# Engineering skills for the future

## The 2013 Perkins Review revisited

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Education for Engineering is the body through which the engineering profession offers coordinated advice on education and skills policy to UK Government and the devolved Assemblies. It deals with all aspects of learning that underpin engineering.

It is hosted by The Royal Academy of Engineering with membership drawn from the professional engineering community including all 35 Professional Engineering Institutions, Engineering Council, EngineeringUK, the Engineering Professors' Council and Design and Technology Association and EEF, the Manufacturers' Association.

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## Contributors

**The report was actively supported by the following organisations:**

EngineeringUK

Institution of Engineering and Technology

Institution of Mechanical Engineers

Institution of Chemical Engineers

Institution of Civil Engineers

EEF, The Manufacturers' Organisation

The Engineering Professors' Council

Design and Technology Association

Chartered Institute of Plumbing and Heating Engineering

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# Introduction

**November 2018 marked the five-year anniversary of the publication of *Professor John Perkins' Review of Engineering Skills* by the then Department for Business, Innovation and Skills.**

A great deal has happened in the last five years, both in terms of the environment within which engineers will operate in future and in terms of major changes in the system for the development and supply of engineering talent.

Given these changes, I was delighted to be invited by the Royal Academy of Engineering to lead the development of a follow-on report. Here, we are seeking not only to document developments in the past five years, but also, and more importantly, in the Year of Engineering, to set out new policy objectives in an effort to ensure an adequate supply of engineering talent for our nation.

As with the previous report, this document is the result of a concerted team effort. Indeed, given that we were working to a much tighter timetable than in 2013, a larger team was assembled to work on the project. I am extremely grateful to all those individuals who contributed, almost entirely on a voluntary basis. I hope that the final report does justice to all your efforts.

I would particularly like to thank Maya Desai, whose sterling work played a crucial role in bringing this project to fruition.

**John Perkins CBE FREng**
January 2019

**"A great deal has happened in the last five years"**

John Perkins CBE FREng

# Foreword

## Engineering 4.0 – what next for engineering skills?

It's incredible to think that five years have passed since the landmark Perkins Review was published, landing on Ministerial desks and across UK PLC boardrooms alike. I remember its launch well and the impact it had right across our engineering sectors. We should commend what Professor John Perkins achieved in highlighting the urgent need to upskill our engineering workforce, and the way in which engineering skills have since been an important policy plank of the government's education plans.

But it is right that we revisit this work and ask ourselves the important and searching questions – have we got the strong supply of engineering skills we need for the decade ahead? Are we ready for a Made Smarter fourth industrial revolution? Are we ready to create 'new innovation' jobs that replace those we displace?

Let's start with the good news. Firstly, we have a national consensus and indeed a government strategy to boost engineering skills, led by industry. Few now disagree with the need for a strong integrated engineering skills system. There is increased awareness of the need for more STEM graduates and pupils, fuelled by the 2018 Year of Engineering. We've seen Tomorrow's Engineers successfully engaging employers across the country, reaching over 300,000 young people in the last year alone. The Careers & Enterprise Company has been created as part of the government's Careers Strategy connecting employers and colleges to source engineering talent. Our UK Catapult Network continues to inspire young people with technology. Engineering degree apprenticeships and better employer engagement have created the foundations we need to develop an engineering talent pipeline for the future. And on top of this there has been the This is Engineering campaign launched this time last year by the Royal Academy of Engineering, presenting a positive image of engineering to 13–18-year olds via social media platforms. All of which is boosting the standing of engineering across the UK.

Many of these success factors stem directly from the recommendations found in the 2013 Perkins Review. This should be celebrated by the Royal Academy of Engineering with pride. But more needs to be done, and we are not close enough to where we need to be as an engineering nation ready for a fourth industrial revolution.

Firstly, we need to put rocket boosters under our collective efforts to make engineering more inclusive. There are still nowhere near enough young women and girls entering our profession. This also applies to UK Black Asian and minority ethnic (BAME) communities too. We are still not representative of wider society – and that has a knock-on impact when attracting young talent, and why we still do not have enough young people studying STEM subjects.

For example, the uptake of physics at A level remains stubbornly low at around 35,000. Just 5% of the typical annual cohort. For girls just 7,000, which is 2 to 3% of the annual female cohort. This must change, and we must galvanise our imagination to become more inclusive, diverse and open.

On top of this we must ensure a constant and stable education system that produces many more engineers to meet our societal demands. There have been too many policy changes, and still too much fragmentation and complexity embedded into our education system. Let's do more to join this up, working in partnership with government.

And let's be honest, our education system is chronically underinvested in too. We need to invest more in our young potential engineers, critically preparing them for the wave of economic disruption that digital technology will create. Put simply, we need more STEM teachers in our system to inspire and create more opportunities for young people. And we all know our impending exit from the EU – however it transpires makes this issue more, not less acute.

Lastly, let's also focus on the existing workforce ensuring they are ready for digital disruption and can prepare to take on new roles in programming and digital design. Better vocational training for adults is a necessity for UK PLC. That's is why getting our Catapults engaged in workforce training is tremendous for embedding best practice on a practical level for millions of engineers in the UK. Getting more buy-in from Westminster is therefore critical, so developing better leadership with a Ministerial lead to coordinate this complex landscape better, is a simple but effective ask.

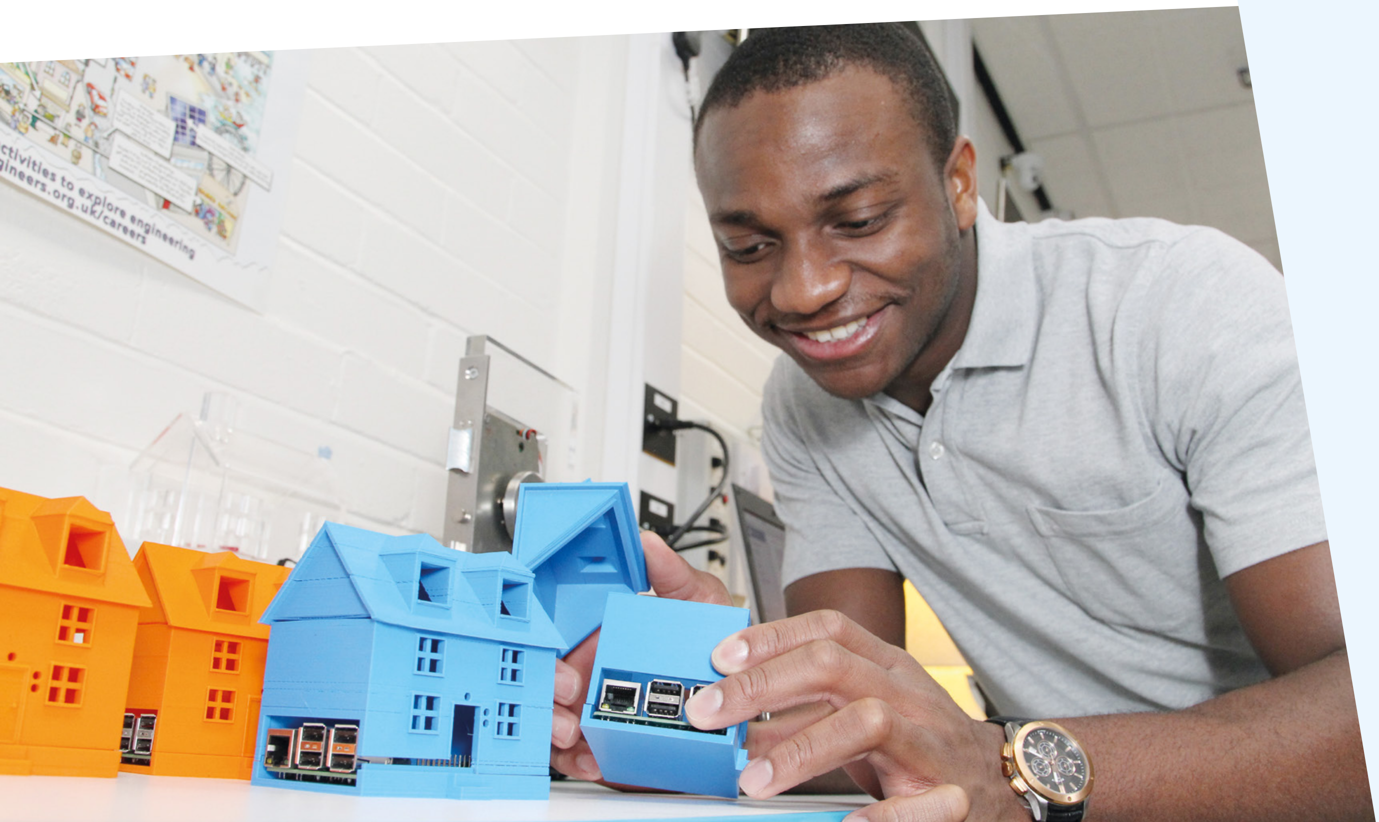
My message to those of you reading this report and revisiting the first review of 2013 is simple and straightforward. We need a national endeavour to promote the virtues of engineering, but the only credible way to do that is by making our profession inclusive and ready to embrace a fourth industrial revolution. I believe if we stay focused, deliver some of these recommendations working in cooperation with government, we can prepare new and existing workers for the positive disruption the next industrial revolution will create.

Let's not waste any time and let's make this a reality for the 2020s!

**Professor Juergen Maier CBE FREng**
January 2019

**"We need a national endeavour to promote the virtues of engineering"**

Professor Juergen Maier CBE FREng



# Executive summary

**It is five years since the publication of the first *Perkins Review of Engineering Skills in 2013* by the (then) Department of Business, Innovation and Skills. Five years on, and during the 2018 Year of Engineering, the engineering profession has examined the progress made by government and the engineering community in addressing the supply of skills for engineering in the UK.**

Engineering is a precious national asset for the UK. It is the ultimate people-focussed profession, working to devise the solutions to many of today's global challenges including clean, affordable energy, ensuring safe and resilient infrastructure, supporting advanced healthcare, mitigating the effects of climate change and keeping people connected in an increasingly digitised world. It is a broad and meritocratic profession that welcomes all kinds of talented people, regardless of their background.

The original review framed the supply of skills as a leaking pipeline system and recommended interventions across a number of areas designed to reduce 'leakage', increase the flow of young people pursuing careers in engineering and ensure those that did were as well equipped to do so as possible.

In reviewing the past five years, the engineering community should hold itself, as well as government and others, to account where progress has not been good enough. Despite significant effort, the available data strongly suggests a shortage of engineers and a worrying stagnation of young people opting to study post-16 the subjects that lead to engineering careers. The historic focus on STEM as a concept may be part of the issue here, as the broad term has masked specific challenges related to subjects such as physics, design and technology and computing. Linked to this and despite some progress indicators, engineering, physics and computing all struggle in recruiting outside the traditional archetypes of white males. Women and people from a variety of minority backgrounds remain vastly and unacceptably under-represented across the broad spectrum of engineering and technician roles. There is a clear business case for a more inclusive engineering profession to attract and retain a more diverse engineering workforce. Professional bodies and engineering employers must take a long-term, data-driven and evidence-based approach to addressing this issue.

There have been some notable recent developments called for in the original review such as the new overarching *This is Engineering* campaign and the recent work of the professional engineering institutions (PEIs) and wider engineering community in partnership with EngineeringUK and the Royal Academy of Engineering to bring greater coherence to school engineering inspiration activities. The government's 2018 Year of Engineering campaign has also given impetus to improved coordination. However, the momentum generated must be maintained, and key elements must be embedded in the education experience of every young person including greater contextualising of the curriculum and improved careers education, not only to prevent further compounding of the engineering skills shortage but to ensure that everyone with the potential to become an engineer has every opportunity to pursue that path.

The full ramifications of the decision for the UK to leave the EU are still unclear, but it has brought into stark relief the importance of nurturing domestic engineering skills. However, the length of time required to enable skills' policies and initiatives to translate into producing fully trained engineers means that, for some time to come, there will be a continuing reliance on imported engineering skills alongside a focus on developing home-grown engineering talent regardless of the outcomes of the UK's shifting position on exiting the EU.

Overall, the aims of this Review remain the same as that of 2013: our education and training systems are the foundation on which our economic success and future security depend. The quickening pace of technological advancement and its effect on our society, heighten the need to ensure that all young people develop the broad range of technical, communication and problem-solving skills that will serve them and our society over the coming decades, both as wealth creators and as citizens. This includes nurturing practical skills and creativity, alongside the development of enabling skills such as complex problem solving and critical thinking and professional behaviours such as ethical consideration and environmental awareness, increasingly identified as critical by employers.

Delivering the government's industrial strategy relies on a strong cohort of people with engineering skills and the very nature of engineering is changing due to increasing digitalisation, which in turn requires an upgrading of the digital skills of engineers and technicians to capitalise on the opportunities offered by the fourth industrial revolution. We therefore need to look at the fitness for purpose of our education and technical training systems not only in schools, colleges and universities, but perhaps more importantly than ever, in lifelong learning and professional development activities to meet this exciting challenge.

For this reason, as well as examining progression on the three original areas covered five years ago, there is additional focus on workforce development.

**"The full ramifications of the decision for the UK to leave the EU are still unclear"**

## Academic foundations and inspiration

There are still key issues in schools that have a significant impact on the number of students that go on to study subjects towards engineering. There continue to be shortages of specialist subject teachers in mathematics, physics, computing and design and technology. In many respects the situation has got worse as there is an increasing problem with the retention of existing teachers and persistent failure to recruit sufficient numbers of graduates into teaching these facilitating subjects. The 2013 review called for government to focus on teacher recruitment, yet in that time the situation has arguably worsened. The Department for Education must get a grip on this situation before it becomes entrenched.

Accountability measures on schools in England favour a narrow set of academic subjects leading to a continued fall in the number of students studying creative, technical subjects such as design and technology that are important in the formation of engineers. There have been welcome increases in the number of students taking A level mathematics, but the uptake with physics remains stubbornly low at around 35,000. This is around 5% of the typical annual cohort. For girls, the figure is around 7,000, which represents between 2% to 3% of the annual female cohort. Five years on from the original review, this remains a persistent issue. For Black, Asian and minority ethnic (BAME) groups however, there is good representation in physics (24%) against the cohort (22%).

The issue of subject selection at age 16 for A levels across England, Wales and Northern Ireland, continues to drive a divide between 'science' and 'arts' that results in too many young people opting out of subjects that lead to

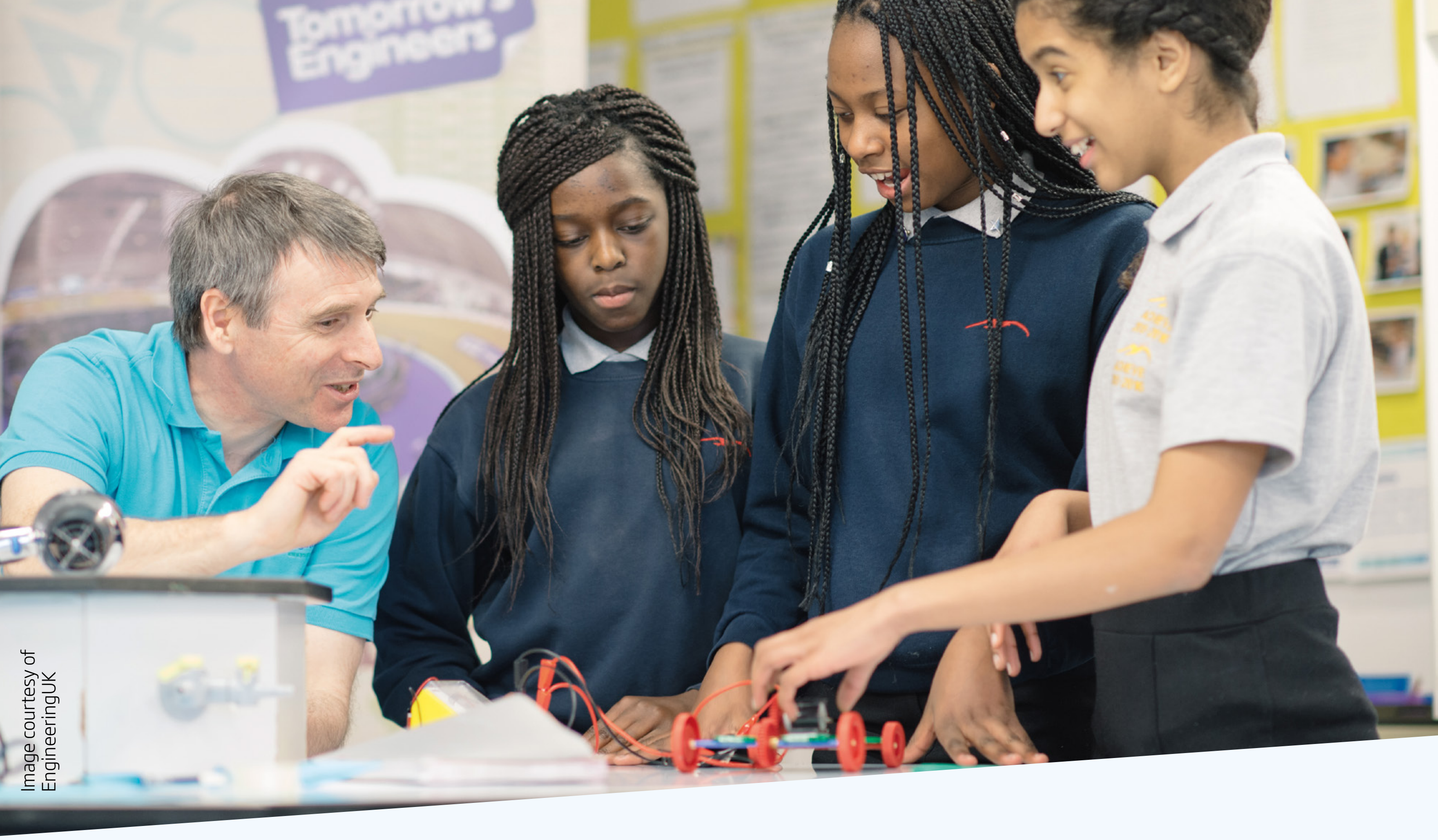



Image courtesy of EngineeringUK

**"Engineering continues to remain largely invisible in the school education system"**

engineering and other creative, technical careers, before they have explored the opportunities that those roles provide. The government's industrial strategy and the increasing digitalisation of the economy now make a compelling case for the Department for Education to undertake a fresh review of the Post-16 academic pathway with a view to introducing a more broad and balanced curriculum such that all young people study mathematics, science and technology subjects along with arts and humanities to the age of 18.

