ROYAL ACADEMY OF ENGINEERING

Lloyd's Register Foundation

The UK STEM Education Landscape

May 2016

The UK STEM Education Landscape

A report for the Lloyd's Register Foundation from the Royal Academy of Engineering Education and Skills Committee

May 2016

Available to download from: www.raeng.org.uk/stemlandscape

ISBN: 978-1-909327-25-2

Cover photo: Royal Academy of Engineering

Authors

Dr Rhys Morgan and **Chris Kirby** with additional research undertaken by **Ms Aleksandra Stamenkovic**

For further information, please contact: rhys.morgan@raeng.org.uk

Acknowledgements

The Royal Academy of Engineering is indebted to the Lloyd's Register Foundation for its generous support that has enabled this study to be carried out.

The Academy is also grateful to the many organisations and individuals listed at the back of this report who provided guidance and feedback with the development of the data gathering for this study. With particular thanks to Yvonne Baker, Chief Executive of STEM Learning.

Contents

Executive summary 4

1 Introduction 10
Historical perspective 11
STEM in the economy 12
The UK engineering workforce 12
Projected demand for STEM skills 13

2 STEM education attainment and progression 14
GCSEs 15
A levels 16
Scottish education system 17
Apprenticeships and other vocational pathways 18
University degree programmes 20
Employment destinations of graduates 21

3 Key issues affecting engineering skills supply 24
Public perceptions and attitudes towards engineering 25
Teachers and teaching 25
Under-representation 30
Careers guidance, curriculum enhancement, employer engagement 32
Curricula, qualifications and accountability 33
Pathways to progression 36

4 Mapping the engineering education landscape 38
Data fields within the STEM Mapping Database 40
STEM enhancement and enrichment activities 42
How is STEM E&E provided? 42
Who provides STEM enrichments activity? 43
What STEM enrichment is on offer? 43
Where are E&E providers active? 46
How is STEM enrichment activity organised? 48
How is quality of provision assessed? 49

5 Gap analysis 52

6 Conclusion 56
Future work 57

Appendices 58
Annex A: Organisations consulted in developing the database 58
Annex B: STEM landscape database fields 59

Executive summary

The UK is facing a well-documented engineering skills crisis. An ageing workforce means that hundreds of thousands of skilled technician and professional engineering roles will need replacing over the next ten years.

However, the supply of individuals into engineering occupations is not keeping pace with demand. This is due to compound factors; from poor perceptions and lack of interest in engineering jobs, low attainment and progression in science, technology, engineering and mathematics (STEM) subjects at school, further and higher education, to young people making career choices outside of engineering (and more broadly STEM) occupations. Engineering also suffers from significant under-representation, notably with women and people from minority ethnic groups.

To improve the number of young people with the qualifications and interest to consider progressing into engineering occupations, the engineering (and more broadly STEM) communities have been working very hard for many years to encourage young people to pursue STEM subjects at school, college and university. In addition, various organisations have been working to improve the quality of teaching and learning across STEM subjects, while others have been working to influence government policy to increase participation and attainment in STEM.

