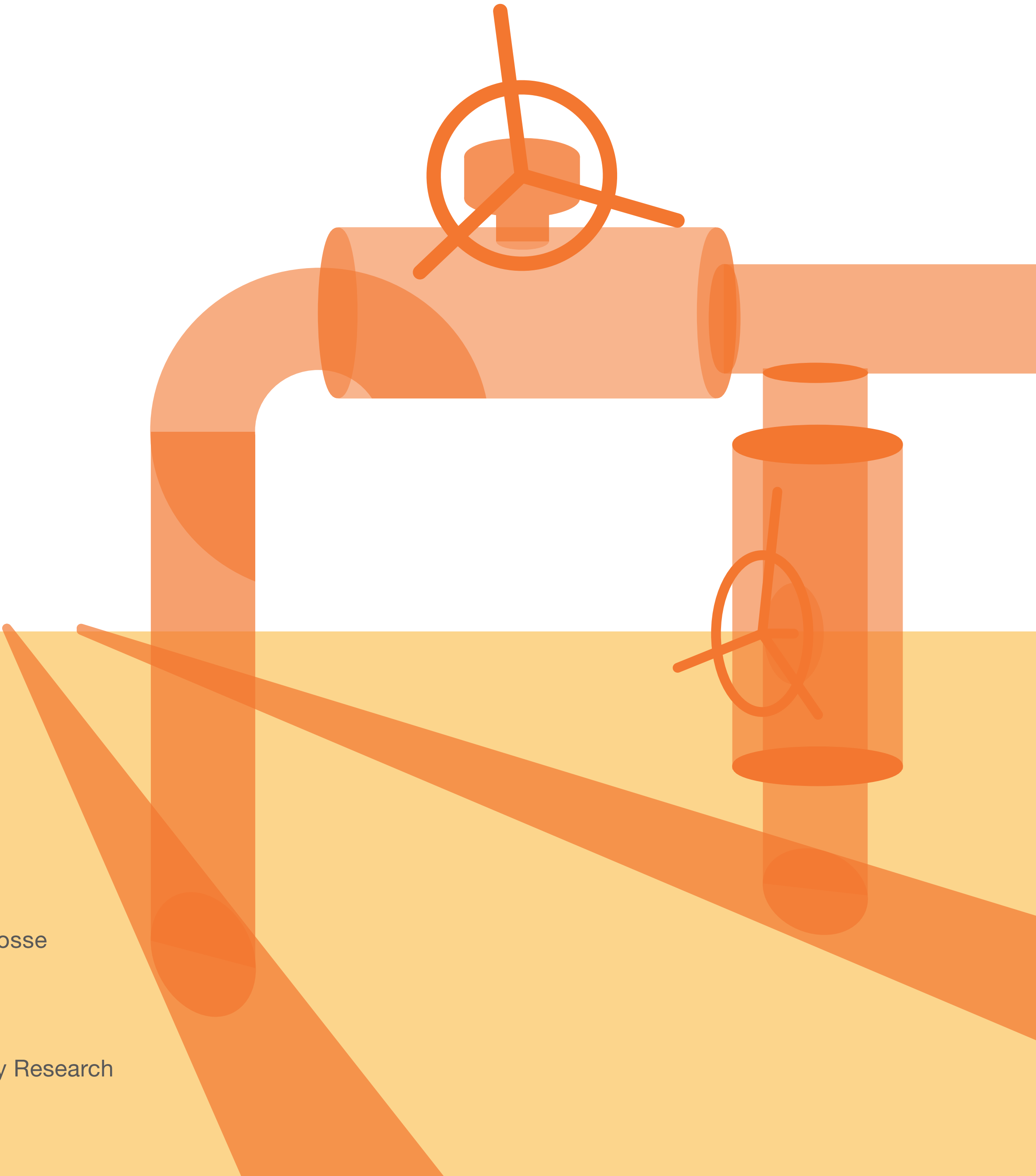
REPORT

WOMEN IN ENGINEERING

FIXING THE TALENT PIPELINE



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Institute for Public Policy Research

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Erratum

Page 6: an earlier version of this report referred to a report by the Institute of Physics (IOP 2012a) as having found that 'close to half of all co-ed state secondary schools had no female students studying A-level physics'. However, this figure referred to the proportion of these schools that *sent no girls on to take* A-level physics, whether at the same school or another (such as a separate sixth form college). We are happy to correct the record.

ABOUT THE AUTHORS

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SUMMARY

Women account for only 7 per cent of the professional engineering workforce in the UK, and less than 4 per cent of engineering technicians (IET 2013). This underrepresentation is far greater than in other European countries. Engineering is a well-paid career, so this gender gap represents a missed opportunity to reduce pay inequality in the workforce. With projections showing that the UK will experience a serious shortage of engineers in the coming years, it also represents a threat to the industry, and to the economy more generally.

The analysis presented in this paper demonstrates that the age of 16 is the critical point at which women are lost to a potential career in engineering. For far more women than men, A-level and vocational subject choices made at this age close the pathway into careers in engineering.

However, the evidence suggests that these choices made at 16 are based on attitudes and perceptions about engineering that have been formed over many years. Engineering is still seen as a career for ‘brainy boys’. Teachers, careers guidance, work experience and families do not do enough to counter this view, and are sometimes guilty of perpetuating it.

Seeking to influence women at the age of 16 is too late. The key to getting more women into engineering is to make it an attractive option for girls from an early age, and to keep repeating this message throughout their education and in their lives outside of school.

INTRODUCTION
WHY SHOULD WE CARE ABOUT THE LACK OF WOMEN IN ENGINEERING?

Engineering is crucial to the UK's economy. It is a diverse industry that plays an important role in maintaining the UK's competitive edge in the global economy. Engineers are required to maintain vital national industries and services such as energy, water, sanitation, communications and IT systems, and have also been proven to be important to innovation, research and development capital, IT capital, organisational capital and leadership capital (Kumar et al 2014). Not only is engineering integral to our economy, it is also a profession that is well remunerated and in high demand.

Despite this, the industry struggles to recruit a diverse workforce. Women represent only 7 per cent of the professional engineering workforce (IET 2013). Not only is this huge gender imbalance detrimental to the industry and bad for gender equality, but it also has wider negative implications for the economy. The UK is in great need of more engineers: an additional 87,000 graduate-level engineers are needed each year between now and 2020, but the higher education system is producing only 46,000 engineering graduates annually, which suggests that the UK has a long way to go to fill this potential skills gap (Kumar et al 2014). One way to address this looming skills shortage is to tackle the gender imbalance within the industry.

