

These are having some effect: the number of female students on UHI's Electrical and Electronic degree has grown from 5% in 2010 to 20% in 2018 and, since 2010 there has been a UK wide 5% increase in the number of women studying engineering. Progress, however, is slow,

so consequently I have researched other ways to expedite change.

Research

Firstly, as a member of the IEEE Collabratec Women In Leadership Community (2020), I have compiled a list of ideas posted in answer to the question “What is your idea to accelerate entrance of women into STEM fields?”. Respondents included students and highly experienced members, with suggestions such as:

- Set up STEM centres, with safe and welcoming environments, to specifically focus on women,
- Make science less complicated and expose girls to STEM from an early age,
- Remove societal pressures and stereotypical bias, by supporting mothers better and sharing caring responsibilities,
- Publicise inclusive engineering opportunities and share promotional cross-school and University webinars,

- Provide a career space for women with confidence building motivational classes,
- Promote women into top positions, and engage actresses, businesswomen and other famous women to be role models,
- Demonstrate real, successful products which have had women's participation.

Secondly, I carried out some Focused Perspective Taking^{TM2} using secondary literature sources. The results are shown in Table 2.

Perspective	Result
Pessimistic	Engineering UK (2018: 13) believes there to be bias in schools, because, despite over 600 UK organisations running Science, Engineering, Technology and Mathematics (STEM) initiatives directed at schools, only 27.1% of girls, compared to 45.6% of boys, studied STEM subjects at A level in 2017.

² Focused Perspective TakingTM is the Institute of Leadership and Management's (ILM's) preferred method of solving problems creatively, by examining different perspectives which lead to solutions to problems, challenges and issues which mix skill in execution, sensitivity, creativity and contingency planning (ILM 2021).

Gender equality and representation within and beyond
the University of the Highlands and Islands

Perspective	Result
	<p>It is not believed that pay disparity (Universities UK 2018) is a factor in discouraging women from engineering careers, neither is poor school attainment in STEM subjects, where women are consistently outperforming males.</p> <p>Engineering UK (2018: 13) note that only 12% of the UK engineering workforce are female, and MAC (2019: 112) cites this as one of the four reasons why only 29% of engineering graduates are working in the engineering profession.</p>
Optimistic	<p>Romano (2020) suggests that female role models and advocates, with female peer collaboration and practical applications to solve world problems, can entice girls to study STEM.</p> <p>According to Study International (2019), an increasing number of schools are incorporating Science, Technology, Engineering, Art and Mathematics (STEAM), to better engage students and to improve creativity, problem solving, and other transferrable skills.</p> <p>In 2017, the University of Zurich found that the reward centre in female brains reacts more strongly to pro-social decisions than in male brains. Yet although biology and chemistry are perceived as social-minded careers, engineering is not.</p>

Gender equality and representation within and beyond
the University of the Highlands and Islands

Perspective	Result
Creative	<p>The UK wide balance of women to men in Creative Arts has been 64% to 36% since 2016/17 (HESA 2020). UHI’s Care and Creative Arts subject network, has female bias, with 81% women in 2019/20, and some arts programmes having no male students at all (UHI 2020b). Combining courses could alleviate the problem. For example, in Italy, the Arduino Uno processor was designed so art students could animate their sculptures (Arduino 2020). They thus learned both art and coding.</p>
	<p>There is a STEAM synergy within the Scottish Government et al. Inverness and Highland City-Region deal for a “creative industries knowledge investment programme to encourage adoption of technology” (2016: 7)</p>
Evidential	<p>Dahle et al. (2017:2) found that female retention was good (87%) on engineering courses offering art as a minor, and that emphasis on the creative facets of engineering increased the number of girls considering engineering as a career.</p>
	<p>Wajngurt and Sloan (2019: 22-23) found that a STEM class with an arts component, positively and significantly affected female students’ intentions to pursue a STEM degree, compared to male students.</p>

Gender equality and representation within and beyond
the University of the Highlands and Islands

Perspective	Result
	Although the number of women in engineering roles has doubled, since 2010, to just over 50000, in 2019 only 14% were in management roles, a drop since 2018 (WISE 2020), affecting the availability of role models.

Table 6.2: Focused Perspective Taking™ Results

The Spider Diagram in Figure 6.3 summarises these options. Although all these proposals are specific, none are timebound, which is expected for a longstanding problem with no expeditious solution (WISE 2020). The easiest to implement is the emphasis of pro-social, creative, and female-influenced examples into curricula. UK establishments can equally easily implement gender diverse, inclusive, and attractive environments and policies (Royal Academy of Engineering 2015), and conduct Equality Impact Assessments, as UHI already does (2019). Elsewhere, however, those options which address deeply ingrained cultural, historical, political and social attitudes, are unlikely to be effective without other intervention.