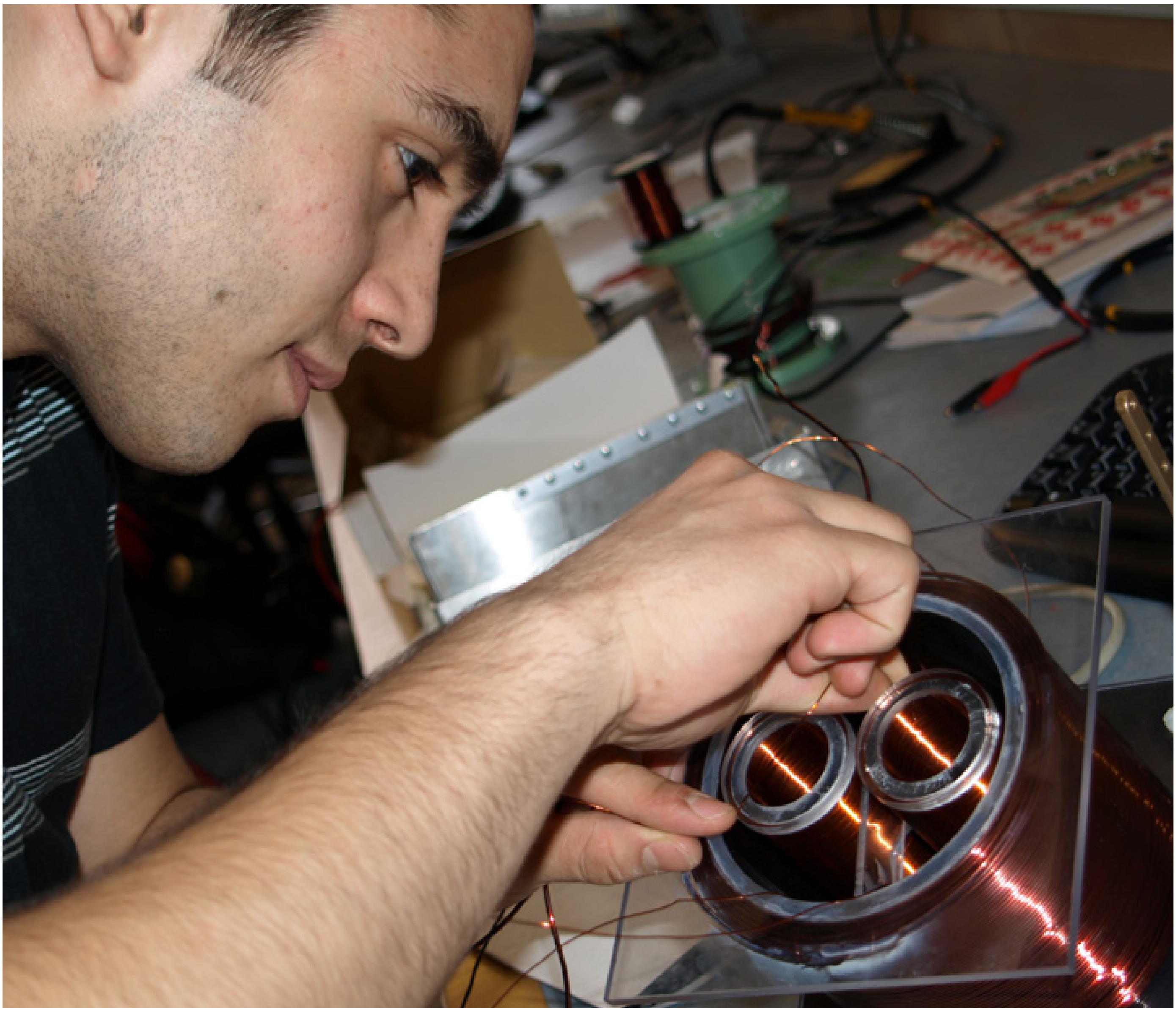


Image courtesy of the University of Birmingham

The sheer number and diversity of the many organisations involved has created a highly complex landscape, which few people properly understand (see **table 1** on the following page). The complexity has also led to inefficiencies and has been arguably ineffective in delivering the necessary change. Despite ten years of intense activity, there has been limited growth in the key subjects leading to engineering. Because of the vast number of initiatives, there is limited understanding of where or how the greatest impact can actually be achieved and also where there are certain issues, or indeed groups of people, which are not currently being properly addressed or catered for.

To better understand the STEM landscape, the Royal Academy of Engineering has undertaken this research, with generous support from the Lloyd's Register Foundation, to provide stakeholders with a detailed picture of the engineering and STEM education landscape; the issues that need to be addressed, the organisations involved and an analysis of gaps in provision. The work is intended to inform the wider community to make strategic decisions on where to focus its support for more effective impact on addressing the impending engineering skills shortage.