Third-sector organisations and researchers, motivated by gender equality rather than economic or business concerns, point out that women continue to be concentrated in particular industries, many of which are low paid and low skilled. Encouraging more women into engineering would help to improve women's position in the labour market, by improving access to better pay and progression opportunities. Engineering graduates have the second-highest starting salaries in the UK, so there is an economic incentive for women to make careers in engineering. However, this is clearly not enough to attract enough of them, and more needs to be done to make engineering an attractive option. Furthermore, widening women's participation in engineering would also benefit society, because the people who understand and influence important scientific developments would better reflect the UK population as a whole.

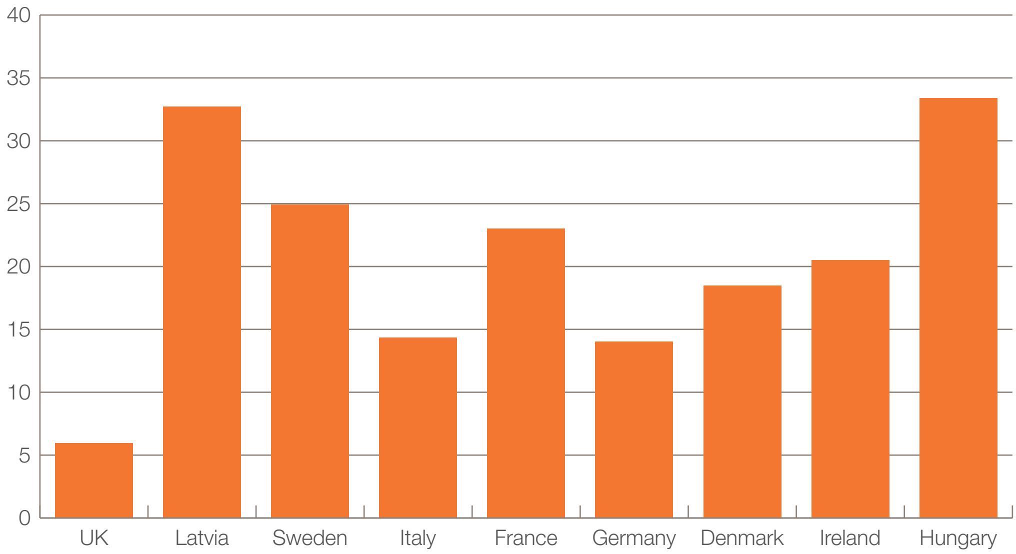
To widen participation, it is important to understand at what points girls and women drop out of potential pathways into employment in engineering. These routes into engineering have been characterised as 'leaky pipelines', in that women are lost to the sector at each educational stage. This paper describes these 'leaky pipelines'. It first sets out headline figures on women in engineering in the UK, contrasting them where possible with those of a number of comparable countries. It then examines each key stage in the path to a career in engineering, in order to better understand the main 'leaks' and what interventions might prevent them.

1. THE SCALE OF THE CHALLENGE IN THE UK

Women are underrepresented in engineering. In 2013, women accounted for only 7 per cent of the professional engineering workforce in the UK, and only 4 per cent of engineering technicians – yet women represent 42 per cent of the overall workforce. This reveals not only that the engineering industry struggles to attract women, but that it currently recruits from a limited talent pool.

Figure 1.1 below illustrates the share, across a number of countries, of engineering professionals who are female. It demonstrates that a lack of women in engineering is not just a UK phenomenon, but a European problem: averaging across Europe, female engineers make up roughly one-sixth of the engineering workforce (VDI 2010). However, the UK has the lowest proportion of female engineering professionals in Europe. Eastern European countries tend to have more women working in engineering. Both Latvia and Hungary outperform the UK in this regard by significant margins, with women accounting for close to a third of engineering professionals in Latvia. The large disparity between the UK and the best performers in Europe indicates that a lot more can be done to improve the gender balance in engineering.

Figure 1.1
Percentage of engineering professionals who are female, by country, 2012



Source: EU Labour Force Survey

Differences in educational systems across Europe may explain why other countries are so much more successful than the UK in attracting women into engineering. Attempts to analyse why other EU countries have higher proportions of female engineers have indicated the importance of students' school subjects at the age of 18 (Kiwana et al 2011). Cross-country comparisons show that a lower proportion of girls in England, Wales and Northern Ireland choose to study maths and physics at the age of 18 than those in Italy and Sweden – both of which have a higher proportion of female engineers than the UK (ibid). These subjects are important in determining whether potential candidates can go on to pursue an academic route into engineering.

The different ways in which science is taught across Europe can help explain the higher proportion of women studying the subject at the age of 18. In Europe, science tends to be split into three separate subjects – physics, biology and chemistry – towards the last few years of lower-secondary education, with students obliged to study at least one of them. The UK secondary school curriculum of A-levels, by contrast, tends to lead to early specialisation, and the UK is one of a number of countries that offers science as an optional, specialist branch. This structure means that students can opt out of learning science subjects altogether in their final years of school (EACEA 2011). Opting out of particular subjects such as science and maths during the final years of school can restrict career pathways, particularly in the sciences.

2. THE CHOICES GIRLS MAKE IN EDUCATION

To better understand the significant shortage of women in engineering, it is important to map out where women, sometimes unknowingly, opt out of engineering career pathways. A large part of the problem is that at the age of 16, many girls remove themselves from these pathways. This suggests that the narrowing of the engineering talent pool starts well before people actually choose a particular career.

2.1 Choices at school

The gender imbalance in engineering is associated with the subject choices British girls make at school (Kiwana et al 2011). The gender imbalance in STEM (science, technology, engineering and maths) subjects begins post-GCSE, when many young women drop out of STEM-related study. Prior to this point there is no evidence of a gender participation gap in subjects at GCSE. In fact, there has been a significant increase in the number of students studying three individual sciences at GCSE in recent years (JCQ 2013a). Girls are now equally or more likely than boys to achieve an A*–C grade in mathematics, core or additional science, and in each of the three individual sciences (ibid).