Where there has been progress made with the curriculum this should be recognised. In England, the new curriculum for computing, for example, has significantly increased the focus on computer science, programming and computational thinking. There are substantial challenges with teacher professional development that the government has acknowledged with new funding for a national centre for computing education. Similarly, the design and technology curriculum is now very progressive and reflects modern engineering design thinking and manufacturing practice, however teacher support is seriously lacking given the low status in schools of the subject. Across the devolved nations, there are welcome developments to broaden the curriculum such as the Welsh Baccalaureate which now develops problem solving, critical thinking and wider employability skills in pupils.

Engineering continues to remain largely invisible in the school education system, other than in specific provision such as university technical colleges (UTCs), which are currently inadequately supported. To address the general issue of school engineering engagement the professional engineering community and wider engineering sector have been delivering well-intentioned school inspiration activities for many years and this has led to a complex and confusing landscape. A 2015 Royal Academy of Engineering report highlighted over 600 third sector organisations supporting STEM engagement in schools. The 2018 Year of Engineering has helped to bring organisations together and we must now build on this to ensure all schools across the UK are supported. All bodies providing and supporting *engineering* inspiration activities in schools must continue this collaborative approach and support the work of EngineeringUK and the Royal Academy of Engineering to coordinate activity across the education system to ensure it has the greatest possible impact. A key additional challenge to be addressed is the development of a consistent evaluation framework to understand what works in engineering inspiration activities to ensure that programmes genuinely make an impact are properly supported.

## Technical education

It is in the realm of technical and vocational education that there have been the most significant changes since the 2013 review with developments such as the Apprenticeship Levy, new apprenticeship standards and the Post-16 skills plan with the impending introduction of T levels. It is too early to tell whether these reforms will be successful, but it is essential that the engineering community support them, as the further education sector has, for too long, suffered continuous, disruptive stream of reforms with little opportunity to assess their effect. The new T levels and apprenticeships must be given time to work.

For T levels, the prime concern is the years of under-investment that have left the further education sector in a financially parlous state. The government is giving a welcome funding boost to the further education sector for T levels, but this is in the context of many year-on-year reductions to 16–18 education funding. There will be challenges around ensuring sufficient numbers of specialist teachers and lecturers to deliver T levels. In addition, we have concerns that the curriculum, intended to be based on apprenticeship standards will be too narrow and not equip students for a broad range of engineering careers, and that the proposed 45-day work placement will be unworkable for many engineering employers.

There have been welcome increases in the number of people undertaking engineering apprenticeships since 2013, though female and ethnic minority representation are abysmally low, at 6% and 8% respectively. Disappointingly, over the last five years the majority of apprenticeships in engineering have been at lower skill levels equivalent to GCSE. Also, the majority of apprentices are aged 19 and over, suggesting that the pathway is currently supporting upskilling of the existing workforce, rather than increasing the pipeline of talent into the sector from school.

Apprenticeships have undergone significant reform since 2013, with the implementation of new employer-led standards, a move to synoptic end-point assessment rather than continuous assessment and the introduction of the Apprenticeship Levy. These have been challenging adjustments for engineering employers who have long championed apprenticeships. The engineering community will no doubt continue to support apprenticeships as employers regard apprentices as being competent, highly valuable and loyal to the business.

Overall, a determining factor in the success of technical education over the next ten years will be the strength of the government's continuing commitment for technical pathways to receive the same respect and prestige as academic routes. There is a once-in-a-generation opportunity to get this right. While it is still relatively early in the implementation of the new reforms, the Institute for Apprenticeships and Technical Education, the Department for Education and engineering employers must all recognise that this is work in progress, be flexible and not fixed on decisions that do not ultimately benefit the individual, businesses and the economy. We must collectively ensure the reforms for this highly valuable skills route are working as effectively as possible.

## Higher education

There has been a welcome positive upward trend in the number of undergraduate engineering students since the last review, though again female representation remains stubbornly low at 15%. BAME students are well represented, at around 26% of the cohort. However, students from lower socio-economic backgrounds are not particularly well represented in engineering (10%) compared with the higher education sector on average (12%). Contrary to a widely held view, the employment of engineering graduates in *engineering occupations* out of those who find work six months after graduation is very high, at over 80%. The transition of female graduates into engineering occupations is similar to males, at just under 80%. However, despite good representation in the undergraduate cohort, BAME students are significantly less likely to find employment in engineering occupations compared to their white counterparts.

In general, most engineering graduates find employment in engineering industries, though many are employed in roles across a variety of sectors including retail, healthcare, finance and entertainment, demonstrating the value that engineering skills and attributes bring to the wider economy.

International students are important for universities and represent around 40% of the total engineering cohort across undergraduate and postgraduate studies, making an important financial contribution both to the higher education sector and the economy. They can also play an important role in filling the skills needs of industry. The government's immigration white paper is therefore very welcome in offering international students greater opportunities

Image courtesy of Brunel University

to find post-study work in the UK. The engineering community does have some ongoing concerns however, specifically the very high £30,000 threshold for five-year visas which would exclude many international graduates working in engineering roles, despite the relatively high early career salaries paid to engineers compared with other professions.

Since the last review, many university engineering departments across the UK have been active in developing innovative teaching practices including; increasing employer engagement, greater team-working and project-based learning approaches, application of engineering to addressing 21st century global challenges and so on. These are all helping to improve the readiness of engineering students for industry but also to highlight the wider role engineers have in supporting society. An interesting development is the increase in the popularity of general engineering degrees. Whatever the cause of this, general engineering provides a useful foundation for the highly inter-disciplinary world in which graduates will enter. It is important that all university engineering departments recognise this inter-disciplinary shift in industry practice, in particular with increases in digitalisation, and shape their programmes to train their students accordingly.

The key concern among the engineering higher education community at present is the outcome of the Post-18 funding review. Engineering is a high cost subject and an increase in fees would seriously damage efforts to increase the number of young people studying it, which would have significant repercussions for the industrial strategy. Whatever the outcome of the review, government must recognise the importance of engineering to the economy and to its industrial strategy. As such, it must be prepared to increase top-up grant funding to ensure that otherwise financially stable engineering departments remain sustainable.

**"International students are important for universities and represent around 40% of the total engineering cohort"**

## Upskilling the existing workforce

The last five years have also seen the fourth industrial revolution gather pace. We must ensure we are future proofing our education and skills system by preparing people for these changes. This also means a much greater focus is needed on the existing engineering workforce and their capacity to engage with and further develop these technological advances. The majority of the engineers and technicians of 2030 have already left the education system. UK industry, the engineering profession and government need a major shift in their collective commitment to supporting lifelong learning and professional development to ensure workers continue to develop new skills in an increasingly technology-driven world.

## A call to action

The 2018 Year of Engineering was a major step forward with government, professional bodies, industry and the wider community coming together in an unprecedented manner to celebrate the pivotal role engineering plays in shaping our world and encourage more young people to join the profession. It is vital that we seize this opportunity and build on the momentum generated to create a sustainable legacy for engineering.

There is a unique opportunity in 2019 for government to demonstrate its commitment to the industrial strategy and to ensuring the UK's strong position in the world outside Europe. This requires significant investment in education and skills for engineering across all phases of education in the 2019 spending review. The recommendations overleaf will be key to ensuring the UK is on the right path to meet its ambitions in the global competitive landscape.

# Recommendations

**Recommendation 1:**

The government should continue to provide visible leadership on engineering skills and nominate a Ministerial lead for engineering skills to be supported by an additional Member of Parliament as an "Engineering Champion" and convene a Ministerial advisory group of engineering stakeholders to address the long-standing skills and diversity challenge in engineering. Devolved administrations should also identify named representatives to lead on engineering skills with which the engineering community can engage.

**Recommendation 2:**

It is vital that the engineering profession draws from the full talent pool. To do this, employers should take an evidence-based and data driven approach to improve recruitment and increase retention and progression of underrepresented groups within organisations. This should include setting recruitment targets to increase diversity in their workforce.

**Recommendation 3:**

Employers, charities, universities and third sector STEM engagement providers should support the current initiative by led EngineeringUK and the Royal Academy of Engineering to drive coordination, simplification and quality of school engineering-inspiration activities through the re-positioned Tomorrow's Engineers programme.

The engineering and education communities should recognise the value of supporting a collaborative approach and rally behind this initiative with a commitment to sign up to a Code of Practice, designed to encourage signatories to work together around a common goal – a coherent vision for inspiring a broad diversity of future engineers. Signatories of this code, including companies, professional bodies, universities, government, third sector and other organisations, should commit to a shared vison through a series of pledges to raise the quality of engineering-inspiration activity, reduce duplication and improve coordination.

**Recommendation 4:**

The community of engineering 'inspiration' providers and funders should agree to use a standard evaluation framework that measures the impact of their interventions in schools for students of all backgrounds. The framework should be sufficiently flexible to incorporate existing approaches and suit individual contexts. This will provide stronger evidence to determine which engagement is most effective in bringing about changes likely to influence young people's educational and career choices – and enable audiences, funders and delivery organisations to make more informed decisions about deploying their resources.

**Recommendation 5:**

As part of the government's industrial strategy, it is timely for the Department for Education to carry out a major review of the Post-16 academic education pathway for England, with a view to creating a broad and balanced curriculum that provides young people with opportunities to study mathematics, science and technology subjects along with arts and humanities to the age of 18. This will encourage a larger and more diverse entry into further and higher engineering education.

**Recommendation 6:**

The government must undertake a wide-ranging review of issues around teacher retention. It should also review perceptions of teaching as a profession among graduates and address barriers to entry. As part of the review, it should examine opportunities with school-leaders, unions and employers to introduce braided-careers for dual teaching-industry professionalism, where professionals from other sectors spend part of their time teaching.

**Recommendation 7:**

The government must do more to support teachers' subject professional development. Teachers who experience high-quality professional learning are more likely to continue teaching for longer. Government and devolved administrations across the UK should introduce a requirement that teachers of mathematics, science, design and technology and computing have a protected entitlement of 40 hours of subject specific continuing professional development every year, with ring-fenced funding.

**Recommendation 8:**

University Technical Colleges (UTCs) lack an established place in the education landscape; the Department for Education should review the UTC programme, make a decision on the future of the model and provide the necessary support for existing UTCs whatever the outcome.

**Recommendation 9:**

The government must ensure its funding mechanism for further education colleges reflects the higher cost of providing engineering programmes such as the new T levels in engineering and manufacturing and in construction and built environment and thus can absorb the anticipated surge in demand.

**Recommendation 10:**

T levels in engineering and related subjects should provide a broad technical education for post-16 students. The Institute for Apprenticeships and Technical Education must ensure that the content of new T levels across engineering disciplines provide sufficient breadth in their core content to enable mobility of college students to a wide range of future options, including apprenticeships *outside* their specialist subject areas and higher education routes, should they wish to choose them.

**Recommendation 11:**

Current conditions on employer spending on their Apprenticeship Levy contributions are highly restrictive. Government should give employers greater flexibility on their skills spending to include funds to support other forms of high quality training provision.

**Recommendation 12:**

UK universities must remain a world-leading and popular destination for international staff and students. To this end, the government should ensure the UK remains within international study partnerships and minimises the hurdles to obtaining a visa for these purposes.

The government should also increase the length of time for post-study work visas to two years to be in line with competitor nations attracting international students into higher education.

**Recommendation 13:**

The government must ensure that engineering and associated high cost subjects in higher education are not adversely affected by the outcomes of the Post-18 funding review. government must ensure engineering courses are adequately funded with increased top-up grant if tuition fees are to be reduced.

**Recommendation 14:**

The increasing digitalisation of all aspects of engineering requires the up-skilling and re-skilling of engineers and technicians. The Engineering Council and PEIs should develop a coherent approach to the professional development of engineers and technicians, both within and outside of membership, to maximise benefits of the new digital paradigm.

**Recommendation 15:**

To maximise productivity gains, the engineering workforce must be fully capable of exploiting technological advances. To this end, Catapults' remit should formally include workforce development and upskilling as a natural corollary to their role at the forefront of technology development.

# Progress since last review

**Red:** Limited progress made since 2013

**Amber:** Some progress made since 2013

**Green:** Significant progress made since 2013

| Original recommendations | Progress to date |
|---|---|
| (Amber) The engineering community, including all the PEIs, should join in partnership with Tomorrow's Engineers, to agree effective core messages about engineering and cooperate to disseminate these messages to young people. | (Amber) Under Tomorrow's Engineers, EngineeringUK, the Royal Academy of Engineering and the wider engineering community are working to bring together impactful engineering programmes into one go-to place to making it easier for teachers to build a sustained engineering engagement journey for their students. As part of this initiative, the community is also working to drive the quality and reach of outreach by investing in and scaling proven programmes and activities. |
| (Green) Government should provide seed funding to develop nationwide roll-out of the Tomorrow's Engineers employer engagement programme. | (Green) The seed funding government provided to support the Tomorrow's Engineers employer engagement programme led to a successful national roll-out, with EngineeringUK providing dedicated employer support managers in all regions of the UK. Building upon the success of this and the knowledge and expertise gained, EngineeringUK will shortly be launching its Employer Skills Partnership, which aims to increase employer-led engagement, impact and coordination at the national, regional and local level. |
| (Green) Government should also encourage and help schools and colleges to connect with employers. | (Amber) As part of the government's Careers Strategy, engineering businesses will provide Enterprise Advisors to support the work of careers leaders within schools, including funding and access to industry experience. |
| | (Green) The Careers and Enterprise Company, set up as part of the government's Careers Strategy, continues to deliver the Gatsby benchmarks, focusing on connecting educational establishments with employers. |
| (Green) A high-profile media campaign reaching out to young people, particularly girls aged 11–14 years old, with inspirational messages about engineering and diverse role models, to inspire them to become tomorrow's engineers. The engineering community, should take this forward as an annual event. | (Green) *This is Engineering* campaign was launched in January 2018 by the Royal Academy of Engineering[1], to present a positive image of modern engineering to 13–18 year olds via social media platforms[2].<br><br>Two seasons of viral campaigns have been released with 28 million views. |

| Original recommendations | Progress to date |
|---|---|
| Government should ensure that the Royal Academy of Engineering and the Institute of Physics are fully engaged during consultation on revisions to A-level physics to ensure that the new A-levels will provide a sound foundation to progress to degree-level study in engineering. | Neither organisation was directly engaged by the Department for Education during revisions to A level physics. The Royal Academy and Institute of Physics produced a report in 2015[3] on the uptake of physics A Levels at school, in the wake of the government consultation on physics, closing in 2015. |
| Government should continue to support schools to increase progression to A-level physics, especially among female students. | The government has funded the Improving Gender Balance project (as part of the Stimulating Physics Network) which has had some success in increasing female A level physics uptake in selected schools[4]. A new trial is scheduled in 2019. |
| Government should focus on teacher recruitment to shortage subjects and also promote physics with maths to schools involved in teacher training. | Challenges with recruitment remain and teaching vacancies exist in shortage subjects such as design and technology, physics, maths and computing. Teaching bursaries are currently offered by the government for Physics and maths teachers, who can receive up to £26,000 to train[5].<br><br>The Further Forces Programme retrains ex-service professionals as teachers in priority subjects (maths, physics, computing etc)[6] and the DfE funded STEM International Recruitment Programme funds recruitment and acclimatisation for teachers from the US, Canada, New Zealand and Australia.<br><br>There is no promotion of maths and physics as a subject combination for teacher training. |
| The engineering community should provide continuing professional development for teachers, giving them experience of working in industry to develop the knowledge to put their academic teaching in practical context, enlivened with practical examples, as well as enabling them to inspire and inform their students about engineering. | The Project ENTHUSE STEM Insight scheme has delivered 231 industry and higher education placements for teachers.<br><br>The IOP's Future Physics Leaders project has created 24 lead-schools to drive improvements in Physics teaching. |