STEM education landscape

Diversity organisations
- WISE
- Athena Forum
- Inter Engineering
- AFBE-UK
- WES
- Your Life
- 10+ additional

STEM activities / providers
- Big Bang Fair
- Tomorrows Engineers
- EDT
- Smallpeice Trust
- Young Engineers
- Primary Engineer
- Arkwright Trust
- STEM in schools
- STEMNET
- Industrial Cadets
- Imagineering
- EESW
- 300+ additional

Mathematics community
- JMC
- LMS
- RSS
- IMA
- 20+ additional

Computing support
- Raspberry Pi / Code club
- Apps for Good
- Coderdojo
- Stemettes
- Young rewired state

Education providers
- Schools
- FE colleges
- 6th form colleges
- UTCs
- National Colleges
- ILPs / GTAs / ATAs
- National skills academies

Museums / Zoos Discovery Ctrs
- Science Museum
- Techniquest
- Nat Space Centre
- Winchester Sci Centre
- @ Bristol
- 50+ additional

Engineering bodies
- Royal Academy of Engineering
- Engineering Council
- Engineering UK
- Inst Mech Eng
- The IET
- Inst Civil Eng
- Inst Chem Eng
- Inst Struct Eng
- CIBSE
- IOM3
- IMarEST
- 30+ additional

STEM teacher support and supply
- Design and Technology Assoc (DATA)
- STEM Learning
- Assoc of Science Educators (ASE)
- Computing at School
- NAACE (ICT subject assoc)
- NCETM
- London Knowledge Lab
- Maths Hubs
- Teach First
- Teaching Leaders
- Brilliant Club

Awarding bodies
- AQA
- Pearson
- OCR
- WJEC
- EAL
- City and Guilds

Government and agencies
- Dept for Education
- Dept Business, Innovation and Skills
- National Careers Service
- National Apprenticeship Service
- HEFCE / HEFCW
- ETF
- OFQUAL
- OFSTED
- NCTL
- Careers and Enterprise Co.
- UKCES

Employers and bodies
- EMPLOYERS
- Sector Skills Councils
- Sector partnerships
- CBI, EEF, BCC...

Charitable trusts & foundation
- Salters Institute
- NESTA
- Gatsby Foundation
- Wellcome Trust
- Nuffield Foundation
- Lloyd's Register
- Ogden Trust
- Comino Fnd
- Sutton Trust
- ERA Foundation
- 1851 Commission
- Reece Foundation
- Edu Endowment fund
- Livery Companies

STEM policy bodies
- ACME
- SCORE
- Education for Engineering
- CASE
- UK forum for Computing Edu
- NCUB
- EPC / CPHC

Science community
- Royal Society
- Royal Soc Chemistry
- Royal Soc Biology
- Inst of Physics
- Royal Institution
- Science Council
- Royal Society of Edinburgh
- Royal Astronomical Society
- Geological Society of London
- British Science Association
- Learned Society of Wales
- 70+ additional learned societies

Table 1: An illustration of the complex STEM education landscape that highlights just a fraction of the organisations engaged in various types of activity.

Key issues in engineering education

The issues that are preventing increasing numbers of young people taking up subjects leading to engineering careers are varied and numerous. The Academy has grouped these issues into seven distinct areas that, if properly addressed, would likely result in meaningful increases in the number of young people pursuing engineering as a career. They are:

- Perceptions of young people, their parents/carers and other influencers, and attitudes towards engineering.
- Teachers and teaching.
- Under-representation of specific groups.
- Careers advice and guidance, curriculum enhancement and employer engagement.
- Curricula, qualifications, assessment and accountability measures.
- Pathways to progression.
- Facilities and capacity in further education (FE) and higher education (HE).

These seven key areas are broad and in places the issues are likely to overlap. In addition, some challenges may be perceived to carry more weight than others. However, unless all are addressed then there is likely to be limited success in increasing the number of young people following engineering career paths. Some of the issues require change in government policy, others need greater and more coordinated input from employers, the engineering profession and the wider STEM community. Many organisations are already working to address some of the issues. Further detail on this is provided in the report.