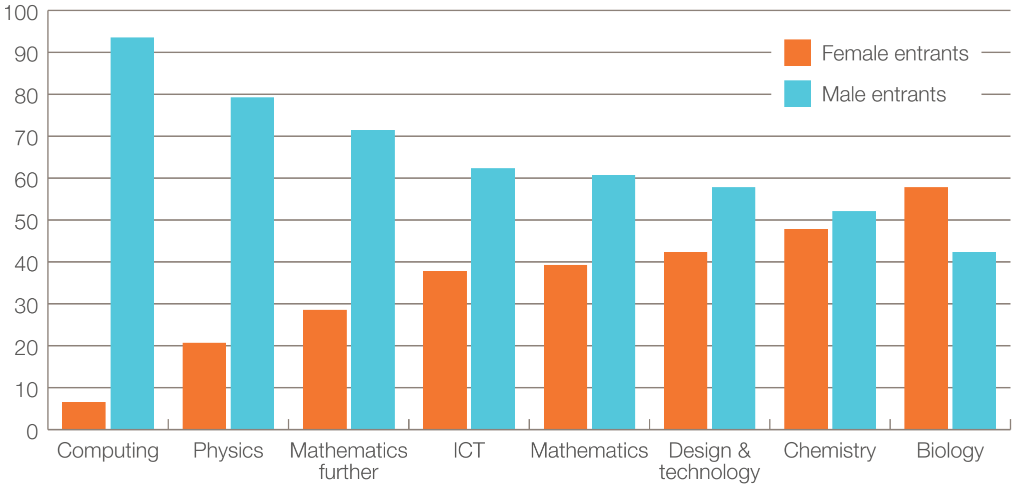
Low enrolment in STEM subjects at A-level among girls is not the result of poor attainment. While the popular perception that boys are better than girls at science persists (ASPIRES 2013), girls who go on to pursue science achieve better exam results than their male counterparts in physics and further maths at A-level (JCQ 2013a). However, despite higher attainment in these subjects, fewer girls than boys enter all A-level STEM subjects except biology (JCQ 2013b). These patterns show that one of the key ‘leaks’ in the engineering pipeline occurs between GCSE and A-level.

Figure 2.1 below illustrates the underrepresentation of women in A-level STEM subjects in 2013, with male entrants disproportionately represented in almost all of them. Only 21 per cent of physics A-level entries, for example, were female. Although still underrepresented, there appears to be a better balance in A-level mathematics, with female students accounting for 40 per cent of all mathematics A-level students. Biology is the only STEM subject in which female students accounted for a greater proportion of entrants than males in 2013. Among the options for study at A-level that were more popular with UK girls were languages, health studies/science, speech and drama and art and design (OECD 2013, Jin et al 2010).

The lack of young female students in A-level STEM subjects creates a problem further down the line, when not enough women have the right prerequisites to consider an engineering or science degree. The very gendered participation in A-level physics should be a primary concern for policymakers and industry. Far fewer young women choose physics than young men. There is a significant disparity between the number of young female students who achieve good science grades at GCSEs and the much smaller number of them who go on to study physics at AS- and A-level. In 2013, just over 72,000 girls achieved grades A*–C in GCSE physics (JCQ 2013b). However, only around 10 per cent of these girls will go on to pursue physics at A-level (JCQ 2013a).

Figure 2.1

Percentage of male and female entrants for A-level STEM subjects in 2013



Source: BIS 2013

The underrepresentation of women in STEM subjects creates male-dominated environments within science classrooms which can help reinforce stereotypes and put off potential female students. In 2011, close to half of all co-ed state secondary schools sent no female students on to study A-level physics (IOP 2012a). However, young women are more likely to take physics if they attend an independent, single-gender school (IOP 2012b). School environment can therefore shape subject choices.

2.2 Choices in higher education

Even if all of these female students who take physics at A-level were to be accepted onto an engineering course at university, they would still make up less than a quarter of all accepted applicants on these courses.[1] There are simply not enough girls taking STEM A-levels to address the gender imbalance at higher education.

Higher education is an established route into engineering, but there is a stark gender imbalance at undergraduate level: in 2012/13, only one in six engineering and technology students were female (17 per cent) (Kumar et al 2014). Because women do not study the right A-levels, such as physics, they are underrepresented in engineering courses at degree level. A recent report from Engineering UK found that the majority of students with A-level physics end up taking engineering courses at university. By contrast, greater numbers of women than men are studying medicine, dentistry, and subjects allied to medicine and biological sciences.

The numbers of female applicants to engineering degrees are well below those of male applicants: in 2011/2012, only 13 per cent of applicants to engineering courses were female – the lowest applicant ratio across all STEM subjects (Kumar et al 2014). There is some diversity in participation within the sub-disciplines of engineering, however: female applicants for chemical, process and energy engineering have not fallen below 25 per cent in the past decade, whereas mechanical engineering has the lowest share of female applicants, at 5 per cent of total applicants.

1 There were 25,293 accepted applicants to UK higher education engineering courses in 2011/12 (Kumar et al 2014).

If the numbers of university engineering entrants were to increase to meet the UK's demand for engineers, it is likely that universities would be faced with capacity constraints. In a recent poll, a number of universities were asked, 'Over what time period could you accommodate a doubling of your intake of undergraduate (and separately) postgraduate engineering students?' Just over half of respondents said it would take 3–5 years, and a further 25 per cent said it would take 6–10 years. This suggests that policymakers need to consider not only means of stimulating demand for engineering courses at university, but also ensuring that universities are able to accommodate greater numbers of students and deliver quality engineering courses (Kumar et al 2014). It has also been argued that capping tuition fees may prevent the UK from attracting talent. Science courses are one of the more expensive courses to deliver, and caps may mean that universities will, in the future, require more financial assistance in order to continue offering engineering courses to UK students.

2.3 Choices in employment

Further down the talent pipeline, another key leak can be identified – at the transition from education into employment. First, women are less likely to enter employment after their degree than men. Of those graduating in 2011/12 from a first degree in engineering and technology, 61.9 per cent of men, compared with 58.8 per cent of women, were in full-time employment six months later (Kumar et al 2014). For those who do gain employment, evidence from the Higher Education Statistics Agency suggests that men are more likely than women to enter engineering and technology occupations: of the same 2011/12 cohort of graduates with degrees in engineering and technology, 70.5 per cent of men but only 56.2 per cent of women were in engineering and technology occupations six months later (HESA 2013). For those completing a second degree in engineering and technology, these figures were 65 per cent of men and 52.5 per cent of women (Kumar et al 2014). Many graduates are opting out of careers in engineering despite having the relevant qualifications and experience.