Gender equality and representation within and beyond the University of the Highlands and Islands

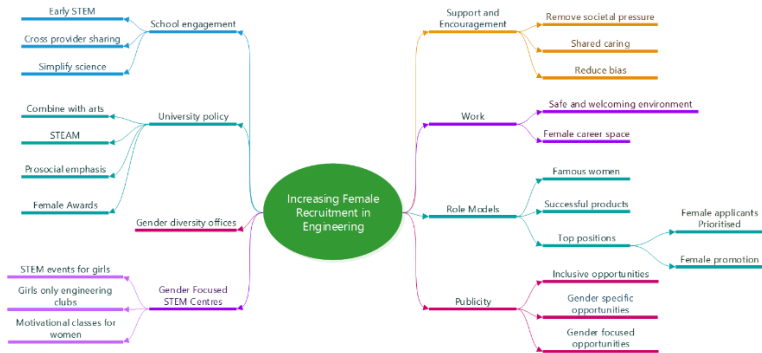


Figure 6.3: Spider diagram of potential ways to increase female recruitment in engineering

The remaining solutions fall into two categories – those focusing on exclusively female incentives, and those using role models and supportive strategies. Whilst exclusively female opportunities are easily implemented, and their effectiveness already positively measured (GirlsWhoCode 2019), care must be taken not contravene the Equality Act (Act of Parliament 2010) by employing illegal positive discrimination. There is also some evidence that these practices exacerbate the problem by alienating male counterparts (Royal Academy of Engineering 2014: 6). Perhaps the most effective solutions focus on promoting role models, who can educate, encourage, support and

mentor a future generation of female engineers (Fryer 2018), giving them the incentive and confidence to succeed in a male dominated career.

Implementation

My next step is to implement the most feasible and cost effective of the potential solutions identified. I have already included examples in my curriculum, which highlight the prosocial benefits of engineering, with some of my students designing prosthetics for Raigmore Hospital (Inverness, Scotland), burglar alarms for supported housing, energy saving products for green economies, and many more. An interesting first-hand example comes from my own work on the Sea-King helicopter radar. One of my students thanked me personally for this, as a Sea-King saved his life when he was born prematurely. This emphasised, to me, the importance of using engineering creatively as a powerful means to help others and advance humanity.



Figure 6.4: Image of a helicopter ([Cosford 2015: Farewell Part 2 by Pete \(comedy nose\) at Flickr](#) / [Public Domain Mark 1.0](#))

I promote creativity through multi-disciplinary, group projects, which, of course, also develops Industry 4.0 skills, particularly when ergonomic and human factors are given equal importance as functionality; advertising this more overtly in the UHI prospectus may entice more female students. Furthermore, I plan to develop more systematic and concerted use of role models by actively seeking women to give guest lectures. Although I believe myself to be a role model, and a mentor, I would like to take a more proactive approach to encouraging schoolgirls into FE and HE STEM subjects, for instance by better engaging with UHI's STEM Femmes project and my STEM Ambassador role. Finally, I intend to demonstrate more female-

engineered product examples, perhaps even including art-inspired design elements, in the curriculum, to better define the benefits of engineering as a career for women.

Conclusion

This chapter has highlighted the problems and challenges encountered by female engineers working in predominantly male environments, both in the engineering classroom and in industry. Although my own experience has been relatively benign, it is well known that prejudice and bias still exist, resulting in many seeing engineering careers as men-only domains. This is to the detriment of the whole profession, with insufficient engineering graduates available, retention of female engineers abysmally poor, products badly designed without female input, and ignorance of the benefits feminine attributes bring to engineering teams. Going forward into the automated era of Industry 4.0, creative multi-tasking and empathetic collaboration are likely to become the dominant skills required for the engineer of the future, and these skills are particularly prevalent in women. Therefore, it is imperative

that everything possible is done to attract more women into engineering.

Whilst little can be done to change historical bias and societal attitudes, the HE engineering environment can be made more welcoming to women. Women are proven to be inspired by an emphasis on pro-social aspects and focus on ergonomics. Incorporating these obviously in the curriculum, along with alternative teaching and assessing methods which favour feminine attributes, such as creative problem solving and group working, may make engineering more attractive to schoolgirls. Using role models more extensively, to highlight the value of women's contributions, can improve female students' confidence, and help them overcome imposter syndrome. Combined with good classroom management, to prevent "laddishness" (Stentiford 2019: 218), and pro-active gender inclusiveness policies, I believe these changes can help to reduce the engineering gender bias, to the benefit of all.

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Author bio

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engage, and encourage females to study engineering. Having worked for over twenty years as an electronics designer, for the defence industry, Lois maintains links with local manufacturers and is championing diversity in higher engineering education to help alleviate the difficulties companies face in recruiting and retaining skilled engineering graduates.

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