Engineering education landscape

The Academy has undertaken a detailed mapping of the STEM education landscape and has identified over 600 organisations that are in some way involved in supporting engineering education. The mapping has been undertaken through consultation with a wide range of stakeholders, using existing databases and web searches. The majority of organisations are specialist education enrichment providers, but the list also includes learned societies and professional bodies, science discovery centres, field study centres, subject associations and teacher support organisations. Many of these organisations will undertake a range of activity; from direct interactions with school students and teacher continual professional development programmes to providing policy advice and guidance to government and other agencies. However, the list of over 600 organisations is not exhaustive and many more small providers are likely to exist, providing various forms of support to young people. The mapping also does not include employers or universities, which provide significant amount of support to the education system.

The support provided by the organisations captured in the mapping exercise that the Academy has undertaken covers the full spectrum of learners, from early years foundation stage and key stage 1 through to key stage 5 (post-16 education) apprenticeship and vocational education, and university programmes.

The analysis suggests that provision mostly consists of activities taking place in schools, delivered by organisations that provide enrichment and enhancement of the STEM curriculum. This enrichment activity plays an important role in providing careers awareness and inspiration to enable young people to see the opportunities afforded by careers in engineering/STEM. The majority of provision is targeted at 11–14 year olds – often cited as a key age before GCSE subject choices are made.

The most common type of activity is 'talks and presentations', followed by hands-on, extra-curricular activities. Providers are distributed across the UK with the majority in the North West and South East. However, it is difficult to properly understand exactly how geographically widespread the activity is undertaken as many of the larger, national organisations have a wide reach across many regions. In terms of support for specific subject areas, organisations are delivering activity across the whole range of STEM, but 'general science' is identified as the most common target subject.

One of the key issues that the mapping study has identified is the lack of consistent evaluation across providers – and in many cases, of any evaluation at all. Where it does take place, evaluation is often limited to brief feedback forms undertaken by students or teachers directly after an event. While this form of evaluation is a useful tool to assess the immediate impact of an activity, it does not help with understanding the longer-term effectiveness of interventions on student decision making. There is therefore a key issue with regards to ascertaining the efficacy of 'single-activity' interventions, such as careers talks and presentations compared with longer-term, sustained interventions, in terms of increasing attainment and progression to STEM education study in post-16 education.

Gap analysis

The mapping activity has also sought to identify gaps in provision needed to address the key issues identified in the report. The analysis shows that there are very few areas where there is no current support for encouraging young people towards engineering/STEM or in improving their attainment in STEM subjects. However, there appear to be key areas where the scale and pace of activity is perhaps currently insufficient to effect meaningful change. In addition, the apparent lack of evaluation or evidence of impact across many programmes is likely to mean that there will be a number of activities that continue to run that do not have any significant effect on attainment or progression in STEM subjects.

The key areas, identified by the Academy through this and other work, requiring further activity from the engineering/STEM community to address the engineering skills challenge are:

- Improving the understanding of, and attitudes towards engineering among young people, their influencers and the public.
- Increasing support for teachers of STEM subjects.
- Greater STEM support in primary schools.
- Improving teaching and learning in the FE sector and promoting practical, technical and vocational pathways to engineering.
- Widening access to under-represented groups.
- Development of innovative teaching and increasing employer engagement methods in higher education.
- Coordination of enrichment activities to reduce duplication of effort and reach schools that are currently underserved.
- Provision of more specific careers information on the routes to engineering careers in different sectors, and further advice and guidance on work experience, industry placements and application processes in engineering.

More detail is provided on the specific areas to be addressed in each of these themes in the report.