Once in work, many female engineers report high job-satisfaction, although there are still problems within the industry regarding the retention of women. For example, two-thirds of female engineers do not resume their engineering jobs after taking maternity leave (Kiwana et al 2011). Furthermore, one US study found that 40 per cent of women with engineering degrees had either left the industry or never entered it (Fouad et al 2012). Evidence from the US suggests that the lack of flexible, part-time work, and workplace culture, contribute to women's decisions to leave their jobs (ibid). Whether this also applies to the UK needs to be explored further. If women feel unsupported in engineering, they may choose to leave to find jobs in other industries. Training, development and support have been identified as factors that are crucial to retaining women within engineering. This extends beyond skills-based development and training to a more comprehensive approach that addresses all the challenges that female engineers face in pursuing a long-term career within the industry.

Not only are girls not taking the STEM A-levels or degrees that lead to careers in engineering, they are also underrepresented in vocational pathways to engineering. Yet one of the strengths of this sector is the value that is placed on vocational career routes. Many of the UK's foremost engineering firms are led by people who started out as apprentices. Overall, the numbers of male and female students completing apprenticeships are roughly equal, so it is not apprenticeships per se that are failing to attract female students (BIS 2013). Rather, it seems that apprenticeship subject choice can be heavily gendered. Men and boys are vastly underrepresented in subjects associated with traditionally female sectors, such as hairdressing and children's care, learning and development. Likewise, female students continue to be underrepresented in engineering. In 2011/12, only 490 female students completed engineering apprenticeships, compared to 10,770 male students; female participation also fell between the level 2 engineering apprenticeship (5.9 per cent) and level 3 (2.8 per cent) (Kumar et al 2014). This is concerning, because representatives of the engineering sector have emphasised how much more meaningful level 3 apprenticeships are, and the qualification is generally considered the minimum requirement for becoming an engineering technician (ibid).

Engineering has been at the fore of government plans to reform apprenticeships in England in order to make them 'more rigorous and more responsive to the needs of employers' (BIS and DfE 2013). New apprenticeships (called 'Trailblazers') are being developed and piloted in several engineering-related industry areas. Furthermore, a majority of newly established university technical colleges (UTCs), which train students in vocational and core academic subjects from the age of 14, are specialising in engineering (Perkins 2013). The Skills and Funding Agency has been piloting schemes aimed at improving diversity in apprenticeships. These newly developed approaches to vocational training present an opportunity to attract more girls into STEM training and engineering careers, although this will require significant active engagement from UTCs and Trailblazer stakeholders. UTCs currently do not publish gender disaggregated data on their enrolment, but the target of the first UTC – the JCB academy – is to have at least 25 per cent female enrolment by 2020 (WISE and RAE 2014), which suggests that the current figures are much lower.

Vocational pathways

Qualification and Credit Framework (QCF) – a qualification framework introduced in the last few years. Qualifications are built up through credits, which allows flexibility. Many previous vocational qualifications are now to be subsumed into the QCF. In Scotland, the Scottish Credit and Qualification Framework (SCQF) is used instead.

BTEC, OCN Nationals/Vocationally Related Qualifications (VRQs) – vocational qualifications which relate to particular work areas. These usually involve work experience. They will now be subsumed into the QCF.

National Vocational Qualifications (NVQs) and Scottish Vocational Qualifications (SVQs) – vocational qualifications which include workplace (or realistic working environment) training and assessment. These qualifications could lead to higher education, or be combined with apprenticeships. They are usually taken after the age of 16 in a further education college, but are also offered by some schools. They are now being replaced by QCFs, but will be retained within QCF qualifications as a brand name which indicates that the qualification was competency-based.

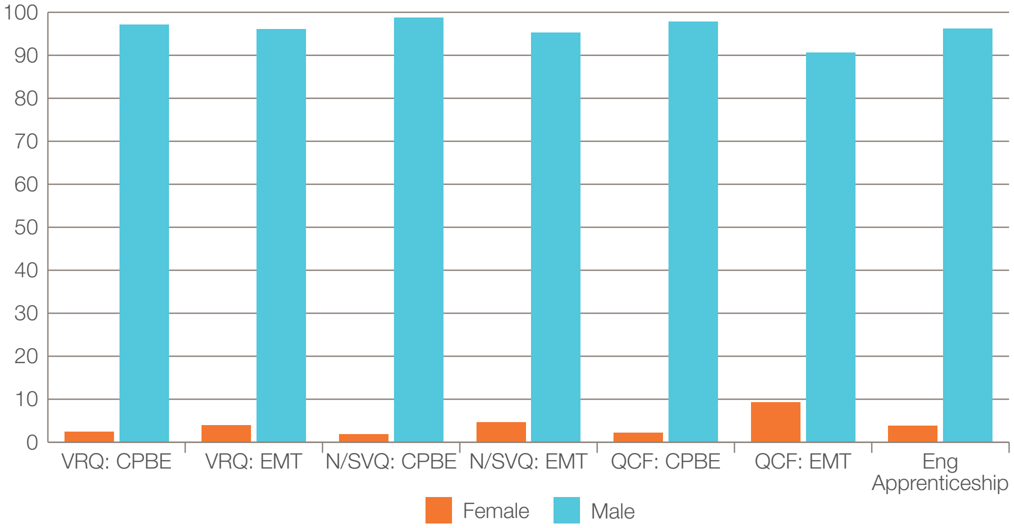
Apprenticeships – on the job, certified training for those aged 16 or over. Apprentices are paid the apprenticeship minimum wage, which is currently £2.68 per hour.

Traineeships – these are for those aged 16–23, last between six weeks and six months, and involve work experience and training in English and maths. Their aim is to prepare participants for work or to enter apprenticeships.

In terms of other vocational routes to engineering, such as NVQs/SVQs, VRQs and QCFs, female representation is also low (see figure 2.2). Across all qualifications in both the 'construction, planning and the build environment' and 'engineering and manufacturing technologies' categories, female qualifiers were outnumbered by men by at least 10:1 (Kumar et al 2014).

There are some indications that the enrolment of women is improving. The number of women completing a BTEC subject in engineering increased by 130 per cent between 2004 and 2012 – far faster than the average increase for all engineering students (Kumar et al 2014). However, while female students' percentage share of BTEC engineering qualification completions has grown, women and girls still accounted for less than 5 per cent of all completers in 2012/13.