**Red:** Limited progress made since 2013

**Amber:** Some progress made since 2013

**Green:** Significant progress made since 2013

| | Original recommendations | Progress to date |
|---|---|---|
| Amber | Developing and promoting L2 and 3 qualifications to create high-quality vocational routes for 16 to 19 year olds | T levels which will replace all publicly funded vocational qualifications at Level 3 and are intended to provide a high-quality alternative to A levels.<br><br>Additional transition support will be offered to those who do not achieve sufficient level 2 entry criteria. |
| Amber | The engineering community should work with employers to encourage and support provision of work experience for post-16 students, studying in colleges and schools. | Within T Levels there will be a 45 day work placement (subject of discussion in this report).<br><br>The government has advised education providers that work experience should form an essential part of all 16–19 programmes of study[7] but there are significant practical barriers to this.<br><br>Tomorrow's Engineers provides guidance for employers on creating meaningful work experience. |
| Amber | Government should develop plans to boost diversity of engineering apprentices, building on the pilots and research commissioned by the Skills Funding Agency. | The government has created the Apprenticeships Diversity Champions Network, which a specific aim to increase the number of women in Engineering apprenticeships. This has resulted in the launch of the 'Woman into Apprenticeships' toolkit and 'Woman on the Tools' programme[8]. |
| Red | Government should build on the UTC experience and seek to develop elite vocational provision for adults so that our people have the opportunity to learn the very latest techniques and approaches in a vocational setting. | The new Institutes of Technology proposed in the 2015 productivity plan[9], and the Industrial Strategy Green Paper[10] will focus on skills at Levels 4, 5 and possibly Level 6 and above[11]. |
| Amber | Engineering employers should encourage their staff to share their skills and knowledge, for example, by participating in the Education and Training Foundation's Teach Too scheme. | The Teach Too scheme, encouraging mutually beneficial collaboration been teachers and industry remains a success. In addition, a number of employers work with STEM Learning to offer placements for teachers. This particular model funds the school to ensure that teachers can be covered for during the one to two weeks they are in industry. |
| Amber | Government should review funding arrangements for engineering degree courses to ensure that it is financially sustainable for HE institutions to deliver high quality engineering programmes. | The Auger review into higher education provision in England (to be published early next year) is looking into the issues of access, quality, choice and value for money for all higher education courses, including engineering.<br><br>Similar reviews have taken place in Scotland (Audit of Higher Education) and Wales (Diamond review). |

| Original recommendations | Progress to date |
|---|---|
| Government should ensure that the £200 million teaching capital fund encourages diversity by seeking evidence of commitment (e.g. through Athena SWAN registration) as a prerequisite for receiving funding. | Changes to regulation and the merger of ECU into AdvanceHE may have compromised this solution.<br><br>The funding provided under the now disbanded HEFCE has since ceased. No evidence has been found in relation to the allocation of this funding based on diversity metrics. |
| Higher education institutions should work with government and commercial banks to ensure their students are aware of Professional Career Development Loans. | Postgraduate loans have been introduced and student numbers are being maintained largely through international students and are thus highly sensitive to changes in migration and visa policy. |
| The engineering community should develop concerted engagement with university students, including work placements to raise the profile of engineering careers and ensure that students on every campus are aware of the full range of diverse opportunities with engineering employers, large and small. | Employability is a growing theme within universities. TEF measures employment in effort to encourage measures.<br><br>Degree apprenticeships represent innovation in the employer/HEI relationship, but the numbers of those accessing them are still small when compared to the numbers of university entrants (approx. 10,000 new DA starts last year[12]). |
| Engineering employers should explore the potential for developing cooperative cross-sector schemes to support postgraduate students. | There are examples of good practice here but so far nothing on a national scale.<br><br>The EPSRC has programmes that provide postgraduate students with projects with real life applications and links to industry. |
| Government, through EPSRC, should seek further evidence of unsatisfied demand for engineers trained to doctoral level, and review arrangements for the support of PhD students in the light of their findings. | EPSRC has recently implemented a further round of Doctoral Training Centres. Anecdotally, the response from industry has been comparable to the previous round. |
| Government should invite employers to put forward innovative proposals to develop engineering skills in sectors suffering acute skills shortages. | There have been some promising sector developments such as the National Skills Academy for Nuclear and the National Skills Academy for Rail. The industrial strategy championed sector deals, such as that for artificial intelligence also have the potential to focus on specific areas of short skills supply. |
| Government should support the Daphne Jackson Trust to extend and develop their fellowship model to support people returning to professional engineering after a career break. | The Trust determined that this extension would lie outside of its current remit. Returnships are being considered by a variety of organisations. |

# Engineering skills supply and demand: a system overview

The UK continues to experience an engineering skills challenge. Precise measurement of skills shortages is inherently difficult. Since the 2013 review significant progress has been made in improving the accuracy of analysis for engineering skills supply and demand estimates. EngineeringUK, the Engineering Council and the Royal Academy of Engineering have undertaken a robust process to define engineering industries and occupations so that analysis across the community is standardised and consistent[13]. Based on this footprint, the number of engineers and technicians in the UK has been identified through analysis of the Office for National Statistics Labour Force Survey; it is estimated that there are around six million people working in engineering and technology roles across all sectors of the economy[14].

EngineeringUK has used this footprint to analyse government *Working Futures* forecasts for employment[15], and it estimates that 124,000 engineers and technicians are required every year to meet current and future demand for 'core engineering' roles to 2024. While some have questioned this demand using anecdotes of unemployment and low pay, a simple calculation of the six million engineers and technicians divided by a typical 50 year career lifespan would suggest an annual requirement of 120,000 engineers and technicians based solely on demographics to replace those leaving the sector due to retirement[16].

It is true however, that this national aggregated demand can hide specific skills needs in particular sectors, such as high integrity welders for the nuclear sector, or systems engineers for the aerospace and defence sectors. Indeed, the high demand for engineers is given increased impetus by the fast pace of technological change which is also driving a fundamental change to the nature of the skills demands[17]. Estimates suggest a growth of 157,000 new jobs in big data for example by 2020[18]. The *Made Smarter* review of industrial digitalisation predicts that within 20 years, 90% of all jobs will require digital skills and identifies the greatest barrier to industrial digital technology adoption as the lack of skills. Advances in digital technologies are widely predicted to lead to an hourglass economy where the middle tier of blue-collar and white-collar occupations is squeezed with growth for highly skilled roles[19]. In recognition of the need to understand the demand for engineering skills at a more granular level, EngineeringUK has recently published a detailed analysis of the *Working Futures* forecast at the regional, sectoral, and occupational level[20].

Current analysis of the shortfall is based on the number of people entering engineering from further and higher education and Level 3+ apprenticeships against this annual demand. EngineeringUK predict an annual shortfall of between 37,000 and 59,000 in meeting the annual demand for 124,000 engineering roles requiring Level 3+ skills[21]. The importance of closing this gap remains clear; engineering related businesses cite the difficulty in recruiting staff with the right skills as the biggest single barrier to achieving their business objectives over the next three years[22].

## Skills challenges with leaving the EU

The difficult task of predicting changes in engineering skills supply and demand is further complicated by uncertainty over Brexit. A significant proportion of the engineering workforce originate from the EU, a supply source that is sensitive to any changes in mobility and migration rules. It is hard to predict at this stage exactly what the effect of future migration legislation will have on the supply of engineers from abroad although restrictions in labour flow are widely expected. ONS Labour Force Survey data suggests that 7.7% of those employed in UK engineering sectors are EU nationals[23]. This equates to 560,000 jobs that, depending on immigration policy post-Brexit, may need filling at short notice.

The Shortage Occupation List, a barometer of the extent of UK engineering's need for migrant workers, has had around 50% of its content consisting of engineering jobs consistently since 2013[24]. Changes that increase the duration or cost of visa applications from the EU or increase the cost of studying in the UK for an EU citizen are highly likely to significantly reduce the inflow of talent from the EU and increase the skills gap.

While it is hoped that exiting the EU acts as a stimulus to focus both government and industry on the need to develop a home-grown workforce, the rapid pace of technology development in industry combined with the length of time to fully train qualified engineers and technicians means that it is impossible to fill all engineering skills gaps in the near term only by increasing UK domiciled engineers and technicians.

Until a final Brexit arrangement for the UK's relationship with the EU is agreed, it is difficult to predict what will happen although indications are the end of EU free movement. The significant monetary and administrative burden in recruiting from outside of the EEA has been well documented elsewhere[25]. There are also concerns about the Tier 2 visa's over-reliance on salaries as a proxy for skills and seniority, and not enough account is taken of the non-financial characteristics of the job[26]. It is also unclear as to whether there would be quota system for the number of visas issued. A Migration Advisory Committee report recently called for the current cap for non-EU skilled workers to be scrapped[27], following the visa limit being repeatedly reached over several consecutive months earlier in 2018.

If the current immigration provisions were extended to accommodate EEA nationals, there is a substantial risk that this could negatively affect UK businesses' access to the flexible, projectbased workforces that they need. Instead, in considering new immigration arrangements for EU nationals once the UK has left the EU, the opportunity should be taken to streamline the wider, global system to improve speed and efficiency. Improvements in the current system, particularly with regard to timing and cost would be welcomed by the engineering community.

There is of course, an alternative possibility with Brexit, with the risk that many engineering businesses may suffer which may in turn cause redundancies across the sector. The Chartered Institute for Professional Development (CIPD) predicts that one in five manufacturing jobs in the UK could disappear[28]. It is therefore extremely difficult to make any accurate predictions about non-UK skills supply and additional demand for engineers and technicians at the current time.

## Diversity in engineering

It is vital that the engineering profession draws from the full talent pool to help meet the anticipated skills need. Not only is this necessary for equality for opportunity, but there is a clear business imperative for organisations to be able to draw on the abilities of a diverse workforce to generate the ideas and products that will ensure the UK continues to compete globally[29]. Given engineering's role in shaping the world around us, it is vital that the engineering workforce broadly reflects the diversity of society to ensure that what is designed, developed and made meets the needs of the many, not the few.

**Figure 1** highlights the diversity challenge facing engineering. The engineering workforce is just 12% female contrasted with 46.9% of the overall UK workforce. 8.1% of the engineering workforce is from ethnic minority groups (compared with 12.7% in non-engineering sectors, and 12.2% of the broader population). In the 21st century, the continuing lack of representation in engineering is unacceptable. It is important that the different points where females and people from BAME communities are being lost to engineering are identified as they ultimately contribute to the underrepresentation of these groups in the engineering profession.

There is significant work across the engineering profession to address these long-standing issues. WISE, a body which works to promote women in science and engineering roles has developed a 'ten-steps' campaign, to ensure that women across engineering, technology, manufacturing and science have the same opportunities for career progression as their male counterparts. The Royal Academy, in collaboration with engineering employers has developed the Inclusion Recruitment Toolkit[31] to support employers to review their recruitment and selection processes and thus reduce the opportunity for bias and to ensure an inclusive recruitment process. Similarly, the Institution of Civil Engineers, Semta and WISE have developed an apprenticeship toolkit to support employers in their recruitment of female apprentices.

Recruitment is not the end of the story though as once people are in the engineering workforce, there is the challenge of retention, greatly boosted by fostering an inclusive workplace where all feel comfortable and valued. The cost to industry of losing engineers (male or female) when they take a career break is significant and there is very often little or no support in place for engineers who have taken a career break who then wish to return to engineering[32]. This is especially relevant to women; 57% of female engineers drop off the engineering register of professional engineers under the age of 45 (compared to 17% for men)[33].

The publication of the first gender pay gap report in 2018 has provided a useful focus for the issue of gender diversity and progression of women in engineering, which compares very poorly to the national average. The introduction of an ethnicity pay gap, would again, highlight the need for engineering companies to do more to recruit, promote and retain a more diverse workforce.

**Figure 1:** representation of women and BAME in engineering roles (2016)[31]

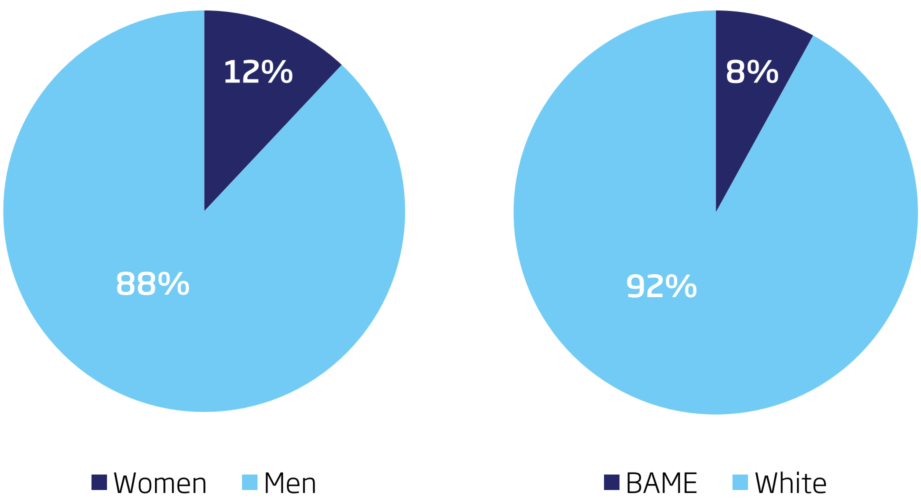



Image courtesy of UCL

It is important that employers take an evidence based and data driven approach to the diversity challenge. For too long, there have been well-meaning, short-duration initiatives implemented that have not delivered the necessary impact. Longer term, strategic aims must be set, with robust measurement tools[34] used to improve recruitment, increase retention and enable progression of all underrepresented groups within organisations. This should include setting recruitment targets to increase diversity in the workforce.

This is a long-term challenge and the engineering community must act strategically to give itself time to evolve the right inclusive workplace environments where engineers from all backgrounds thrive, flourish and ultimately maximise the success of engineering in the UK.

**Recommendation:**

It is vital that the engineering profession draws from the full talent pool. To do this, employers should take an evidence-based and data driven approach to improve recruitment and increase retention and progression of underrepresented groups within organisations. This should include setting recruitment targets to increase diversity in their workforce.

# Academic foundations

Since the 2013 review, the engineering community has raised serious concerns over the modest increase in the number of young people choosing to study STEM subjects that lead to engineering through the compulsory phase of education. Shortages of teachers in key subjects, a content-heavy curriculum, school accountability measures focusing attention on a narrow set of subjects and, until recently, poor-quality careers education, have all played their part in limiting the number of people progressing towards engineering.

The 2013 review set out two complementary contexts through which young people may be encouraged into engineering. The first is strengthening academic foundations through school experience by improving provision of the principal subjects for engineering. The second involves exposure to inspirational experiences, including outreach, STEM clubs and leisure activities linked to engineering. Ideally the two should work in tandem - not only does young people's ability to progress in engineering rely heavily on their attainment in mathematics, science and technology subjects but their experience of the taught curriculum should be exciting, encouraging their curiosity and enhancing their understanding of the world around them, in addition to developing their wider employability skills and highlighting the career opportunities that engineering can bring.

Public sector finances continue to be squeezed and the impact on education continues to be felt including in areas such as school funding, teacher shortages and insufficient funded provision of subject-specific teacher Continual Professional Development (CPD).

The engineering and wider STEM communities have been supporting education for many years, but despite many initiatives, there has been limited growth in the number of students pursuing subjects leading to engineering. Indeed, the proliferation of well-intentioned activities in an uncoordinated and increasing crowded landscape is likely to have caused confusion and impacted on the effectiveness of the activities in promoting a coherent message around progression to engineering careers.

These concerns were echoed in a 2018 report from the National Audit Office. While some of the £990 million spent on initiatives undertaken in the decade since 2007 have been successful, there was criticism that the approach had not been well coordinated across departments. This led to a call for a shared vision across government, alongside demonstration of better value for money[35]. The Department for Education (DfE) has since taken on a more formal co-ordination role across government, which includes reviewing STEM initiatives across the various stages of the education pipeline. DfE is also collaborating with organisations from across the engineering sector, enabling the wider sector to feed in to this work, which the engineering community is encouraged to engage with.

## Shortages of specialist teachers

Evidence shows that teachers' effectiveness is a key factor in a young person's academic interest and engagement in a subject[36]. This was highlighted in the 2013 review with a specific recommendation for government to target recruitment in the key shortage subjects of physics and mathematics. Despite various initiatives[37] the number of specialist STEM subject teachers at secondary level has remained largely stagnant since 2015 despite marked increases in pupil numbers[38].

In addition, there is increasing evidence of severe difficulties in teacher retention. Reports around excessive workload, below inflation pay rises over the last six years and a general low morale across the profession are deterring potential candidates from considering the teaching profession[39]. This has led to significant teacher training shortfalls. **Figure 2**, shows the under-recruitment of teachers to key subjects for engineering in schools in England for 2017/18[40]:

This issue is in danger of becoming entrenched, with teacher recruitment targets in STEM subjects now missed for five consecutive years. This in turn means that while schools are struggling to fill vacancies, large numbers of pupils are being taught by teachers who do not have a relevant qualification in the subject. In 2016 only 63% of physics teachers held a relevant post A-level qualification in the subject, a shocking indictment for one of the world's richest economies[41].

This is compounded by the wastage rates from teaching, which are currently at 10.5% (the number of teachers leaving as a proportion of the total number of teachers in service)[42]. In October 2016, figures showed that 30% (over 6400) of teachers who joined the profession in 2010 had left teaching within five years and science teachers had a 5% higher rate of leaving than the average[43].