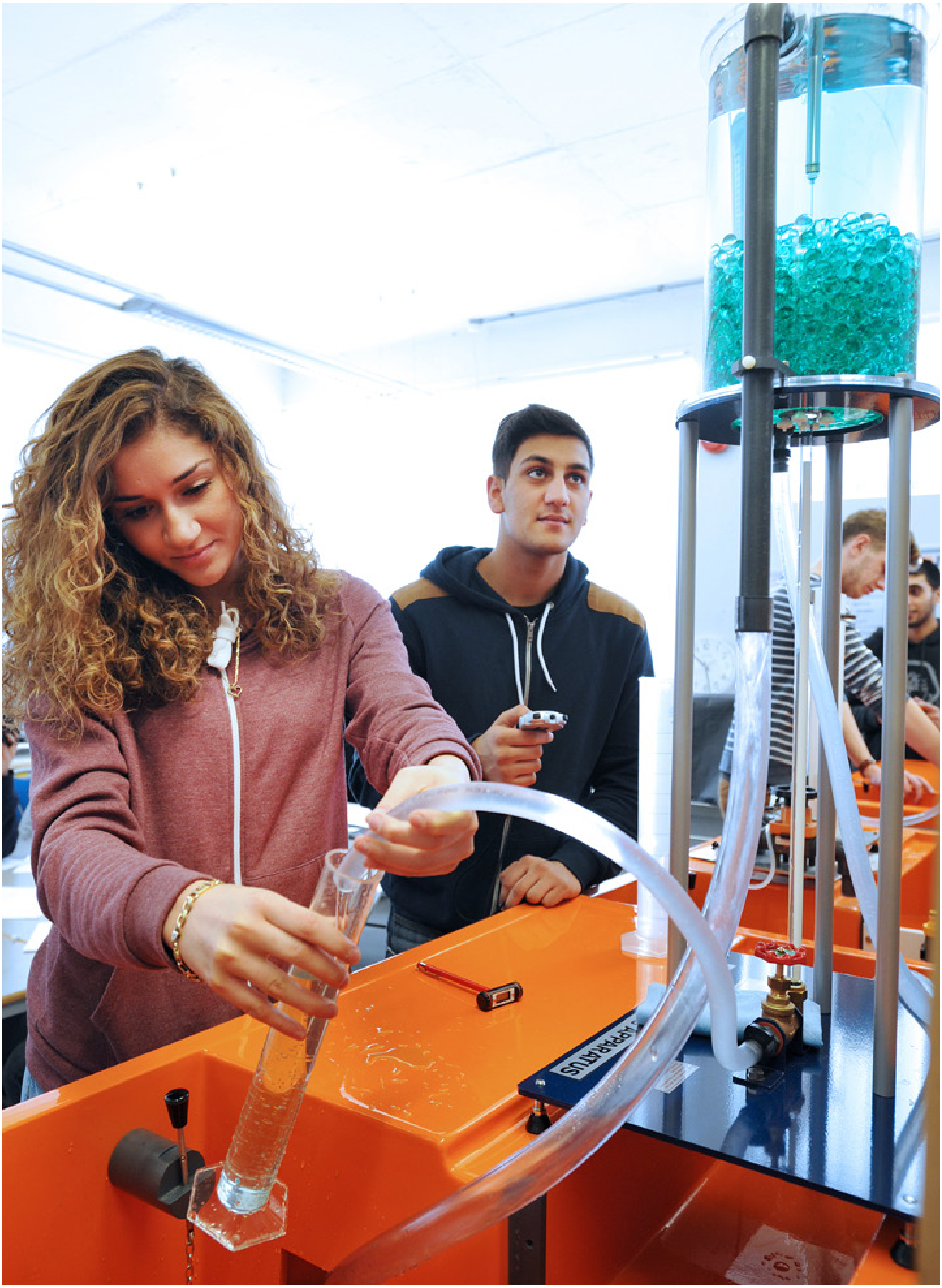


Image courtesy of the Brunel University London

1 Introduction

This report provides a detailed snapshot of the engineering, and more broadly STEM, education landscape across the UK in 2015/16. It provides background on the factors that are impacting the supply of skills into engineering – from GCSEs (and equivalent qualifications) through university education and beyond. The report also highlights key issues affecting the number of people pursuing engineering as a career. It provides analysis of the wide range of organisations involved in the engineering/STEM education support landscape, and highlights where there are currently gaps in provision or where support is insufficient to address skills needs.

STEM subjects are seen as critically important to the UK's economic success. Engineering alone accounts for 25% of gross value added for the UK economy and manufactured goods account for 50% of UK exports[1]. Science, engineering and technology underpin the whole economy, including power generation and electricity distribution, utilities, the food chain, healthcare, and our physical, transportation and information and communications infrastructure. Engineers and other STEM-qualified people are also pervasive across the wider economy and can be found in arts and entertainment sectors, sports, education and financial services. Some are employed in STEM roles in non-STEM sectors, others are in non-STEM roles, but recruited because of their STEM background. Medicine, dentistry and medical-related subjects are not included in this analysis.