Figure 2.2
Achievement of vocational routes to engineering by gender (2011/12)



Source: BIS 2013

3. WHY DO GIRLS REJECT THE IDEA OF A CAREER IN ENGINEERING?

It is clear from the preceding analysis that engineering faces a recruitment challenge rather than a retention problem. Not enough women are choosing the right subjects at A-level and the right vocational pathways that lead to careers in engineering. However, understanding this recruitment challenge requires an analysis that delves deeper than simply examining subject choices at A-level. It must also examine attitudes towards and aspirations for STEM and science careers from as early as the age of 10. Previous research has shown that because of perceptions and attitudes formed from early ages, by the time they turn 14 many girls have ruled themselves out of a career in engineering (Kiwana at al 2011). This means that interventions aimed at influencing young women's career and subject choices the age of 16 will be too late.

This section focuses on the drivers that shape subject and career choices.

3.1 Perception of STEM subjects and engineering careers

> *'I said [to my daughter] why can't you do science? She said "oh no it's a boy thing". They had an after school science club and she said "I'm not going because it's all boys". I said well you should at least go along and see if you enjoy it. She went twice and then she stopped going because it was all boys and she had no girls to talk to.'*
> Archer 2013

Research has shown that gender, ethnicity and social class all shape what careers are perceived as 'normal' and desirable among particular groups. Gendered attitudes towards science continue to limit women's progression in scientific careers. Scientific careers are still largely perceived as masculine, although this is more true of some scientific careers than others. Even women who work in the sector believe that engineering is seen as a 'male career' (Atkins 2013), associated with cars, construction, and heavy machinery. While medicine also requires science A-levels, far greater numbers of women have entered the profession in the past four decades, to the point where women now outnumber men at medical school (GMC 2013). A career in medicine is perceived as a 'normal' or desirable choice for women, because it is seen as a caring or nurturing profession consistent with prevailing attitudes about women (ASPIRES 2013). Because of these attitudes towards physical sciences, many women do not consider careers such as engineering to the same extent that men do.

These attitudes are working against efforts to achieve gender equality in the sciences. The damaging stereotypes they involve also influence subject choice at school, with STEM subjects still seen as 'boys' subjects', despite girls' higher attainment in them. Evidence has shown that female students who self-identify as feminine are likely to feel that STEM subjects are 'not for them', even if they enjoy them (ASPIRES 2013). STEM subjects are also often perceived to be too hard, which puts off a number of potential students: ASPIRES' survey of 10–13-year-olds found that 80 per cent agreed with the statement 'scientists are brainy' (Archer 2013). Over half of female engineers interviewed by Atkins (2013) believed that potential students were being put off by the idea that engineering is 'too difficult'. While the 'brainy' image relates to the wider problem of low recruitment into STEM subjects and engineering, it is also a gendered (as well as a racialised and class-related) issue. Despite the fact that girls perform better than boys in GCSE science and maths, boys are still more likely to see themselves as clever enough to pursue A-level STEM subjects. The ASPIRES study found that groups that tend to be underrepresented in science – such as women, working class and pupils from particular ethnic minorities pupils – have relatively less confidence in their abilities to do well at science or mathematics than other students, even if they have an average or good level of attainment in science (ASPIRES 2013). Women not taking the right A-levels based either on perceptions or lack of confidence in their abilities unnecessarily narrows the future talent pool, and is therefore a key area for intervention.

Teachers can further compound these gendered views about science. Previous evidence has identified an unconscious bias in teachers, who view boys to be 'better' and/or more 'naturally able' at science than girls (Carlone 2004). Furthermore, evidence has also found that some schools encourage boys to pursue science to a greater degree than they do girls. This is of particular concern, given that teachers have been found to be more influential for girls than boys in determining whether they go on to study particular subjects at A-level. One survey found that over half of girls pursuing physics at A-level were influenced to do so by a teacher, compared to just under a third of boys.

Because of these gendered attitudes towards subject choices and careers, by the age of 14 many girls view STEM careers as 'interesting but not for me'. ASPIRES research, a longitudinal study exploring the attitudes of students between the ages of 10 and 14 towards science-related careers, has shown that at age 12/13, girls tend to be more interested in pursuing a career in the arts, while boys were more likely to say they aspired to a career in engineering (Archer 2013). Girls who define themselves as 'girly' (highly feminine) are particularly unlikely to aspire to a career in science, and 'girly' girls who aspire to science careers tend to change their science aspirations or drop them altogether at age 10/11. Girls who do aspire to science and STEM-related careers are not only more likely to describe themselves as 'not girly', but they also tend to be highly academic (ASPIRES 2013).

Because many still believe that most science-related careers are masculine or reserved for the brainy few, key influencers such as teachers and families believe that a career in engineering will be inhospitable and undesirable for women. Nearly half (44 per cent) of all STEM educators interviewed by Engineering UK said that engineering was an undesirable career for their female students because it is seen as a career for men (IFF Research 2013). In another study, more boys than girls reported having been encouraged to think about engineering as a career, particularly by their parents (BIS 2014). Such differential encouragement can have implications for young female aspirations – it removes many potentially great students from the engineering talent pipeline.

How people view themselves in relation to particular subjects or careers is important in determining aspirations and shaping career options. The Institute of Physics defines self-concept as the 'students' sense of themselves in relation to the subject; the value they place on the subject and their willingness to engage with it' (IOP 2012b). Self-concept is one of three key factors that ASPIRES research identifies as having the strongest relationship with science aspirations. If girls do not self-identify with science then it is unlikely that they will pursue a science-related career. This is particularly problematic for subjects such as physics, which are largely viewed as masculine and male-dominated – more so than other STEM subjects – and which young women are therefore less likely to self-identify with. Self-concept can prevent girls from considering a STEM career even if they enjoy and have good attainment in STEM subjects. As well as self-concept, attitudes towards school science and parental attitudes to science are two other key factors that drive student science aspirations (ASPIRES 2013).

3.2 Poor understanding of engineering careers and the engineering pathway

Part of the problem with the perception of engineering as 'male' and 'too hard' is wider ignorance about engineering careers and the 'engineering pathway' among schoolchildren and their key influencers – parents, teachers and career advisers. The Institute of Employment Studies has found that parents, teachers and advisers (as well as the young women they influence) hold outdated views on STEM occupations (Newton et al 2012), and the Welsh government (2013) has found that career paths into engineering are poorly understood by learners. This is driven by a disconnect between curricula and careers, which means that students are only informed about more commonplace and culturally visible professions (Finegold 2011). This leads to misconceptions about careers in the engineering sector and the transferability of STEM qualifications – both of which could discourage girls from pursuing them. This is important, as the findings of an UPMAP study have suggested that views about the transferability of science qualifications are a key indicator of whether students will go on to study STEM subjects after age 16 (ASPIRES 2013). Work experience could be one means of addressing this misconception, but only one in five girls (21 per cent) surveyed by the Wellcome Trust had done work experience in a STEM field (Wellcome Trust 2013).