There is no easy answer to this. Bursaries and payments to encourage graduates into teaching have played a part but are not closing the gap sufficiently for certain STEM subjects – unsurprising given the demand for those graduates in high-paying industries. Another approach may be for government to write-off student loans for graduates teaching for a certain time-period. This may again be part of the answer but given the poor retention of teachers, a more fundamental review of working conditions for teaching is required.

The government should also explore a more braided-career approach with greater permeability between teaching and other professions. This would require the support of school leaders and teaching unions. Engineering graduates and professional engineers can play a meaningful role in teaching. They have the technical knowledge to be able to teach the shortage STEM subjects. A stronger narrative about the benefits of teaching as a career, part-time or for a certain time-period, and appropriate teacher training, could provide a part of the solution. Identifying and addressing the barriers to increasing the role of engineers and other professionals in teaching and further promoting this type of teaching-industry porosity is therefore strongly encouraged.

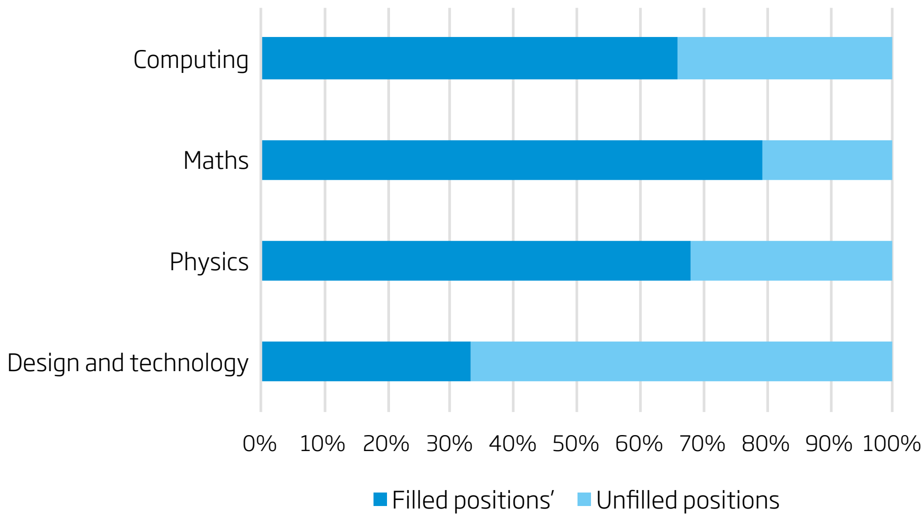



**Figure 2:** Recruitment to target (100%) of teachers for key subjects in England (2017/18)

Professional engineering bodies can also play a role in explicitly acknowledging the value of teaching to the profession and allowing it to contribute towards the standards for registration as a technician or engineer. It is important that there is a consistent policy across the engineering profession to enable engineers to move from teaching into industry and vice versa, using their experience in one to inform and shape the other[44].

**Recommendation:**

The government must undertake a wide-ranging review of issues around teacher retention. It should also review perceptions of teaching as a profession among graduates and address barriers to entry. As part of the review, it should examine opportunities with school-leaders, unions and employers to introduce braided-careers for dual teaching-industry professionalism.

## Teacher Professional Development

Even with a sufficient supply of specialist STEM teachers, there remains a need to ensure teaching professionals have access to subject-specific continual professional development (CPD) to help them keep abreast of developments in their subjects and real-world applications, particularly in fast-moving subjects such as computing and design and technology. Evidence shows that access to subject-specific CPD can also be an effective mechanism of stimulating teacher retention by inspiring teachers, further engaging them with their subject and encouraging support networks as well as playing a role in contributing to overall school success and pupil outcomes[45]. The increasing sophistication of educational technologies in supporting teaching also needs to be exploited and the implementation of EdTech for enhanced personalised learning needs to be part of the CPD mix for teachers.

However, across England there is apparently significant variation in CPD spending per teacher with no clear correlation between background funding levels and development spend[46] although increased financial pressures mean schools are finding it increasingly harder to release teachers for subject-specific CPD[47]. It is recognised that schools can struggle to identify quality training with proven impact and to that end, we welcome the DfE funding five CPD Excellence Hubs that target 1,500 teachers on CPD planning and evaluation in the most challenging areas of the country in the programme's initial phase[48].

There are many good quality teacher CPD programmes available that support STEM teachers although it must be noted that STEM coverage does not always equate to an adequate engineering focus[49]. To ensure the appropriate embedding of engineering in schools, which spans many parts of the national curriculum, teacher CPD is essential. In 2017 around 1 in 5 STEM secondary school teachers reported they knew 'little' or 'almost nothing' about engineering or lacked confidence in giving advice about careers in engineering[50]. According to research, engineering is seen by secondary students as a force for good but is rarely encountered in schools. This lack of exposure leads to a hazy and varied understanding of engineering, with girls feeling particularly poorly informed and not seeing the subject as relevant to their lives[51].

In 2014 IMechE and IET devised the *STEM Insight* scheme, providing extended 'careers-awareness' placements for STEM teachers in industry and HE. The programme delivered by STEM Learning and the Scottish Schools Education Research Centre through Project Enthuse, aims to meet some of the more challenging Gatsby Career Guidance benchmarks around contextualisation of the curriculum. The two main engineering funders, together with the Institution of Structural Engineers and the Biochemical Society have committed £300,000 to date. The programme is an excellent way for engineering employers to engage teachers in CPD activity. The engineering profession should work with STEM Learning to promote the programme more vigorously[52].

Since the 2013 report, one of the most significant developments is our understanding of how children's views and perceptions of possible careers are formed at an early age[53]. This highlights the importance of primary school teachers providing an appropriate, accurate and inspiring STEM education. This is a critical area where appropriate subject-specific input into initial teacher training and ongoing CPD support is required. This is particularly important as girls in primary schools are forming identities in which they are excluding themselves from pursuing science and engineering careers[54].

Although it is recognised that subject CPD is a more complex issue than school leadership decisions on funding and time, investing in the development of teachers, the most fundamental part of the education system, must be an overriding priority. Consequently, a clear expectation from governments across the UK in the form of a requirement for subject-specific CPD would be a huge step forward.

**Recommendation:**

The government must do more to support teachers' subject professional development. Teachers who experience high-quality professional learning are more likely to continue teaching for longer. Government and devolved administrations across the UK should introduce a requirement that teachers of mathematics, science, design and technology and computing have a protected entitlement of 40 hours of subject specific continuing professional development every year, with ring-fenced funding.

## Curriculum

STEM subjects are recognised as critically important across all parts of the UK and are promoted strongly in all countries. However, engineering is not a national curriculum subject in any of the UK's educational administrations. Engineering is difficult to define as a subject with a body of knowledge. It is rather an inter-disciplinary subject, the merging of science and mathematics with design, art and creativity to solve complex technical problems. The Royal Academy of Engineering in partnership with the University of Winchester described the need to develop in learners a series of *engineering habits of mind;* characteristics or attributes that are identifiable in engineers including creative problem solving, adapting and systems-thinking and other important behaviours such as ethical judgement. They have been working with schools and other organisations to embed them in the education system[55]. Many of these skills are recognised as important for the 21$^{st}$ century[56], but engineering is absent as a clearly definable curriculum subject and as a consequence has suffered from a lack of attention across all the school systems. However, there have been recent developments across parts of the UK to recognise, cultivate and nurture these meta-skills.

In Scotland, there have been welcome revisions to the curriculum and a new focus on ensuring students leave school with the skills, experience and knowledge needed to enter the world of work. The Curriculum for Excellence, implemented in 2010, encourages teachers to deliver interdisciplinary learning, linking knowledge and skills to broader themes. In 2017, Scotland introduced its STEM Education and Training Strategy with performance measures including metrics based on STEM teacher training numbers, increases in STEM foundation apprenticeships, and specific targets for increasing the number of females passing physics and computer science[57].

The Welsh Government is currently developing a new curriculum for Wales based on Professor Graham Donaldson's report *Successful Futures*, which presented a vision for the future of education Wales[58]. It is telling that it sets the development of STEM skills from age 3 to 16 front and centre, recognising their importance in a world increasingly driven by science and technology. The new curriculum will be used throughout Wales from 2022. Within the six areas of learning being developed, science and technology are linked together – an important statement of the connection between the subjects.

The new national curriculum in England implemented in 2014 has disappointingly taken an opposite approach, focusing on increasing knowledge among students with a corresponding significant increase in content in the curriculum for schools to deliver. This has reduced the opportunities for teachers to contextualise subjects, making them relevant to students and their lives and improving their science capital, an important feature in improving progression in STEM subjects[59]. It also means that there are fewer opportunities to identify, expose and exploit the links between science, mathematics, computing, and design and technology; it is in this space that engineering comes alive. This was also the premise of research published in 2016, which sought the views of key stakeholders on bold actions in schools that could bring about the degree of change in engineering uptake. Within the compelling vision of the future of engineering education in UK schools, the report proposed that pupils should be explicitly taught about engineering and the manufactured world as part of existing lessons from primary level upwards. It also called for maintaining a broad curriculum for all until the age of 18[60].

The increasingly precarious position of design and technology remains a source of significant concern. The revision of the study programmes in the 2014 national curriculum have created a highly progressive subject with the potential to deliver a broad range of design skills required by the industrial strategy, far removed from lingering antiquated notions of the craft-based origins of the subject. However, despite four years of delivery, there has not been any package of teacher support leading too often to a gulf between the intended and delivered curriculum.

The Royal Academy of Engineering and the Design and Technology Association are conducting a major review into the state of design and technology in schools. It is important that government engages with the findings in recognition of the subject's critical role in realising the Industrial Strategy's vision of an advanced, skilled economy.

By contrast, the national curriculum for computing, which was introduced in 2014 with significant changes to programmes of study, has recently received a very welcome £80 million investment to provide support to teachers. However, the engineering community does have concerns over the new GCSE in computer science as it is catering for a small minority of students with a heavy skew towards boys[61]. The UK lacks a more general computing qualification that covers the full curriculum and that would be taken by most young people, developing their computational skills and critical awareness, which are essential in an increasingly digitally driven world[62].

More generally, children are using digital technologies and media at increasingly younger ages and for longer periods of time. However, teaching methods within the formal education system remain largely unchanged rather than building on the familiarity and enthusiasm many children have from their personal computing devices (games, tablets).

### Accountability measures and school inspection

The engineering community has concerns that accountability measures on schools are driving perverse behaviours that are leading to falling participation in creative and technical subjects. The English Baccalaureate accountability measure for secondary schools in England has focused school leaders' attention on a small number of notionally *academic* subjects. In many cases, this has resulted in a narrowing of curriculum options leading to reduced teaching in creative subjects, increased class sizes and a reduction in GCSE entries and subjects such as design and

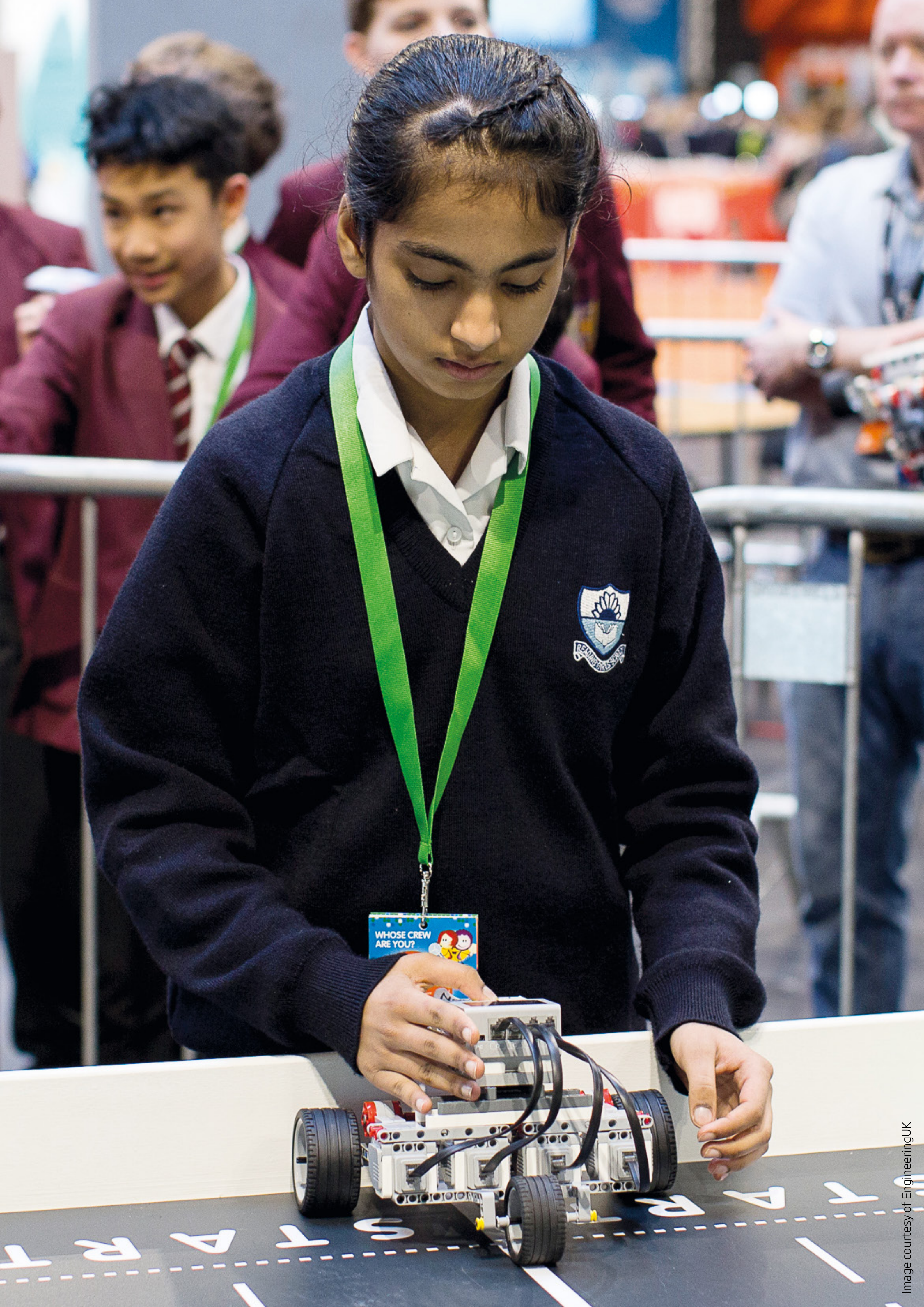


Image courtesy of EngineeringUK

technology being dropped from the curriculum entirely[63].

This headline measure on a narrow set of academic subjects for schools is also fuelling a continuing perception among students, parents and the wider public that academic subjects are more important than technical subjects, which has significant consequences for the parity of esteem of technical education in the post-16 sector. A promising development however is the recent attention Ofsted is paying to what they have referred to as a broad and balanced curriculum and it is hoped this is sufficiently represented in the next Inspection Framework.

Much of the DfE's stance has come from concerns over England's position in international the OECD led Programme for International Student Assessment (PISA) tables. This has driven increasing focus on improving knowledge and understanding in mathematics and science at an increasingly younger age, which in turn has driven school inspection and accountability measures to focus on progression and attainment in a narrow cluster of subjects.

The PISA tests cover a wide range of measures and the UK fares well in many aspects outside the narrow measure of academic standards. For example, in the 2015 PISA study, 28% of pupils in England expressed a hope to be working in a science-related career by age 30[64]. This was above the average across industrialised countries (24%) and the average across high-performing countries (22%).

The engineering community welcomes the news that in the 2021 assessment PISA will include assessing students' creativity skills as an important step in acknowledging their role cultivating students who can succeed in modern, globalised and ever-changing economies. Wales is one of the pilot countries for this programme and the engineering community will be paying close attention.

An interesting development in Wales is the introduction of the Welsh Baccalaureate. This novel qualification ensures a combination of core subjects (English and mathematics), academic qualifications and a skills challenge certificate, which requires pupils to undertake an individual project, an enterprise and employability challenge, a global citizenship challenge and a community challenge. This type of broad curriculum develops students understanding of 21$^{st}$ century challenges and enhances *engineering habits of mind* skills such as problem solving, creativity and critical thinking.

## Post-16 curriculum

Beyond that, the engineering community would like to see all students studying a broader curriculum that includes mathematics and science to age 18. Unlike most other OECD countries, the education system in England, Wales and Northern Ireland sets individuals on an arts/science divide from the age of 16, in effect even earlier when choosing GCSE subjects at age 14, a topic explored in the first Perkins review. Several reports over the past few years have also recommended the compulsory study of science[65] and mathematics to age 18[66] not only as a way of boosting the number of young people choosing engineering (and other STEM) careers, but also as a mechanism for recruiting more women and other underrepresented groups.

A broader curriculum would also provide more opportunities to develop creativity, critical thinking and communication skills. The squeeze on creative subjects in schools has been well documented elsewhere – particularly the impact of the English Baccalaureate and Attainment 8 and Progress 8 measures.

When students move to the post-16 academic curriculum, the engineering community has further concerns about the differential uptake of subjects with high progression onto further and higher engineering education. The 2013 review suggested a focus on progression rates to the engineering gateway subjects of maths and physics with a special plea for action to address the challenge of encouraging girls to study physics.

It is very encouraging that the 2018 figures show maths as the most popular A level, with almost 100,000 students taking it (a 26.8% increase since 2010) and very encouragingly 40% of these students are female, as shown in **figure 3**[67].