1 Engineering for a successful nation Royal Academy of Engineering 2015 http://www.raeng.org.uk/publications/reports/engineering-for-a-successful-nation

Historical perspective

In 2002, the late Sir Gareth Roberts FREng FRS, a respected UK engineer, was asked by the then Chancellor of the Exchequer to undertake a review of science and engineering skills in the UK. The review was commissioned as part of the government's strategy for improving the UK's productivity and innovation performance. It stemmed from the government's concern that the supply of high-quality scientists and engineers should not constrain the UK's future research and development (R&D) and innovation performance. The final report, *SET for Success*, identified a shortage in the number of young people pursuing science, engineering, maths and technology, and it first introduced SET (science, engineering and technology) into the UK policy lexicon[2]. The report also highlighted the importance of mathematics skills for the innovation economy and the the government's subsequent *Science and Innovation Investment Framework 2004-2014*[3] introduced the acronym STEM to include mathematics.

In 2005, the Higher Education Funding Council for England (HEFCE) identified a number of STEM subjects as 'strategically important and vulnerable subjects' (SIVS) with concern that higher education institutions would cut back on provision because of falling demand[4]. There was also concern that SIVS would be under threat because of the inherent cost of provision (in terms of capital and other costs associated with laboratories, consumables and technician support) in their subject delivery.

As part of the Science and Innovation Investment Framework, the (then) Department for Education and Skills mapped the STEM landscape in 2004 and identified over 470 STEM initiatives[5]. Concern was expressed that there were too many schemes, and the government sought to rationalise its support and focus on those that were seen as the most effective to achieve greater impact for the same amount of money. In 2006, the National STEM programme[6] was established by the Department for Education and Skills to provide a coordinated approach for government support to address the STEM skills issue in schools and colleges. This completed in 2010.

From 2010, the coalition government continued to recognise the importance of STEM subjects in schools and took various measures to improve participation and attainment in STEM by young people. This included continuing support for programmes such as the National Science Learning Centre, the Big Bang national science and engineering fair, STEMNET and the creation of YourLife[7], a campaign to encourage young people to take maths and physics at A level.

At the same time, during the significant reform of the education system under the coalition government, some policies have emerged with potentially negative impacts on STEM. For example, many within the STEM community are concerned about the possible impact of packed new curricula in science and mathematics on the number of students pursuing STEM subjects beyond 16. The lack of specialist teachers across key subjects such as maths, physics, design and technology (D&T), and computing continues to be a major concern. Furthermore, qualification, assessment and grading reforms, and school accountability measures focusing on a narrow set of academic subjects risk having negative consequences for uptake of other more practical subjects, such as D&T and art and design, which are also important in creative engineering disciplines. More details on these issues are presented in the later section.

2 SET for Success, Sir Gareth Roberts, http://webarchive.nationalarchives.gov.uk/+/http:/www.hm-treasury.gov.uk/ent_res_roberts.htm
3 Science and Innovation Investment Framework 2004-2014, http://news.bbc.co.uk/nol/shared/bsp/hi/pdfs/science_innovation_120704.pdf
4 HEFCE 2005, http://www.hefce.ac.uk/kess/subjects/
5 STEM Programme report 2004 https://www.nationalstemcentre.org.uk/res/documents/page/stem_programme_report_2006.pdf
6 STEM Cohesion Programme Final Report, https://www.gov.uk/government/publications/the-stem-cohesion-programme-final-report
7 YourLife campaign http://yourlife.org.uk/

STEM in the economy

The application of STEM contributes greatly to the UK's wealth, and it is well known that engineering creates the modern world's infrastructure. STEM activities contribute significantly to the UK economy. Various studies have shown how broad areas within STEM generate wealth and contribute to our economy. Among them are:

- £370bn gross value added (GVA) from 'easily identified' engineering sectors in the UK economy[8].
- £208bn GVA from mathematical sciences research[9].
- The UK ICT industry estimated[10] to be worth £58bn each year.
- Over one million people in the UK (in 2012) employed directly by physics-based businesses[11].
- £2.8 billion positive net trade position of the UK pharmaceutical industry[12].