By contrast, the most frequently cited reasons for choosing engineering among female engineers interviewed by Atkins (2013) were the variety of career options and routes (62 per cent), and the fact that engineering was 'a good route to lots of other interesting careers' (56 per cent). These reasons in themselves demonstrate sound knowledge of engineering careers – knowledge which the majority of students lack. Indeed, seven out of eight female engineers surveyed by Atkins believed that greater awareness of what engineers do was needed, 77 per cent believed that greater awareness of the wide range of careers that engineering graduates can enter was also required, and almost two-thirds of women engineers believed that careers advice about engineering was weak (ibid).

It appears that better careers guidance at key stages would help steer more female students towards mathematics and physics, and would also help to break down misconceptions about what an engineer does and who can become an engineer. However, it has been found that some career guidance may reinforce stereotypes about who should choose what career (Newton et al 2012). In 2013 it was found that three-fifths (57 per cent) of STEM educators had been asked to provide careers advice in the previous year, but only 31 per cent felt confident about providing careers advice about engineering (IFF Research 2013).

Related to biases and perceptions of what are considered 'normal' careers, women who have completed their A-levels can face subtle discrimination when attempting to pursue careers in engineering. Interviews for university engineering courses often consist of all-male interview panels and male-dominated group exercises. These types of practices do not encourage diversity within university departments and can put women at an unfair disadvantage. Furthermore, women can continue to face recruitment practices with engineering firms that do not fully challenge the lack of diversity in their firms.

3.3 Families as key influencers

Both parents and young people (aged 11–14) believe that parents are the most important influencer of young people's career choices: 68 per cent of the young people aged 11–14 interviewed said they were influenced by their parents 'a lot' when it came to career choice – more than by their teachers and career advisers (BIS 2014). In research by the Wellcome Trust (2013), only 18 per cent of young people reported feeling that teachers are the most useful source of careers information, compared with 39 per cent who said their family was. In a survey for the Department for Business, Innovation and Skills (BIS 2014), parents or carers were also found to be most likely to pick themselves as the most influential figures in providing careers advice for their child.

Family knowledge and encouragement of engineering and engineering careers is important in shaping science aspirations. More specifically, how much science capital a family possesses has measurable impact on their children's aspirations from as early as the age of 14 (and sometimes even earlier). 'Science capital' refers to a family's science-related qualifications, understanding, knowledge (about science and 'how it works'), interest and social contacts (for example, knowing someone who works in a science-related job) (Mujtaba and Reiss 2012). Despite generally positive views of science and engineering, parents and carers aren't always well equipped with the 'science capital' necessary to support children into STEM subjects and engineering careers (ibid).

This matters because, in terms of students' choices about taking physics and maths to A-level, home support has been shown to have more influence than ability and attainment (ibid). The ASPIRES longitudinal study found that girls who tend to maintain science- or STEM-related aspirations were often from middle-class backgrounds and belonged to families with a high or medium level of science capital (ASPIRES 2013). If a young female student comes from a low-science-capital family, she is less likely to be exposed to a wide range of STEM career possibilities, including engineering.

Other research has found similar evidence. Research by Atkins (2013) found that almost four in 10 women engineers had a family connection to the occupation, most frequently their father, and 11 per cent had a friend who was an engineer. Taken together, this suggests that the influence of close family or social factors can play an important role in encouraging girls into engineering.

Addressing the lack of science capital available to girls is one way of overcoming the gender imbalance in STEM subjects and engineering occupations. Improving families' knowledge about STEM is likely to lessen the impacts that stereotypes have on shaping career aspirations. Encouraging more young women to pursue STEM subjects and the 'engineering pathway' will therefore involve working with families as well as students.

4. RECOMMENDATIONS

In the above analysis we identified some of the main challenges in attracting female talent towards engineering, largely concentrating on the educational pathway. In this chapter we outline actions that could help overcome these challenges. This is by no means an exhaustive list; instead, we try to suggest actions that target interventions in primary and secondary school – where girls tend to drop out of the STEM pathway, and consequently the engineering pathway, in large numbers. Many interventions targeted at improving the number of female engineers tend to emphasise decisions made after the age of 16. However, the evidence suggests that this may be too late, as attitudes towards STEM have become entrenched by 14. Instead, more thought should be given towards aiming interventions at a much younger cohort.

The main challenges to attracting more female talent towards engineering that we have identified are as follows.

1. Too few girls acquire the prerequisites, particularly physics, at A-level.
2. An unhelpful perception of STEM and engineering careers, among both girls and their families, as 'masculine' or 'brainy'.
3. Poor understanding of engineering careers and the engineering pathway.
4. The fragmented STEM ecosystem, which can lead to an ineffective use of resources.

Responses that could address each of these challenges are set out below.

Challenge 1: Too few girls acquire the prerequisite qualifications in STEM subjects

Young women represent only 21 per cent of A-level physics students, and this prevents greater numbers of them pursuing engineering careers.

To address the underrepresentation of women in STEM subjects at A-level, the government could require schools to **report the proportion of girls taking STEM subjects at A-level and GCSE**. This would incentivise schools to monitor and evaluate participation in STEM subjects by gender. This self-assessment would highlight any significant discrepancies in participation, making it more likely that schools will address it as a priority. To ensure that participation is more equal, schools could also employ part-time STEM administrators whose remit would be to reduce gender inequality in STEM subjects.

Any review of the 14–19 education system should consider ways to increase and widen participation in STEM education. In England, science is perceived as a specialist route at A-level. The current A-level structure could **move towards a structure similar to that of the international baccalaureate**, which requires students to study mathematics and at least one science subject. Maths could be offered at different levels to cater for different levels of ability and interest. A more comprehensive curriculum could help to increase the number of students studying STEM subjects post-16, and could incentivise students to keep more options open by pursuing a science subject. This could result in fewer students specialising in only three subjects without taking maths or a science, which would keep greater numbers of students in the engineering talent pipeline. Broadening the curriculum would not only boost the pool of potential engineering candidates, but it could also improve the level of scientific literacy among the public more generally.

However, we also know that only addressing subject choices at the age of 16 is not effective. The low numbers of women in STEM is the result of a build-up of biases and perceptions formed much earlier. While broadening out the curriculum at secondary school is helpful, more work will still need to be done to keep women on the engineering pathway, such as tackling perceptions and attitudes towards STEM and STEM subjects.