Physics uptake is more mixed. For the five years to 2017, the total number of A-level physics entries has increased by 6% and the percentage increase for females was 7%. In 2017 however, female students made up just 22.2% of entrants for A-level physics, (up from 21.7%), the highest proportion of female entrants since 2009, and achieve slightly higher than males[68].

Given that females are achieving at least as well as males, why are more females choosing not to pursue physics? Over the past five years, substantial evidence has emerged that highlights the cultural context in which young people frame their perceptions of school subjects and that gender stereotyping creates barriers to student choice[69]. The Institute of Physics work has identified evidenced recommendations that focus on whole-school approaches to improving uptake and outcomes of girls studying physics. Predictably, schools experiencing gender divides in physics are highly likely to be experiencing it in other subjects too (for example an overrepresentation of females in English literature) and thus tackling this issue as a whole school (for example by appointing a senior member of staff as ‘gender champion’ and training for all teachers in unconscious bias) will have a beneficial impact on inclusion beyond single subjects[70].

It must be emphasised that it is not only a gender divide that causes concern here. About 72% of A-level physics entries come from just over a quarter of schools[71] and at least one study found that there are approximately 500 schools that send no students on to A-level physics or maths[72]. These schools tend to be in areas of higher deprivation, raising serious issues around equity of educational opportunity.

**Recommendation:**

As part of the government’s industrial strategy, it is timely for the Department for Education to carry out a major review of the Post-16 academic education pathway for England, with a view to creating a broad and balanced curriculum that provides young people with opportunities to study mathematics, science and technology subjects along with arts and humanities to the age of 18. This will encourage a larger and more diverse entry into further and higher engineering education.

## University technical colleges

In 2013, the review suggested that the government had made a strong start to raising the status of vocational education by introducing university technical colleges (UTCs). The aspiration for these new institutions, sponsored by universities and linked with industry, was admirable.

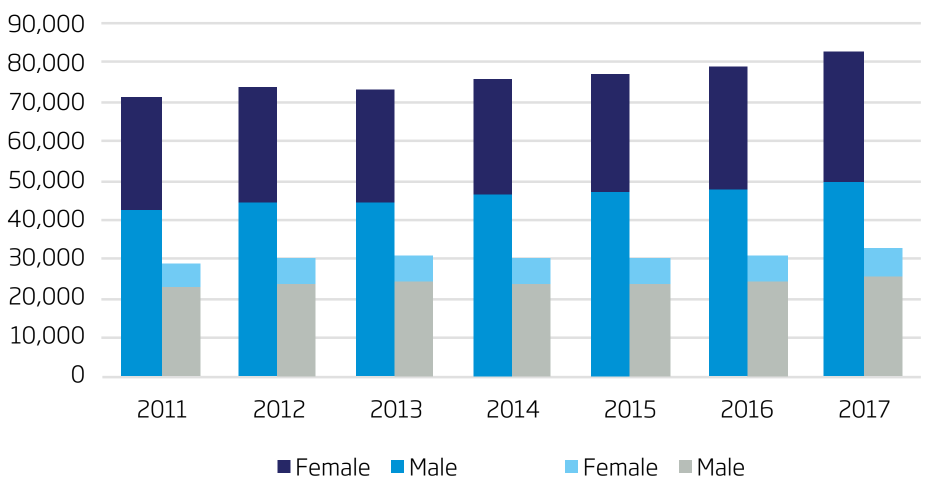



**Figure 3:** trends in participation for A level mathematics and physics among boys and girls in England

Employers viewed them as a credible means of getting more young people into STEM industries[73]. Since then UTCs have had struggled to make an impact with mixed success and several closures.

There are examples of UTCs performing very well[74]. Some have impressive employer engagement with co-creation and delivery of the curriculum, high-quality teaching and interesting examples of project-based learning approaches. These successful features of UTCs can provide valuable lessons for whole of the education system.

However, many UTCs struggle to attract sufficient numbers of students due to the entry age at 14. Anecdotal evidence suggests that local schools can see them as a threat to funding and don't recommend the UTCs to their stronger academically performing students. There are also challenges with ensuring sufficient gender diversity in the cohort, although there are examples of getting it right[75]. All of these difficulties have, in turn led to retention challenges[76] and poor attainment.

More generally, there is a strong likelihood that the challenges that UTCs face are due to the difficulties of being an education innovation in a national and local education landscape that is not set up to accommodate (and accurately assess) them. It is not desirable or fair to students, parents and providers that the current situation continues. The potential of UTCs must either be fully exploited, or else other options of technical education provision in secondary education explored.

**Recommendation:**

UTCs lack an established place in the education landscape; the Department for Education should review the UTC programme, make a decision on the future of the model and provide the necessary support for existing UTCs whatever the outcome.

## Engineering Inspiration – the challenge of engineering careers education

The 2013 review highlighted the need for better coordination of engineering inspiration activities and championed the *Tomorrow's Engineers* programme, led by EngineeringUK as the coordination mechanism. Over the intervening period, there has been substantial activity in this area and a welcome positive movement in young people's perceptions of, and aspirations towards engineering.

Data from EngineeringUK's Engineers and Engineering Brand Monitor (EEBM), a periodic survey of public attitudes towards engineering, show the proportion of young people aged 11 to 16 who would consider a career in engineering has risen 11% over the five-year period (**Figure 4**)[77].

Yet it is clear that the engineering profession continues to suffer from a general lack of visibility and understanding among young people. The proportion of EEBM respondents aged 11 to 16 reporting that they know 'almost nothing' or only 'a little' about what engineers do is still too high at 37%. Such a lack of understanding has clear implications for how young people view the profession and, in turn, its suitability as a possible career path[78].

In 2017, 43% of 14 to 16 year olds indicated they had not thought at all about becoming an engineer at a key time in their decisions about subject choices and educational pathways. This proportion is markedly higher among girls than boys (54% compared with 32%) highlighting the continued need to consider the cultural narrative and archetypes associated with engineering and demonstrate through action that it is a profession where both genders can and do succeed.

A large-scale study of UK teenagers carried out in 2014 by the IMechE showed how their broad values and attitudes to engineering, clustered around five personality types. The report, *Five Tribes*, highlighted how, if we wish to attract more young people into engineering, we must move on

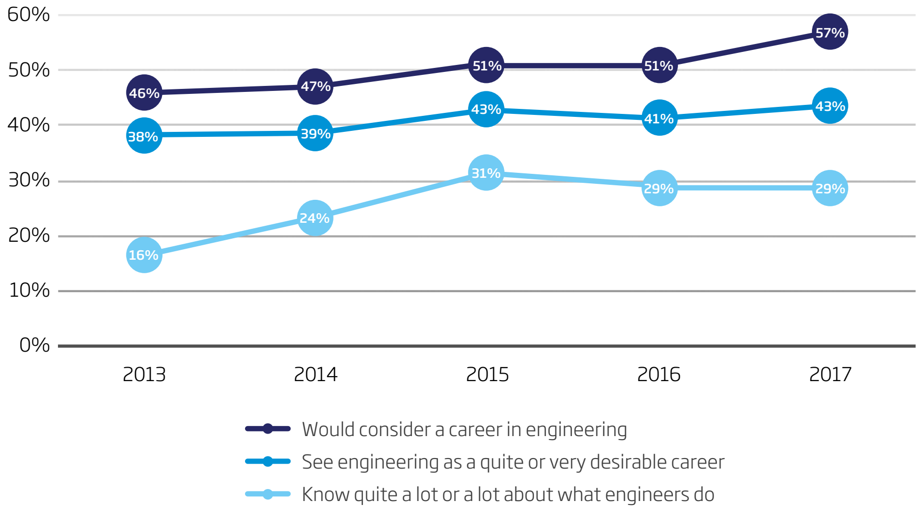



**Figure 4:** Knowledge, perceptions and aspirations towards engineering among young people aged 11 to 16 over time (2013-2017)

from our consideration of them as a homogenous group and do more to capture their interests and maintain a broader 'gene pool' of talent in the sector[79].

Greater support is also needed to ensure key influencers of young people are well-equipped to provide advice and guidance. Parents, guardians and teachers rank highly as sources of careers advice young people would be most likely to act upon, yet it is apparent that their knowledge of engineering is often limited. In 2017, just 31% of parents surveyed indicated that they knew 'quite a lot' or 'a lot' about what engineers did and only 36% expressed confidence in giving advice to their children about a career in engineering. This will have a bearing on the degree to which they are able to inform their children's educational and career decisions[80].

## Careers education in schools

In 2015 the DfE established the independent Careers & Enterprise Company (CEC) to provide strategic careers coordination for schools and colleges, employers, funders and careers programme providers in England. In 2017 the DfE published the *Careers Strategy* for schools and colleges in England which draws extensively on the Gatsby Foundation's *Good Career Guidance* report, notably on eight internationally derived benchmarks of what constitutes effective careers provision and has tasked the CEC with helping delivering this.

The *Careers Strategy* provides clear direction for schools to deliver careers advice to all 12 to 18 year olds comprising knowledge of the labour market, exposure to workplaces, encounters with work, and further and higher education institutions. Significantly, all schools must appoint a careers leader who is responsible and accountable for the delivery of their school or college's programme of careers advice and guidance. Ensuring this role is appropriately embedded in the school leadership team will be critical to delivery success.

It is also important that this is coordinated with relevant government backed initiatives such as the CEC developed Enterprise Adviser Network, which now reaches more than 2,000 schools and colleges[81]. It is essential that the engineering community coordinates efforts with the CEC to ensure that their networks encourage more engineering employers to engage with schools and colleges.

Despite the introduction of Gatsby benchmark four in the government's *Careers Strategy* explicitly requiring this type of contextualisation, the prognosis for achieving this within the existing curriculum is limited.

In Scotland, the Career Education Standard (2015) reaches back from early years to working life and sets out specific learning points and the role of parents/carers, teachers/practitioners, employers and Skills Development Scotland to support and improve young people's ability to make informed decisions about future pathways. Developing the Young Workforce (DYW) is a seven-year programme, launched in 2014 that encourages businesses to engage directly with schools and provide careers guidance and work experience to pupils aged 3 to 18.

As with Scotland and Wales, Northern Ireland operates a state funded careers advice programme in schools. The Northern Ireland approach includes commitments to a quality assurance framework, e-delivery and labour market information, work experience and access to impartial advice[82].

## Coordinating outreach and inspiration

2018 marked the government's *Year of Engineering* campaign, which encouraged the engineering community to work together to promote the wide variety of opportunities that the profession offers to young people. The government's visible support provided a focal point for the engineering community and it is highly desirable that this continues.

As part of its contribution to the year, the engineering community, led by the Royal Academy of Engineering, launched *This is Engineering*, a multi-year digital communications campaign. In its first year, the films showing inspiring young engineering role models attracted over 28 million views through various social media channels. The early success of the campaign is very encouraging, and it is significantly extending the community's reach among teenagers to reframe engineering, presenting it as an exciting and vibrant profession with a diverse array of career opportunities that support humanity through creative, problem-solving endeavours.

**Recommendation:**

The government should continue to provide visible leadership on engineering skills and nominate a ministerial lead for engineering skills to be supported by an additional Member of Parliament as an 'Engineering Champion' and convene a ministerial advisory group of engineering stakeholders to address the long-standing skills and diversity challenge in engineering. Devolved administrations should also identify named representatives to lead on engineering skills with which the engineering community can engage.

The engineering inspiration and outreach landscape has long been fragmented and patchy. Just 28% of young people aged 11 to 14[83] reported having taken part in a STEM careers activity in the last year, and worryingly wider research into employer engagement within education suggests that those who need it most often have the least access[84].

The Royal Academy of Engineering's report on the UK STEM education landscape showed over 600 organisations were found to be operating in this space[85]. The report raises concerns around the effect this confusing state of affairs would have on its target audience with a strong call for better coordination.

There has been a recent initiative to do this from the engineering community via the renewal and advancement of the Tomorrow's Engineers programme. The ambition is to bring together impactful engineering programmes into one place, enabling all young people to engage with the best quality programmes through a curated journey of activity over a period of time. This initiative will also drive quality and facilitate reach by investing and scaling proven programmes and activities that have a shared commitment to meet an agreed quality benchmark. If this ambition is realised, the Tomorrow's Engineers programme has the potential to significantly reduce the challenges that surround the deployment, access to and effectiveness of STEM outreach. However, this is heavily contingent on the input and engagement of outreach providers, funders and endorsers, teachers and young people and we urge both communities and government to actively support this initiative.

**Recommendation:**

Employers, charities, universities and third sector STEM engagement providers should support the current initiative led by EngineeringUK and the Royal Academy of Engineering to drive coordination, simplification and quality of school engineering-inspiration activities through the re-positioned Tomorrow's Engineers programme.

The engineering and education communities should recognise the value of supporting a collaborative approach and rally behind this initiative with a commitment to sign up to a Code of Practice, designed to encourage signatories to work together around a common goal – a coherent vision for inspiring a broad diversity of future engineers. Signatories of this code, including companies, professional bodies, universities, government, third sector and other organisations, should commit to a shared vison through a series of pledges to raise the quality of engineering-inspiration activity, reduce duplication and improve coordination.

It is not enough to help employers engage with schools; we must also support the identification of the most impactful, evidence-based quality interventions and experiences. The Royal Academy of Engineering[86], EngineeringUK[87] and the National Audit Office[88] have all identified the lack of consistent evaluation or evidence of impact across these programmes. Evidenced-based insight into what types of outreach can most effectively influence young people's progression in STEM subjects and career choices will enable schools to better differentiate between the many opportunities on offer – and the engineering sector to more efficiently use its resources to address the skills shortage.

Since 2014 IET and IMechE have piloted a programme that aims to drive higher quality and better coordination of engineering engagement through the Engineering Education Grant Scheme (EEGS). The key features of the programme through which £1.2 million of STEM activities have been funded including significant external match funding, include the rigorous reviewing process of how each application matches several clear funding criteria linked to a standard evaluation metric. Some 190,000 young people have taken part in projects funded by the programme, which the two PEIs see as having potential to reduce the fragmentation that has plagued engineering outreach.

**Recommendation:**

The community of engineering 'inspiration' providers and funders should agree to use a standard evaluation framework that measures the impact of their interventions in schools for students of all backgrounds. The framework should be sufficiently flexible to incorporate existing approaches and suit individual contexts. This will provide stronger evidence to determine what types of engagement are most effective in bringing about changes likely to influence young people's educational and career choices – and enable audiences, funders and delivery organisations to make more informed decisions about deploying their resources.

# Technical education

Five years ago, the Perkins review described the dual routes into engineering – the academic and vocational pathways – and the need to increase the number of engineering technicians. The aspiration was for a responsive technical education system, which could respond rapidly to the changing skills needs of the economy.

In the intervening period, it is the technical and vocational education system in England that has changed most significantly with reforms to apprenticeships and full-time college-based qualifications, the introduction of the Apprenticeship Levy and the creation of the Institute for Apprenticeships and Technical Education (IfATE).

Underpinning all the reforms is the principle that to succeed, both apprenticeships and T levels must be of the highest quality and not perceived as less rigorous than academic pathways. For engineering, apprenticeships and technical education have been a key mechanism for developing the workforce, and many of today's senior engineers started off as apprentices. Engineering employers have always supported apprenticeships, recognising the investment in training is returned through high-quality skills, competence and increased loyalty to the business. It is essential therefore that, despite early challenges faced with the introduction of new apprenticeship standards and T level qualifications, the engineering community works with government and supports these reforms. While it is still relatively early in the implementation of the new reforms, the IfATE, the DfE and engineering employers must all recognise that this is work in progress, be flexible and not fixed on decisions that do not ultimately benefit the individual, businesses and the economy.

A key part of the success with technical education will need to be in its simplicity. A system that shows how individuals can progress through the technical education system and enter into employment or continue with higher skills development, including study at higher education or engineering degree apprenticeships. A simplified pathway diagram is presented in **figure 5**.

## T levels

T levels, a new suite of post-16 qualifications proposed by the independent review of technical education chaired by Lord Sainsbury and accepted by the DfE in the Post-16 Skills plan[89], are arguably the most significant change to the English qualification system since the introduction of GCSEs. The intention to create a new, high-quality, technical alternative to A levels while also simplifying the vocational qualifications landscape that currently has some 13,000 publicly funded qualifications on offer is welcome. Instead just 25 T level qualifications will be offered based on 15 broad occupational clusters or 'routes', such as *engineering and manufacturing*, *construction*, and *digital* with optional pathways and further specialisms for students to choose[90].

Set to be phased in from 2020, the qualifications will provide a two-year, largely classroom-based programme based on common standards with apprenticeships. In addition, students will be expected to undertake a substantial 45-day industry placement and meet expected minimum requirements in core subjects; English, mathematics and digital.

The engineering community is very supportive of T levels. If delivered successfully, they offer a potentially powerful context through which the UK can reframe the importance of technical education in sectors such as engineering, manufacturing and construction. The promotion of technical education and the

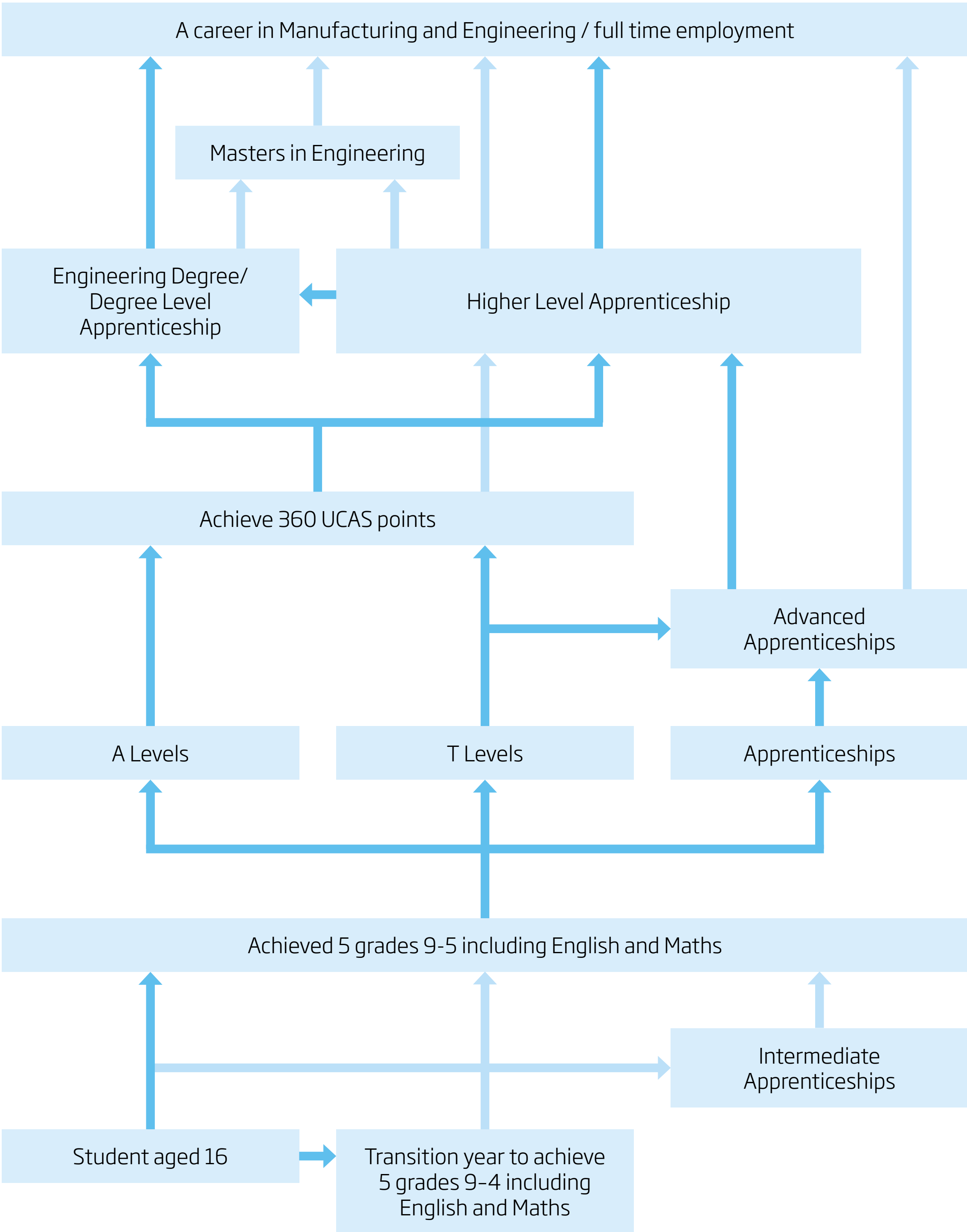



**Figure 5:** Simplified technical education pathway diagram developed by EEF, the Manufacturers Association 2018

simplification of the vocational qualification landscape has the backing of many employers. T levels have the potential to be a great success, and with cross-party support they have potential to have both credibility and longevity which is especially important to an education sector that has seen too much piecemeal reform over many decades and significant failures such as the 14 to 19 diplomas.

Likewise, parents will need to be assured that T levels have genuine currency and that there are clear progression routes from there to higher technical qualifications, apprenticeships, higher education and employment. The recent announcement that T levels will receive UCAS points[91] is greatly welcomed. The engineering profession urges all universities to review their entry requirements[92] and where appropriate recognise T levels for entry. Equally transition to apprenticeships must be facilitated and it is incumbent on employers to consider how this can work. There are examples in the Scottish education system that explicitly anticipates and provides for movement between vocational and academic streams through defined 'articulation pathways'[93]. However, ensuring a successful implementation of T levels is not without the challenges highlighted below.

## Funding

Many providers will need substantial up-front financial support to ensure that they are ready to deliver the new qualifications. The Post-16 Skills Plan acknowledged that the further education sector remains in a highly financially challenging state with years of under-investment[94]. The government has created a £38million capital fund to help ensure the first providers in 2020 have the facilities needed. But this is unlikely to be sufficient for all providers expecting to deliver courses such as engineering with its high associated capital costs.

In terms of delivery of T levels, the Treasury has committed an additional £500 million funding per year for providers, recognising that T levels will have longer guided learning hours than many current technical qualifications. However, a longer-term funding approach is needed, recognising the current underfunding of 16 to 18 providers[95], to ensure stable provision for T levels and stimulate colleges and other providers to work with local skills agencies such as Local Enterprise Partnerships (LEPs) to better plan and invest in strategic local skills provision to meet employer needs.

There is also a substantial cost difference with different subjects. Often colleges will subsidise provision of high cost laboratory-based subjects from lower-cost subjects. The government should commit to a sustainable model of funding in the forthcoming spending review, that stimulates and incentivises colleges to grow high-cost subjects that will drive the economy forward such as engineering, construction and digital.

**Recommendation:**

The government should ensure its funding mechanism for post-16 providers reflects the higher cost of delivering engineering programmes such as the new T levels in engineering and manufacturing and in construction and built environment and thus can absorb the anticipated surge in demand.

## Content

Representatives from the engineering community, from employers to professional bodies are working with the Department for Education (DfE) to write the content for the T levels. The starting point for developing T level content is existing apprenticeship standards, such that they are developing knowledge, skills and behaviours identified by employers as being of value. However, it is important to remember that apprenticeships are designed for occupational competency resulting in very specific skills development and T levels have a different purpose. They are college-based technical


Image courtesy of University of Leicester

qualifications and for engineering that should provide students with a breadth of knowledge across a wide range of discipline areas (beyond that expected in a narrow occupational apprenticeship) with an additional degree of in-depth specialist content towards the end. It is important therefore, that the IfATE and the DfE work with engineering employers to draft the content recognise that a broader approach will enable much greater occupational mobility for young people in engineering at the end of the qualification. In addition, T levels should meet the required content for professional registration with the Engineering Council and PEIs. The assessment process developed for T levels should also ensure that they serve the creative and practical nature of the qualification. For engineering, this includes the knowledge *and* skills that employers value including *engineering habits of mind*[96] and wider employability skills such as communication, teamworking and organisational skills and important professional behaviours such as ethics.

To this end, the DfE and IfATE should build on the work led by the Royal Academy of Engineering with the wider engineering community to map the 'core content' of the T level for engineering and manufacturing with the standards required for professional registration at Engineering Technician (EngTech) level.

**Recommendation:**

T levels in engineering and related subjects should provide a broad technical education for post-16 students. The IfATE must ensure that the content of new T levels across engineering disciplines provide sufficient breadth in their core content to enable mobility of college students to a wide range of future options, including apprenticeships outside their specialist subject areas and higher education routes, should they wish to choose them.

## Recruitment of teaching staff and professional development

Another key issue for implementation of T levels in 2020 will be ensuring sufficiently skilled staff for providers. Further education colleges and other post-16 providers are suffering from a lack of expert engineering lecturers and face similar challenges with recruitment and retention as in the school system[97]. There is an aging workforce demographic with lecturers having spent many years out of industry and being unaware of latest advancements[98]. The Industrial Strategy recognition of this challenge, subsequent additional funding and programmes such as *Taking Teaching Further* and *Teach Too* are welcome as attracting inspirational teachers with the right skills who have relevant industry experience.

Further education lecturers need regular CPD to deliver education and training in cutting edge technologies being used by business. The recently announced plan for T level professional development by the Education and Training Foundation is welcome and the engineering profession and other providers of CPD support should work with it to ensure effective pedagogies that nurture a wide variety of skills along with up-to-date industry practice for engineering and associated T levels is spread widely.

### Employer support

Employer support will be vital to the future success of T levels, yet the Chartered Institute of Professional Development (CIPD) highlighted in its 2018 report that only 40% of employers surveyed had heard of T levels. This is an issue because one of the most significant challenges facing the implementation of the T levels is the requirement of a (minimum) 45-day industrial placement for each student. Only a quarter of employers surveyed by the CIPD thought they would be able to provide a placement of sufficient length[99]. Significantly more effort needs to be made to communicate to employers the position of T levels in the education landscape.

The placements for T levels are not optional and nor are they just general work experience, but they are intended to be a core part of the qualifications: occupationally-specific and designed to support the practical and technical competencies required for the specific pathways and specialisms chosen by the student.

However, the UK's track record with work experience is poor. The most capable students with the most committed and experienced college work placement liaisons can struggle to find a suitable placement in sufficiently short travel-to-work distances. There are additional barriers for engineering. The best-intentioned employers can also struggle with additional costs including direct supervision and environments where safety equipment and protective clothing are required, and time with engineers needing to take time away from their usual duties to supervise students. There are also additional administrative burdens such as safeguarding and risk assessment requirements that will need to be completed.

With the engineering sectors dominated by 90% of businesses with fewer than 10 people, these are very real concerns that need to be addressed if work placements are to be successfully implemented. In addition, greater clarity is needed for employers in defining a 'meaningful' work placement that benefits the young person and the employer and is understood by the education provider. A more flexible and imaginative approach to these work placements may be needed if, in the first instance, employers are to provide the meaningful experience envisaged and some more creative thinking may be required here. For example, where a *directly* relevant engineering placement cannot be found for a student with a particular specialism, there may well be relevant work *elements* to be found among a cluster of local employers that can at least provide a grounding in the work exposure and skills envisioned. LEPs, local Chambers of Commerce and other relevant bodies should also play an active role in ensuring businesses are encouraged and supported in offering work placements.

## Apprenticeships

There has been significant reform to the apprenticeship system in England since the last Perkins review with the transition from apprenticeship frameworks to employer developed apprenticeship standards, a government target of three million apprenticeship starts by 2020, the introduction of the Apprenticeship Levy and the establishment of the IfATE.

The engineering community has welcomed government's promotion of apprenticeships as a rewarding progression pathway. The apprenticeship model, with its combination of on-the-job learning and concurrent technical knowledge acquisition, provides a strong basis for an engineering career. Engineering companies, large and small, have a long history of engagement with apprenticeships at Levels 2 and 3 as shown by **figure 6**. However, the UK has had a long-standing issue with sufficient numbers of people taking higher level engineering technical qualifications including higher apprenticeships and in the last three years, the numbers of higher apprenticeships are measured in hundreds compared with the tens of thousands for lower level apprenticeships.

While larger, prestigious engineering organisations tend to have heavily oversubscribed apprenticeship programmes, it will remain a challenge to recruit sufficient volumes of applicants with the necessary pre-requisite qualifications to undertake a challenging engineering programme, which will take a number of years to complete. The first review recommended a system to pool the applications to apprenticeships to retain applicants in the system and allow them to be considered by other engineering organisations. Where candidates are not successful with one employer, they could be automatically passed on to the supply chain and wider engineering industry. There are now various examples of this practice such as Semta's automotive apprenticeship clearing house. There are plans to expand this provision across the wider engineering and manufacturing sector in 2019 and the IfATE and employers should support its development.

### Apprenticeship Levy

The Apprenticeship Levy was introduced in April 2017 and requires employers with a salary bill of over £3 million to pay a 0 .5% levy of the wage bill to government. While the principle of the levy is largely supported by industry, the rules around Apprenticeship Levy spending have come under significant criticism from employer, college and provider groups as being hard to navigate and inflexible. In 2018, there was a welcome softening in the government stance, and from April 2019 larger employers will be able to transfer up to 25% of their levy funds to businesses in their supply chains. In addition, companies with smaller wage bills

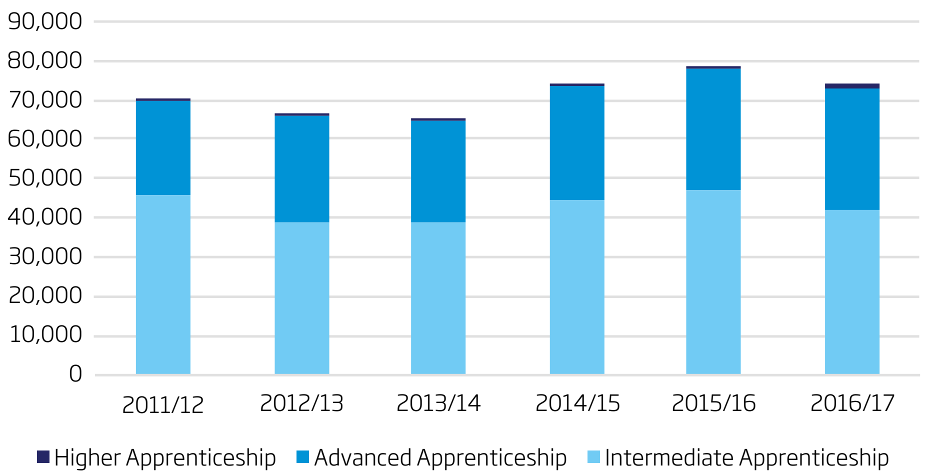



**Figure 6:** engineering and manufacturing apprenticeship starts for in England 2011-2016[101]

that are exempt from the levy, will see a reduction in the amount they must contribute to the cost of training when they take on apprentices[101].

There are also concerns that smaller employers who are not used to navigating the further education and training system, do not have the knowledge or resources to identify suitable local apprenticeship providers within the two-year time frame to draw down their levy contributions. While one of the key aims of the levy was to stimulate a responsive training market that would see colleges and providers offering, negotiating and delivering the provision that employers wanted, there appears to be little evidence this has happened[102].

There remains great potential to make the Apprenticeship Levy work for the engineering sector. However, the prescriptive rules have detracted from the notion that employers are in the driving seat and in control of their funds.

The maximum amount that employers can spend on an apprenticeship is dependent on which funding band that particular apprenticeship standard (or framework) sits, ranging from £1,500 to £27,000. Employers and other partners demonstrate to IfATE of the cost of external training and assessment and high cost subjects like engineering often soon hit the £27,000 cap.

The ongoing funding band reviews (expected to be completed by summer 2019) are widely perceived as forcing cost reductions, which carries the risk of lowering quality of provision and dissuading employers from taking on apprentices.

Despite general frustrations from business groups over the levy, starts in engineering apprenticeships have held up well in comparison to other sectors[103]. However, there are some issues here that need addressing. For example, EEF found that while 80% of manufacturers had successfully taken on a new apprentice, 9% had postponed or cancelled planned apprenticeships. Similarly, while 38% had started an engineering apprenticeship for an existing employee, 11% had delayed or cancelled them specifically because of the levy[104].

There is a widespread perception that there is underspend in the available levy money being reclaimed. Analysis by the Open University suggests an estimate of £1.8 billion paid into the levy by businesses in the first year, but only 8% of these levy contributions has been spent[105]. The lack of published, transparent financial information is unhelpful. The levy is contribution to training by business and industry and the IfATE and Treasury should make the finances publicly available for scrutiny.

Many employers believe apprenticeship schemes are not the best use of their training money and would like to use it for other forms of training provision[106]. Greater flexibility to workforce training would likely lead to a greater chance of improving skills and productivity across all sectors of the economy.

**Recommendation:**

Current conditions on employer spending on their Apprenticeship Levy contributions spend are highly restrictive. Government should give employers greater flexibility on their skills spending to include funds to support other forms of high quality training provision.

## Apprenticeship standards

The most significant reform to the structure of apprenticeships is the move from apprenticeship frameworks to new standards created by groups of employers. Standards are developed by groups of employers and are explicitly designed to be responsive to industry needs. Engineering companies were quick to develop many of the first ‘trailblazer’ standards and found it difficult to navigate the requirements of the new standards while DfE policy was still being formed. In addition, early standards in engineering were slow to be approved by the DfE and as such were not always ready for delivery in a timely manner, which dented employer confidence in the reforms. More recently however, there has been improvement in the expediency of approving new apprenticeship standards.

There are two overarching concerns that the engineering community has with the new apprenticeship standards. First, that there is no longer a separate qualification attached to the apprenticeship, but rather the apprenticeship itself is the qualification. Second, that the assessment approach has changed from continuous assessment throughout the apprenticeship to a synoptic end point assessment at the end of the apprenticeship.

The removal of recognised qualifications from apprenticeship standards is drawing considerable criticism, with particular concerns around the impact on occupational mobility of apprentices and ability to access further and higher education[107]. This is a significant gamble with the lives of a whole cohort of apprentices if apprenticeship standards themselves are not recognised as 'qualifications' in their own right.

The introduction of synoptic end point assessment is also causing concern. This will require the examination of the apprentices at the end of the apprenticeship. For engineering, this may be after three and a half years of training. This is a significant shift from the previous apprenticeship frameworks which took a modular approach and built a package of qualifications, competencies and proven knowledge and as such is a big concern for employers who want to be able to continually measure the competence of apprentices during their training. A further challenge for end point assessment is the requirement by the DfE and IfATE for the assessment to be undertaken by a 'wholly independent assessor.' Employers have concerns that these assessors will be hard to find, as they will require up-to-date knowledge of specific industry practices, but not have any links to the companies involved. There is an opportunity for professional engineering bodies to play a role here as they regularly assess individuals for professional registration. The IfATE should engage with PEIs where there are challenges to find suitable assessors.