Challenge 2: Addressing the unhelpful perception of STEM and engineering careers, among both girls and their families, as 'masculine' or 'brainy'

Action must be taken to challenge popular perceptions of STEM and engineering careers among girls and their families. There must be a broad attack on stereotypes to debunk myths surrounding women in science and perceptions about careers in science. This will require action from the industry, professional bodies, third-sector organisation and schools.

To tackle these unhelpful stereotypes, the government should invest in **equality and inclusion training for teachers**, which should be undertaken as part of teacher training courses and also be offered as part of continuing professional development (CPD). Equality and inclusion training would support teachers to challenge their own unwitting biases, and those of their students and their institutions. They would be trained to understand gender stereotypes and messages, and to discuss and challenge (or 'deconstruct') those stereotypes and messages with students.

Training could also alert teachers to the many lesson resources that are already available for STEM subjects to challenge gender stereotypes. It could also be used to make teachers aware of current gender imbalances and biases, and give them ideas about how to challenge them. They could also hear case studies about promoting STEM subjects or vocational routes to girls. For example, Ofsted (2011) found that one school had been effective in challenging stereotypes and 'hard selling' mathematics to young women, with the result that equal numbers of male and female students started the subject in year 12, whereas in the previous three years the same course had been male-dominated. Making teachers aware of these case studies would demonstrate what is possible, and encourage them to take greater responsibility for challenging gender inequality in their own institutions.

Schools should appoint a senior member of staff to be responsible for ensuring that gender equality is embedded in the whole school ethos, including careers guidance and choice of subjects at the ages of 14 and 16. It should be the role of this person to work with heads of subjects to ensure that teaching in STEM subjects in particular is designed to appeal to male and female students equally. ScienceGrrl (Zecharia et al 2014) suggests that schools be given funding for these leadership positions.

The second way to address students' perception that STEM is not 'for them' is through contact with **role models and connecting students with mentors**. Research conducted by Ofsted in 2011 showed that role models shape young women's career choices (Ofsted 2011). In terms of STEM, the need for more female STEM role-models has been highlighted by many of the groups campaigning around the issue of women in STEM, including the Girl Guides, ScienceGrrl, the Stemettes, the Women's Engineering Society and Women in Science and Engineering (WISE). Evidence suggests that one-to-one meetings with professionals tend to have a significant impact on girls' career aspirations, and could lead to further opportunities for sponsorship, such as work experience or careers guidance (Ofsted 2011). Although one-to-one meetings are very effective, they are expensive – one alternative is having larger meetings between students and role models. It is also important to emphasize the diversity of role models: they should represent society both in terms of gender, race and background, and also in terms of age – younger, as well as older, role models need to be involved.

The largest number of STEM role models is currently provided by STEMnet's STEM ambassadors, 40 per cent of whom are women.[2] Ambassadors are lower-cost alternatives to one-to-one meetings, but for these meetings it is important that students are exposed to role models on more than one occasion. Meetings between ambassadors and students during school visits should address gender stereotypes directly. Ambassadors should be trained to explicitly improve girls' and young women's knowledge and understanding of the place of women in society, and challenge gender stereotypes with targeted career education.

Together, professional and educational bodies such as the Engineering Development Trust, national academies such as the Royal Academy of Engineering, employer associations such as EEF and the voluntary sector can all help to combat unhelpful stereotypes. Given the current skills shortage and the glaring lack of gender equality within the industry, most of these institutions are already active in helping to promote engineering as a viable career option. Part of promoting engineering includes working towards dismantling stereotypes. For example, WISE recently piloted a discussion workshop titled 'Science: It's a people thing' at the Big Bang Fair, an annual science and engineering fair, where girls were able to freely discuss and dispel myths about women in science. This is now available as a resource for teachers and groups to use.[3] These types of initiatives, if they are effective, need to be supported and amplified across different schools and events. Directly addressing stereotypes about engineers is important if we want to improve the numbers of women entering engineering. We support John Perkins' recommendation that the engineering community as a whole should work together to better coordinate messages about engineering (Perkins 2013).

Challenge 3: Poor understanding of engineering careers and the engineering pathway

Not only do students have a poor understanding of engineering careers, but many families and teachers do not have enough knowledge about science careers in general. Interventions should aim to change the view that science leads to a narrow set of careers – instead, the message should be that science keeps doors open. Given that science capital can determine career aspirations, ensuring that key influencers have enough information is crucial to encouraging more young women to consider an engineering career.

Part of the solution is implementing better career education and guidance from an early age. The ASPIRES project, ScienceGrrl and the Institute of Physics recommend that **careers advice** be integrated into the curriculum from primary school onwards, and learning made more relevant to the realities of STEM industries. This could involve teaching about STEM-related careers in STEM lessons. Some schools may need teachers to receive additional training to raise career awareness, and part of that training could involve creating links between teachers and industry.

In terms of embedding this type of learning in the STEM curriculum, there are already many resources to support industry-relevant, enriched learning. These resources not only teach students about STEM industries and careers, but also increase their enthusiasm for them. There is evidence that girls, in particular, become more engaged in STEM subjects, such as physics, when learning is framed in relation to the 'bigger picture' rather than individual ideas. However, the disparate array of career-related lesson plans, lesson enrichment ideas

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2 http://www.stemnet.org.uk/ambassadors/

3 http://www.iop.org/education/teacher/support/girls_physics/people-thing/page_61998.html

and project-based learning that is available can be overwhelming for schools. Continued support should also be given to the CREST Awards,[4] Tomorrow's Engineers,[5] the Big Bang Near Me scheme[6] and STEM Clubs.[7]

Strengthening links with industry is important to improving students' understanding of career pathways. The government and schools should **encourage greater engagement between employers and students**. Research has found that three or more contacts with employers make a difference in influencing choices. There is evidence that the relationship between schools and businesses could be improved, and that barriers that prevent firms from accessing schools need to be lowered. Part of attracting talent to engineering is ensuring that students understand what a career in engineering involves: access to businesses – through work experience programmes, for example – could help to raise awareness of engineering careers. Local employers could play a greater role in efforts to this end by working with primary and secondary schools and offering young female students real-life contact with the world of engineering. Local firms could also help by offering role models and support schemes such as STEMnet ambassadors. However, as the Education and Employers Taskforce has recommended, better coordination is required to ensure that all schools have links to the engineering community. To facilitate these relationships at local and national level, businesses need to be made aware of entry-point services that can provide them with advice and guidance for engaging with schools. This should be a common system that schools can use, reducing the need for schools to individually negotiate a scheme with each employer, which can lead to patchy and fragmented relationships with employers. These interventions can be facilitated through intermediaries such as the Education and Employers Taskforce's Inspiring Futures programme[8] or Tomorrow's Engineers – organisations that work to bring employers and schools together. A part-time STEM coordinator could also ensure that schools are working with Tomorrow's Engineers, Inspiring Futures or similar facilitators.