There are inevitably ongoing concerns from industry with the introduction of new apprenticeship standards and the implementation of T levels. This will be a time of change and adjustment, but the prize of a new, simplified technical education system with robust employer-led standards and qualifications is worth persevering with. Engineering industry needs to give time to allow the new system to be embedded. At the same time government should recognise that the whole new apprenticeship system is under development and there may need to be flexibility with the processes and practices in place, to ensure that new apprenticeships work for all involved; individuals, providers and employers.

It is also vital that the overarching technical education policy landscape remains stable to allow the new system time to embed in. It is vitally important that the engineering community and IfATE stay closely engaged in a productive dialogue to ensure the continued success of engineering apprenticeships.

### Apprenticeship systems across the devolved nations

Skills and apprenticeship provision are devolved to Scotland, Wales and Northern Ireland. The three nations have not adopted the English approach and have preferred to align their provision with existing recognised qualifications, developing new provision according to labour market need, rather than the English approach of approving standards as they are developed by employer groups. For employers who work across England and one or more of the devolved administrations it means that there is no common currency of apprenticeship skills and competencies.

Scotland's youth employment strategy, DYW, emphasised building vocational routes to work and more access to vocational options during the final years of schooling. This includes the introduction of Foundation Apprenticeships (essentially alongside school-based Highers with college attendance and work placements) and Modern Apprenticeships, widening access to engineering and other industries. The range of foundation apprenticeship subjects is driven by the nature of growth industries and skills shortages and the uptake has exceeded Scottish government targets[108].

The Welsh government has developed Pre-Apprenticeship Programmes that allow young people to progress on to a high-quality apprenticeship offer. These start with Junior Apprenticeships, open to 14 to 16 year olds, that introduce pupils to work-based learning while studying GCSEs in English and maths.

Efforts are also being made to link regional skills demands to the creation of new apprenticeships, thereby addressing engineering shortages and stimulating growth in key economic sectors. The creation of post-16 skills provision is driven by annual reports produced by the Regional Skills Partnerships (RSP). Some RSPs have already identified advanced manufacturing and construction as sectors for focus.

Northern Ireland's apprenticeships are similarly structured to those in Wales and the (previous) English frameworks.

### Higher and degree apprenticeships

In 2015, the government extended the new apprenticeship standards to create new higher-level degree apprenticeships at bachelor and master's level within the overall funded programme. While still in their infancy, there are already 15 new standards for degree apprenticeships within engineering, construction and digital subject areas and a further 11 are in development. Latest DfE data suggest that around 2.5% of higher apprenticeships started in 2016/17 were in engineering and manufacturing technologies, which equates to around 900 apprentices[109] and there is optimism among the engineering community that they will continue to expand.

Degree level apprenticeships in Wales were introduced in October 2018 with digital/ICT being the first framework offered. The Wales apprenticeship advisory board is chaired by the head of CBI Wales and draws membership from businesses. Engineering degree apprenticeships are being developed in response to assessed skills needs and are due to start in 2019, with the first in engineering, advanced manufacturing and construction.

Graduate Apprenticeships are also being rolled out in Scotland, to bachelors, and in some cases master's level qualifications, with twelve universities and colleges involved in 2018. Within engineering, routes include civil engineering, cyber security, engineering: design and manufacture, engineering: instrumentation and measurement and IT software development.

# Higher education

## Students

Higher education continues to be an important pathway to professional engineering careers and since the last review, there has been a welcome increase in the number of students who started undergraduate engineering degree courses. These are up by 14.9%, which equates to over 25,000 UK domiciled entrants to engineering first degrees in 2016/17 with an additional 10,000 EU and non-EU entrants (**figure 7**). This is against a more modest growth of 10.7% in all other subjects and a declining demographic among 18–20 year olds[110].

Within the engineering subject area between 2012/13 and 2016/17 some disciplines have fared better than others. Mechanical engineering still dominates the landscape followed by electronic and electrical engineering, which continues a decline started in the early 2000s. First degree entrant numbers for chemical, process, and energy engineering grew impressively by 56.5% and similarly aerospace engineering by 31.1% albeit both from lower starting positions. Perhaps most interestingly, general engineering has seen an increase in first degree entrant numbers (by 18.5%), overtaking civil engineering to become the third most popular engineering discipline (after mechanical and electronic and electrical engineering). This trend is a welcome development as engineering is becoming increasingly multi- and inter-disciplinary and general engineering degrees will provide students with a greater breadth of knowledge across a range of subject areas before opting for a specialist area in later years of study.

### Diversity in engineering higher education

The gender diversity in engineering subjects across higher education remains stubbornly low, with a slight increase from 13.4% in 2013 to 15.9% in 2016. When 56% of the higher education population is female, it is unacceptable that so few women choose to study engineering.

Engineering does very well in terms of ethnic diversity, with representative cohorts among black students (8.3%) against the total student population (8%), and larger proportions of Asian students (17% compared to 11.6%). However, engineering does not perform favourably (8%) among students with disabilities compared with the higher education sector as a whole (12%).

Engineering has a wide variety of entry routes into higher education study. While the typical expected entry requirements are maths and physics at A level, there is in fact much more flexibility for entry qualifications. A 2015 Royal Academy of Engineering report highlighted that only 52% of the undergraduate cohort in 2011/12 had an A level in mathematics and 44% had an A level in physics. **Table 1** shows the breakdown for pre- and post-1992 universities and includes a number of other qualifications[111].

While mathematics and physics continue to be presented as the preferred subjects for entry to engineering, it is welcome that higher education institutions accept a variety of qualifications for entry as this supports widening participation in the profession. Of course, students with mathematics and physics will be able to access the widest range of university degree courses, and so it is important that these subjects continue to be supported and promoted by the engineering community in schools.

However, despite the broad entry routes, for socio-economic participation the record on access for engineering higher education is not good compared to other subjects. In 2013, twice as many students (39%) from the most affluent socioeconomic group (POLAR 3 quintile 5) participated

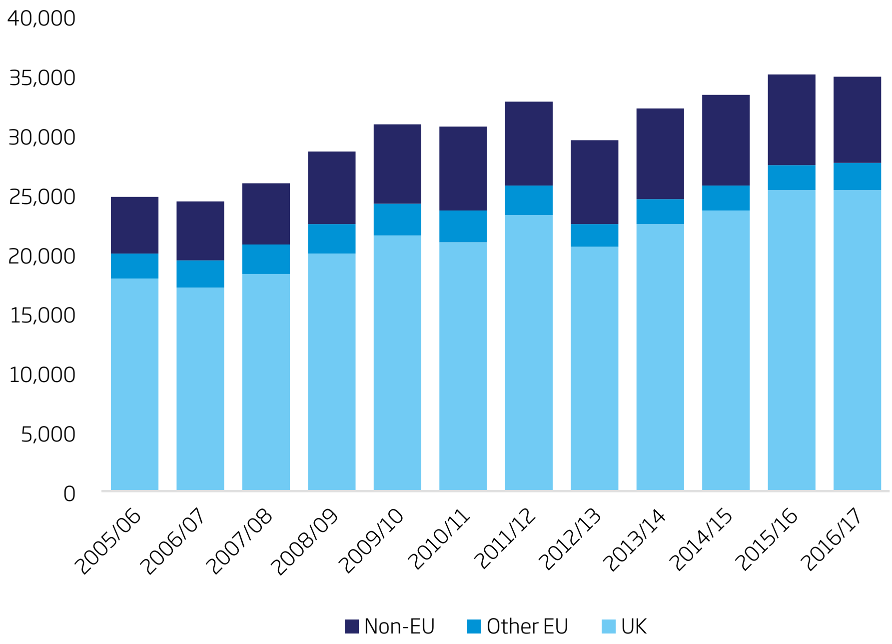



**Figure 7:** Engineering first degree undergraduate entrants by domicile over time (2005/06 – 2016/17)

| | Pre-92 (%) | Post-92 (%) | Whole cohort (%) |
|---|---|---|---|
| A-level maths | 70.0% | 22.1% | 51.6% |
| A-level physics | 59.8% | 18.8% | 44.1% |
| A-level chemistry | 26.6% | 5.5% | 18.5% |
| A-level general studies | 14.0% | 7.3% | 11.4% |
| A-level further maths | 13.0% | 0.7% | 8.3% |
| A-level biology | 10.6% | 4.3% | 8.2% |
| Scottish Higher maths | 11.3% | 2.6% | 7.9% |
| A-level D&T | 7.8% | 7.3% | 7.6% |
| Scottish Higher physics | 10.6% | 2.3% | 7.4% |
| A-level geography | 6.6% | 4.8% | 5.9% |
| A-level electronics | 3.9% | 2.3% | 3.3% |
| A-level computing | 3.2% | 3.0% | 3.1% |
| Advanced Scottish Higher maths | 4.4% | 0.3% | 2.8% |
| Advanced Scottish Higher physics | 4.2% | 0.3% | 2.7% |
| AS level maths only (no BTEC, access course, OCR diploma) | 1.2% | 2.6% | 1.7% |
| BTEC HNC/HND engineering | 0.6% | 3.3% | 1.6% |
| OCR national diploma | 0.0% | 0.2% | 0.1% |
| Access courses | 0.0% | 0.0% | 0.0% |
| Those that hold none of the qualifications requested | 13.3% | 57.7% | 30.3% |
| **Total number of students** | **6,429** | **3,992** | **10,421** |

**Table 1:** The percentage of engineering students holding each entry qualification (any grade) as recorded by HESA

in engineering degree programmes compared to lower socioeconomic groups (19%) (POLAR3 quintiles 1 and 2)[112].

Since 2012/13 engineering has also seen a very substantial 20% fall in part-time students. Traditionally, engineering has always had a smaller part-time intake than most other subject areas. However, this has implications for degrees' attractiveness to a more diverse population of engineering students because alternative modes of study are likely to attract non-traditional applicants. Across all higher education, one in five students (20.4%) is aged over 30, but for engineering, the proportion is just 4.7%.

The failure of engineering higher education to attract large parts of the population – particularly women and returners to education – has significant implications for the nation's future skills needs. It denies those with the potential to become engineers the opportunity to do so and reduces both the size and quality of the talent pool to work in the engineering sector.

For now, the access work started by the Higher Education Funding Council for England (HEFCE) and the Office for Fair Access is set to be continued by the Office for Students (OfS). The work is mostly conducted on the basis of attracting students from particular backgrounds rather than attracting them to particular subject areas. The broadening of widening participation activity by the OfS to support under-representation beyond socioeconomic background would be welcome. For example, universities' access and participation plans could include a description of access activities to support female students into engineering, for which centralised funds should be made available.

## Postgraduate students

UK postgraduate student numbers on engineering and technology courses have not grown as substantially as the recruitment of undergraduates. In 2016/17, there were around 4,890 UK students starting taught postgraduate courses, up from up from 4,170 in 2012/13[113].

In addition to taught postgraduate degrees there are around 4,100 students undertaking postgraduate research in engineering in the UK[114]. Of these, some 1,500, or just under 40%, are UK domiciled, with non-EU international students taking up the bulk of the remainder at 45%. There is a welcome disproportionately high representation of women in postgraduate research roles at 24%.

## International students

International students remain an important cohort for engineering. Non-UK students represent just under 40% of the total student cohort, and importantly, over half of the taught postgraduate cohort. As well as being a substantial source of export income for the UK, international graduates are also a potential resource to meet the engineering skills demand.

The prospect of postgraduate work experience in the UK particularly attracts international students and this helps to attract the brightest and best to meet our engineering skills needs. Once they leave the UK following postgraduate work experience, which research suggests the majority of international graduates do[115], the networks they have established support international business and research relationships[116].

The engineering higher education community has, for some time, been concerned over the government's stance toward post-study work visas for international students and the wider messaging around opportunities for international students coming to the UK. The proposals in the recent immigration white paper for the introduction of post-study work for a period of up to one year for PhD students and six months for graduates is welcome recognition of how international students can add value to the country. However, the UK will continue to lag behind its global competitors if it does not extend the post-study work visas to two years.

In addition, the engineering community has concerns over the high £30,000 salary threshold which may have implications for engineering researchers in higher education. We await the further announcement of a lower salary threshold requirement for graduate entry jobs.

**Recommendation:**

UK universities must remain a world-leading and popular destination for international staff and students. To this end, the government should ensure the UK remains within international study partnerships and minimises the hurdles to obtaining a visa for these purposes.

The government should also increase the length of time for post-study work visas to two years to be in line with competitor nations attracting international students into higher education.

## Employment outcomes of engineering graduates

A 2016 Royal Academy of Engineering report on the employment outcomes of engineering graduates revealed some interesting insights[117]. Using *Destinations of Leavers of Higher Education* (DLHE), data showed that six months after graduation:

- around 66% of engineering graduates enter full-time work compared with 58% for all higher education subjects
- 56% of the engineering graduates entering full-time work, went into engineering occupations. This equates to 85% of the employed cohort taking on engineering jobs
- the proportion of female graduates entering engineering employment was 80%, only marginally lower than the male graduates at 85%
- students from black, Asian and minority ethnic backgrounds were significantly less likely to go into engineering occupations (40%) compared with their white counterparts (60%).

In 2016, the government published the first longitudinal employment outcomes (LEO) data providing more granular statistics for graduate employment outcomes over time[118]. While the proportion of engineering graduates in employment or further study is marginally lower than across all disciplines after a period of years, they command significantly higher salaries (**Table 2**).

The data indicates that engineering graduates enjoy approximately average employment levels when compared to all graduates, but the fourth highest median earnings by subject area (after medicine & dentistry, veterinary science, and economics).

## Related degree disciplines

It is also worth noting that graduates from subjects other than those grouped under the 'engineering and

| | After one year (2013/4 cohort) | After three years (2011/12) | After five years (2009/10) | After ten years (2004/05) |
|---|---|---|---|---|
| **Percentage in employment and/or further study (%)** | | | | |
| Engineering and technology graduates | 86.4 | 86.1 | 84.4 | 82.0 |
| All disciplines | 86.4 | 86.5 | 85.4 | 82.6 |
| **Median earnings** | | | | |
| Engineering and technology graduates | £25,000 | £29,500 | £32,600 | £40,000 |
| All disciplines | £18,900 | £22,800 | £25,700 | £30,600 |

**Table 2:** Longitudinal employment outcomes of engineering graduates

technology' subject group in higher education data form a significant part of the engineering workforce. In fact, 60% of all full-time UK domiciled graduates in 2016 who entered a 'core engineering' occupation six months after graduation, came from subjects other than engineering and technology, with computer science, building and planning, physical sciences and mathematics all contributing to engineering skills supply[119]. All of these subjects with significant progression rates into engineering industry show that there are many sources of graduates likely to have the right skill sets for engineering who should be considered by any efforts to attract more graduates into engineering.

## Provision of engineering higher education and innovation in teaching and learning

### New higher education providers in engineering

Both the 2011 White Paper and the Higher Education and Research Act 2017 (HERA) sought to encourage new higher education providers into the market. While the number of higher education institutions has increased, very few of the new entrants offer engineering because of the high cost of entry to establishing and delivering engineering programmes. Two notable exceptions are NMiTE (New Model in Engineering and Technology) in Hereford, which will be admitting its first cohort in September 2019 and the Dyson Institute of Engineering and Technology, which admitted 33 undergraduates for the first time in 2017. A third new engineering higher education institution, being created by the PLuS Alliance of universities – King's College London, Arizona State University and the University of New South Wales will also be established in the coming years. These three institutions will provide a distinctive contribution from existing engineering higher education provision, but it is far too early to assess how they will impact the higher education landscape.

### Innovation in teaching and learning

Over the past five years, there have been substantial developments in the methods of teaching engineering across higher education with many institutions adopting new approaches. While some universities continue to stick largely to well-established models, most are exploring some form of innovation to provision. A forthcoming publication by the Engineering Professors' Council and the IET identifies six dimensions to innovation within engineering higher education[120]. These include:

- broadening the diversity of students through new recruitment and admission processes, introducing more inclusive curricula
- a stronger emphasis on project work throughout degree programmes
- increasing the level of inter-disciplinary activity that students undertake - working with students across all disciplines in engineering and, in some cases, with other subject areas
- improving collaboration with industry, including exposing students to real-life, active engineering problems faced by businesses
- incorporating greater levels of creativity and idea-generation into degree programmes to enhance and emphasise the creative nature of engineering
- improving workplace experience of students, through wider application of industrial placements and courses that support professional formation of undergraduate engineers, such as developing ethical consideration and judgement – an important behaviour in professional engineers.

In addition to these areas, some universities are taking a different approach, highlighting to students through modules and project work, the role of engineers in addressing societal challenges such as the UN Sustainable Development Goals or the Global Grand Challenges for Engineering. These new approaches are all increasing the diversity and richness of engineering higher education and universities that are not engaged in this activity should take steps to develop their programmes accordingly.

### Placements

Placements, sandwich courses, internships and other opportunities for workplace experience not only improve students' learning experience – providing practical experience and broader insight into the needs of employment – but also allow employers and students to establish relationships that are likely to progress to employment.

In the five years since 2013, the number of sandwich courses across all higher education has increased by more than a third (34.6%), and for engineering have risen by a little less (30.1%) but starting from a relatively higher base than most other subject areas[121]. Several initiatives – such as 'engineering work with', a brokerage platform created by National Council for Universities and Business with support from the Engineering Professors' Council – have been launched in the last five years to increase engineering placement activity by stimulating demand among students and supply among employers. The actual rise in sandwich courses and the anecdotally reported rise in placements more generally suggests that progress is being made in this area.

Other than formal sandwich courses, there is no reliable data about the number or quality of placements in general. The student review website Rate My Placement has gathered around 2,000 reviews of engineering placements over the past five years, which amounts to around a fifth of all its reviews.

### Accelerated degrees

The HERA 2017 has also facilitated the introduction of accelerated degrees, for example reducing three-year bachelor degrees to two years. Accelerated degrees have higher contact hours in a year and reduced student vacation periods, to shorten the overall length of time of the degree programme. For engineering, given the current intensity of engineering degrees (typically 20 contact hours per week) and the importance of vacation periods for students to undertake work placements and for academics to focus on research activity, the demand for accelerated courses on the part of students and the willingness to offer them on the part of higher education institutions has been limited. However, this may be an area that some teaching-focused universities will explore further over the coming years.

## Funding for engineering higher education

At the time of the first Perkins Review, the English government was pursuing the higher education policies laid out in its 2011 White Paper Students at the heart of the system. This approach tripled the level of tuition fees to £9,000 a year, releasing more funding to the higher education sector without a direct cost to budget deficit. For high-cost, laboratory-based subjects such as engineering, HEFCE provided additional top-up grant funding. This additional important funding stream continues to be available for certain disciplines. Chemical and materials engineering, along with other laboratory-based subjects, will continue to receive at least £1,515 of additional funding per student in 2018/19, while software engineering will receive a lower £252.50 top-up grant per student[122]. The latest analysis of the costs for engineering degree programmes suggests per capita cost ranges between around £9,500 and £12,000 per year[123]. With teaching-related income ranging from about £9,500 to £10,750 (before bursaries, fee waivers and other access costs), most engineering courses require cross-subsidy. This can be achieved by subsidising across disciplines or by income from higher-fee paying international students.

In 2018, the DfE commissioned an independent review into post-18 education in England under the leadership of Philip Augar, which is due to report in early 2019. In the initial stages of the review, the Education Secretary expressed support for a model of differential fees across different subject areas, based on encouraging student demand, the relative cost of providing different courses and previous patterns of differential earnings. This model would have potentially disastrous consequences for engineering if it resulted in an increase in fees for engineering degree programmes.

Whatever the outcome of the review, it is essential that the government ensures the sustainability of engineering higher education and does not inadvertently set up barriers to widening participation and social mobility. Indeed, with the importance of engineering to the industrial strategy and the UK's future competitiveness, it is important for the government to examine mechanisms to ensure that engineering higher education is adequately funded to ensure the necessary graduate skills supply for the future.

**Recommendation:**

The government must ensure that engineering and associated high cost subjects in higher education are not adversely affected by the outcomes of the post-18 funding review. Government must ensure engineering courses are adequately funded with increased top-up grants if tuition fees are to be reduced.

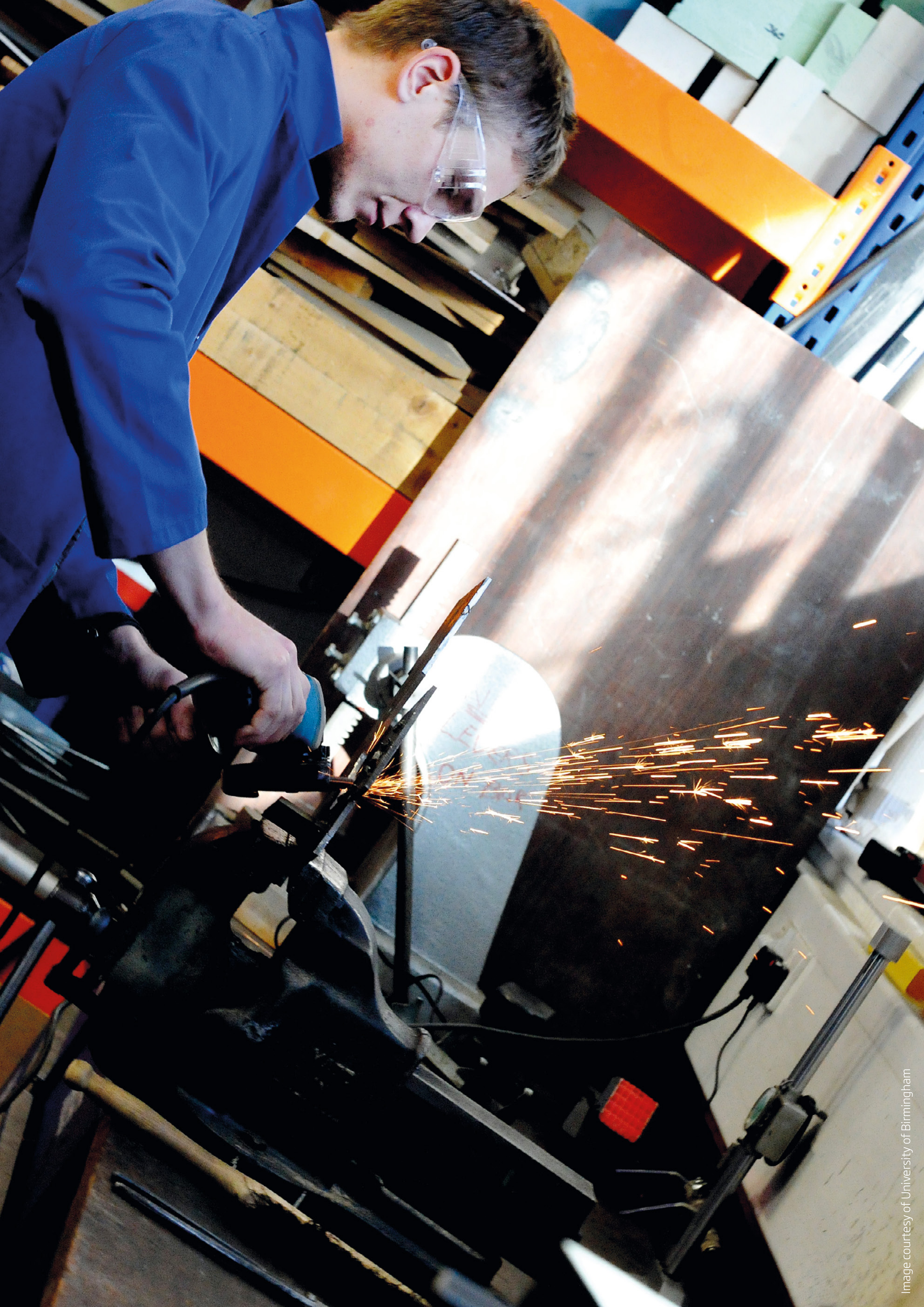


Image courtesy of University of Birmingham

# Workforce development

As the first Review noted, in today's competitive world, the skills and capabilities of the workforce are vital to economic sustainability and growth. There has been much discourse on the reasons why the UK is lagging behind competitor nations when it comes to productivity, but what is agreed is that workforce skills (in addition to the education levels of that workforce, a related issue but not a proxy measure) lie at the heart of this[124]. The fourth industrial revolution is driving huge changes to the nature of work and it is widely recognised that future workers need to be adaptable to succeed and willing to constantly learn and retrain[125]. This becomes especially pressing as economies move to find new sources of growth and innovation to stay competitive.

As well as the demographic argument (the majority of the workforce of 2030 have already left the education system), there is a growing recognition that skills acquisition is a lifelong process. The notion that people leave the formal education system fully formed is an antiquated one, something employers have long been aware of in their own attempts to mould and shape their workforces to meet their changing needs.

A large part of this challenge was highlighted by *Made Smarter*, the first major UK-focussed report to consider the resulting impact on the nature and extent of digital skills demands in the workforce[126]. The review highlighted the gains to be through the adoption of industrial digital technologies but identified the largest barrier to this as being a lack of digital skills. There is also a focus on SMEs who are falling behind in terms of digitalisation and upskilling, often due to fear or lack of understanding of what digitalisation involves or the potential associated costs.

Unfortunately, UK employer investment in upskilling their workforce remains among the lowest of the major EU economies[127] and spending on vocational training in the UK is half the EU average, and just over a quarter of the level spent in France and Belgium[128]. This culture needs to be addressed and changed and there is a major challenge for industry and the professional bodies to drive upskilling and reskilling among the existing engineering workforce. It is hoped that Brexit will provide a stimulus for employers to think more strategically about how to fully unlock the skills potential of their workforces.

While there are some outstanding examples of employer investment and upskilling programmes, it is too often seen as preserve of larger organisations.

There is a growing need for employers to understand not only how engineering skills and knowledge can be transferred across disciplines and sectors but to be able to import skills and expertise through conversion courses for those who were previously on a parallel career track. PEIs have a pivotal role here as a hub between individuals and industry, informing, supporting and motivating both to ensure their needs are met. Professional registration can also help confer mobility to engineers, highlighting knowledge, skills understanding and competencies that individuals have.

At the same time, increasing digitisation is driving an alignment across engineering sector skills requirements as the boundaries of traditional engineering disciplines are blurring. A degree of commonality is also encouraged by the general shift by all sectors towards more complex engineering systems, requiring a very different engineering skill set than more traditional roles. It seems the workforce is generally willing; a recent survey showed over half of engineers surveyed said they would be willing to retrain to obtain a different set of skills and 65% said they would be willing to transfer to a different sector[129].

The landscape of workforce upskilling is multifaceted and complex, but PEIs and the Engineering Council can play a lead role, engaging with industry and coordinating the activity on behalf of the profession.

**Recommendation:**

The increasing digitalisation of all aspects of engineering requires the upskilling and reskilling of engineers and technicians. The Engineering Council and PEIs should develop a coherent approach to the professional development of engineers and technicians, both within and outside of membership, to maximise benefits of the new digital paradigm.

The most significant recent developments in workforce development are highlighted below and include an acceleration in the devolving of skills remits to regional bodies. It is important that the expected loss of European funding to UK regions in support of research, innovation, supporting businesses (including regional provision of business and management skills training) does not leave (previous) recipient regions unsupported. This regional focus also has implications for how the engineering community engages in the future and has the potential to deliver much more targeted support.

There are also pre-master's in engineering available from some universities, suitable as a path for those with a first degree in the physical sciences or to those who have taken a break in education and wish to return to engineering.

The overarching message is one of the importance of coherence (these initiatives must complement and support each other), landscape navigation (so employers and workers know how to find and access these schemes) and robust evaluation (understanding what works). It is also important to avoid short termism, the focus should be on building fundamental career-orientated skills rather than simply trying to get someone into their next role.

## National Retraining Scheme

The government's National Retraining Scheme (announced in the 2017 Industrial Strategy White Paper) has the potential to support upskilling as well as reskilling of existing employees. Industry will continue to take responsibility where there is a business specific training need. The scheme will initially target skills shortages in key sectors such as digital and construction skills[130].

## Catapult centres

The Catapults, independent networked centres designed to transform the UK's capability for innovation and help drive future economic growth, were created from 2011 onwards and have developed strong links between academia and industry. Funding for Catapults comes from an even mix of government (BEIS) core funding, commercial and collaborative (public and private) research and development funding.

While the Catapults lack an official skills remit, some of the Catapults and their centres such as the HVMC Manufacturing Technology Centre (MTC) and Advanced Manufacturing Research Centre (AMRC) are now very involved with the skills agenda and are running sizable apprenticeship schemes as well as growing a portfolio of industrial courses related to emerging technologies.

This is a natural outcome as changes to technology drive requirements for future workforce skills and knowledge throughout the supply chain. In short, it is not enough for the UK to develop innovative new technologies, if the workforce is not equipped to utilise them. Securing market opportunity and delivering sustainable productivity gains will only come when there is alignment between innovative technology, workforce skills and the capabilities of the supply chain.

Catapults have existing strong networks with industry and academia, a remit to horizon scan and are at the forefront of technological development, so they are well positioned to understand industry's future needs. It is sensible that this 'foresighting' around technology should identify the changing workforce skills that will be needed at all levels to ensure the UK is able to fully take advantage of new technologies and opportunities in domestic supply chains.

However, as with school inspiration activities, it is essential that workforce skills development undertaken by Catapults is part of a coordinated and collaborative approach to national training, working with other organisations such as Semta, and programmes such *Made Smarter*.

We are aware of an ongoing International Workforce and Innovation Study being carried out by the HVMC under Gatsby Foundation sponsorship to identify good practice in workforce development and will be following this with interest.

**Recommendation:**

To maximise productivity gains, the engineering workforce must be fully capable of exploiting technological advances. To this end, Catapults' remit should formally include workforce development and upskilling as a natural corollary to their role at the forefront of technology development.

## Institutes of Technology (IoT)

First proposed in the 2015 productivity plan[131], the Industrial Strategy Green Paper[132] announced funding of £170 million and a focus on skills at Levels 4, 5 and possibly Level 6 and above[133]. The bidding process is currently ongoing with the outcome expected early 2019.

It is unclear as to the exact gap that IoTs fill in an already overcrowded landscape. There is a strong argument that the funding could be used to enhance existing provision such as existing established centres of excellence in high level STEM provision such as the Catapult Centres. It is essential that whatever form IoTs take, they complement and support existing successful, national specialist models and their corresponding networks for developing advanced skills and their value must be monitored through student progression and through analysis of benefits to employers.

## Local Enterprise Partnerships (LEPs)

LEPs connect local authorities and business and are thus well placed to identify the local skills needs. They have been tasked with the leading (or supporting) of local industrial strategies (aligned to the national Industrial Strategy) to identify local strengths and challenges, future opportunities and the action needed to boost productivity, earning power and competitiveness. Additionally, they will be contributors to Skills Advisory Panels to support employers, education providers and local government in identifying current and future local skills needs shaping the provision and funding of post-16 education and training and careers guidance.

## Regional skills deals

In summer 2018, the DfE announced the regional skills deal for the West Midlands Combined Authority, with up to £69 million in funding to boost productivity and jobs opportunities in the region[134]. The new deal includes a range of initiatives from piloting the National Retraining Scheme improving apprenticeships in small businesses, investing in local colleges and boosting adult education, to improving careers advice and business-schools collaborations.

There is huge potential for these deals to target a region's specific skills needs and barriers but it is essential that it is coordinated alongside existing initiatives (including the forthcoming devolution of the Adult Education Budget) to support and strengthen each other. It is also essential that these initiatives have a proper evaluation framework from the outset. Such programmes are an opportunity to experiment, learn and understand what works in this space, which requires robust evidence and evaluation, so the findings can also be shared and applied across other regions if and when similar deals are created elsewhere.

# Conclusions

**In the context of a continuing shortfall in the supply of engineering talent, this review has examined the various aspects of the education and training system for the formation and development of engineers and technicians across the UK.**

While there has been progress and reform in certain areas, in particular improvements to careers education in schools, the reforms to apprenticeships and the implementation of new technical qualifications in England, this review has brought into sharp relief many issues that continue to impact engineering skills in the UK.

Given that the objective should be to increase the supply of engineering talent in order to provide the skills needed to implement the government's Industrial Strategy, it is shocking that parts of the population, notably ethnic minorities and women, are seriously under-represented in the engineering profession.

The challenges for engineering skills start in schools, with too few students engaged in subjects that lead to engineering. This is partly due to a shortage of specialist teachers and professional development opportunities in subjects such as physics and computing to improve teaching and learning, making content relevant and inspiring for students.

However, it is also due to curriculum, assessment and accountability measures that favour student knowledge and understanding in a narrow set of subjects (in England in particular) rather than the development of a broad range of knowledge and skills and an equal weighting to creative and technical subjects.

The engineering community has tried to bridge this gap with informal inspiration activities in schools. However, the proliferation of these well-intentioned activities in an uncoordinated manner has meant duplication of activity in some areas and little or no provision in others leading to a confused and patchy landscape of support.

The 2018 Year of Engineering has done much to bring coherence to school activities and the engineering profession, industry and wider community must build on this with a shared commitment to working collaboratively.

In technical education there have been substantial developments, with reform of apprenticeships and the introduction of the Apprenticeship Levy and the introduction of T level qualifications to simplify post-16 qualifications offered to students. Both these developments have come under criticism from employers and employer bodies, but they must be given time to work and the engineering community must get behind them as their successful implementation has the potential to be world leading.

Higher education has also experienced change in recent years. Some engineering faculties and departments have developed innovative approaches, increasing design-based project work for students, improving industry collaboration and offering more work placements.

The forthcoming review of funding for post-18 education has the potential to seriously affect provision in engineering higher education and the government must ensure that supply of engineering skills for the UK is not adversely affected by the outcome.

Finally, the last few years have seen an increase in the importance of upskilling and reskilling the existing workforce to improve productivity and make sure that engineers and technicians skills are relevant for the fourth industrial revolution and digitalisation. The engineering profession has an important role to play in ensuring that this is undertaken in a coherent, structured manner.

Overall, there is optimism in the sector and a new appetite for collaboration at all levels of the education and skills system. Engineering companies, employer representative bodies and professional organisations have a real opportunity to ensure the UK is in the best position to compete in the global competitive marketplace. Working together, we can succeed.

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