Role models can also help to improve students' understanding of engineering careers and the engineering pathway. Teachers' contact with role models or ambassadors from industry could be used to contextualise learning and improve teachers' and students' careers knowledge. Role models (STEM professionals visiting schools) could also be supported by STEMnet to develop longer-term relationships with teachers, act as their link with industry, and give them up-to-date information about STEM workplaces and careers. ScienceGrrl suggests that teachers and ambassadors could talk via alternative communication channels such as Skype and Google Hangouts (Zecharia et al 2014).

Awareness of vocational routes needs to be much better supported. Young women's significant underrepresentation in engineering apprenticeships is likely to be due in large part to families and students having only a vague understanding of apprenticeships, and to stereotypes, which shape a lot of what is understood of apprenticeships. Vocational education is often misinterpreted as a route for less bright students, and as a 'male' route to work. While teachers can help tackle misconceptions about vocational routes, a 2012 survey found that most teachers (52 per cent) were 'not at all confident' about providing information on apprenticeships (Education and Employers 2012), and as a result they are less likely to encourage students to consider vocational routes instead of other educational routes, including A-levels. Furthermore, some schools offer little or no access to firms offering apprenticeships. Teachers require better training to help them understand vocational routes, which would in turn help to expose students to technical

4 http://www.britishscienceassociation.org/crest-awards
5 http://www.tomorrowsengineers.org.uk/
6 http://nearme.thebigbangfair.co.uk/
7 http://www.stemclubs.net/
8 http://www.educationandemployers.org/programmes/inspiring-the-future/

routes. Better contact with employers who offer engineering apprenticeships would also help students and families to understand the paths towards engineering careers.

It is also important to increase science capital among families, and to encourage them to see science as a viable route for their children. Working directly with families would help to improve science capital. Families are more likely to be interested in science careers if they have a better understanding of them, and how they lead to well-paid jobs.

The way that information is presented is important to achieving a better understanding of science-related careers such as engineering, because the way that information is processed varies greatly between groups. Information can be classified as 'hot' or 'cold'. 'Cold' information is presented in traditional ways – via seminars, websites and booklets. This may be effective on its own for middle-class families, or families with high science capital. 'Hot' information, on the other hand, tends to be more helpful in influencing decision-making processes among other groups, including working class families. This information is delivered in more interpersonal ways, such as receiving information from friends or other people in a personal network (ASPIRES 2013). This approach goes beyond mentoring and role-models, and can be more persuasive in influencing students to consider particular careers.

All of the strategies mentioned above should help to ensure that schools and families have up-to-date information. This will require dedicated effort from industry, professional engineering institutions and voluntary organisations. However, these methods should not only be targeted at high-achieving students and their families. In order to effectively debunk the 'brainy' scientist image, conscious effort must be made to make sure that students, families and teachers understand that science is for everyone. Science and maths should be discussed as means of keeping career options open for everyone, not closing them down. Careers advice should be also targeted at groups of students who do not traditionally identify with science, and who may require more tailored approaches.

Challenge 4: The STEM ecosystem is fragmented, which increases the likelihood of duplication

There are currently many disparate state-funded and third-sector projects aimed at encouraging girls into STEM subjects and engineering. However, few of these projects are monitored and evaluated in any meaningful way. This is partly because third-sector projects only receive short-term funding, and long timeframes are required both in order to achieve serious transformations and to monitor and evaluate them. As a result, interventions are duplicated, and much of the potential learning from the interventions is lost. The UK Resource Centre had the level and timeframe of funding required to achieve more sustained results, and to act as a hub to cohere provision addressing gender imbalance in science, engineering and technology, but the current Coalition government decided not to renew its funding. However, STEMnet has government funding until 31 March 2015.

An organisation such as STEMnet should be given funding to act as a hub to coordinate the fragmented provision of interventions, map provision, and organise conferences and networking events to allow practitioners, role models and ambassadors to share good practice. This central body could also maintain contact with independent providers and keep them informed of findings about good practice. It could also better coordinate NGOs and initiatives to collect and share centralised records of good (and bad) practice.

Even if the funding for STEMnet's projects is not continued after 2015, funding should be provided to monitor and evaluate the impact of STEMnet's projects on the A-level and career choices of students that were involved in it, in order to capture some of the longer-term impact of the interventions.

CONCLUSION

These recommendations for action attempt to challenge misconceptions and ignorance about the reality of STEM careers. The key is to change girls' and young women's self-concept, and to widen their aspirations so that they at least consider an STEM career. Keeping more women in the engineering talent pipeline will require many interventions: there is not a single silver-bullet solution for addressing the lack of female engineers, and only pursuing one single intervention is unlikely to have any meaningful impact.

Misconceptions about engineering continue to influence who pursues a career in engineering. Many still consider engineering a 'man's job', and it is associated with a workplace culture that may put off prospective female workers. These attitudes pose real challenges when attempting to correct the gender imbalances in the sector. Better training for education providers and teachers would help to break down unhelpful stereotypes.

To help overcome these barriers to attracting greater female talent to engineering, government, schools and business all have roles to play in influencing career choices and aspirations. We propose a series of actions that could help widen the talent pool. To tackle the lack of students acquiring prerequisite qualifications, Ofsted could expand its criteria to include gender equality. Moving towards broader curricula could also help to retain students on the engineering pathway.

While these actions help to directly address the lack of students acquiring the necessary prerequisites, they are not enough. How people view themselves in relation to science is important in determining their future career choices. As such, strategies to increase female engineers need to address young women's self-concepts. We propose equality and inclusion training for teachers, and access to diverse role models and mentors for pupils from primary school onwards. Better careers advice would help to de-mystify career options in science – again, this should start as early as possible, and be implemented in the primary school curriculum, and it should also involve working with local employers. Because aspirations are in part shaped by family and other key influencers, it is also important to work with families to boost science capital. Increasing science capital would mean that more students and families know that pursuing science keeps doors open instead of shutting them down, and would meant that more young girls will consider engineering as a rewarding and fruitful career option.

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