STEM skills are also critical in the move to rebalance the UK economy and improve productivity[13]. A sufficient supply of individuals with the right skills underpins this change as well as ongoing economic growth. It is likely that the next 30 years will see technological changes at least as great as those of the last 30.

The UK engineering workforce

The UK economy employs approximately 30 million people of whom 5.8 million people are employed in STEM-based occupations, around 20% of the total workforce. This figure excludes others involved in STEM-related occupations, such as doctors, nurses or those teaching STEM subjects from early years to university level. The 'Engineering the Future' alliance of the professional engineering community estimates there are some 4.3 million people working in engineering occupations alone[14]. Of these, some 3.5 million people are working at advanced technician level or in professional engineering occupations within engineering companies.

Workforce skills are a key contributor to competitive advantage and business performance. Many innovative organisations rely on the regular intake of good quality STEM graduates to refresh their innovation capabilities[15]. Innovation-active enterprises employ higher proportions of graduates in general and, in particular, a higher proportion of STEM graduates than their non-innovative counterparts[16].

> **"Scientists, technologists, engineers, mathematicians: these are the high-end knowledge workers who turn the wheel of the global economy."**
>
> Accenture 2011

8 Jobs and growth: the importance of engineering skills to the UK economy. Royal Academy of Engineering 2012.
9 Deloitte. Measuring the Economic Benefits of Mathematical Science Research in the UK. 2012
10 UK Trade and Investment. Feb 2014
11 Deloitte. The Importance of Physics to the UK Economy. 2012
12 Association of British Pharmaceutical Industry www.abpi.org.uk
13 Fixing the foundations: creating a more prosperous nation. HM Treasury. July 2015. www.gov.uk
14 The Universe of Engineering: A Call to Action Report. Engineering the Future. November 2014. www.engineeringthefuture.co.uk/universe/default.aspx
15 The Royal Society. Hidden wealth : the contribution of science to service sector innovation. 2009. p. 92
16 The Council for Industry and Higher Education. STEM Review: the Science, Technology, Engineering, Maths Supply Chain. 2007

Image: Royal Academy of Engineering

> **"If we are going to succeed as a country then we need to train more scientists and more engineers."**
>
> Prime Minister, Rt. Hon. David Cameron MP 2013

In 2014 the Confederation of British Industry (CBI) reported[17] that a STEM skills base is vital to our future as a knowledge-intensive economy. In 2010 around 40% of the UK workforce were classified as 'knowledge workers'; by 2020 it is expected to be over 50%[18]. Jobs in the future will increasingly require skills that STEM study helps to develop; not only technical knowledge but also skills such as critical thinking, logic, mathematical reasoning and numerical analysis, design and a broader grasp of scientific method. The value of these competencies is such that demand for people with STEM skills is widespread and growing among businesses in non-STEM as well as STEM sectors.

Projected demand for STEM skills

Demand for skilled people arises for two main reasons: replacement demand to replace people who retire or leave the sector for any reason; and expansion demand to fill new roles created by business growth. The UK Commission for Employment and Skills (UKCES) consistently reports shortages in STEM skills linked to innovation[19] and that vacancies requiring STEM skills are more likely to be 'hard to fill' than vacancies overall[20].

EngineeringUK, the body that promotes engineering on behalf of the professional engineering institutions, predicts that between 2012 and 2022 there will be demand for 1.82 million people in engineering occupations at all levels, based on its analysis of UKCES data. Of those, around 1.6 million people will be needed at advanced technician (level 3+ qualifications) and professional engineer (graduate) level.

The majority of this need, EngineeringUK suggests, will be replacement demand, with around 1.3 million workers required each year to replace an ageing workforce and those leaving the engineering sectors. In addition to this, the UK productive economy is expected to grow and expansion demand for people in engineering is expected to increase by a further 300,000 by 2022.

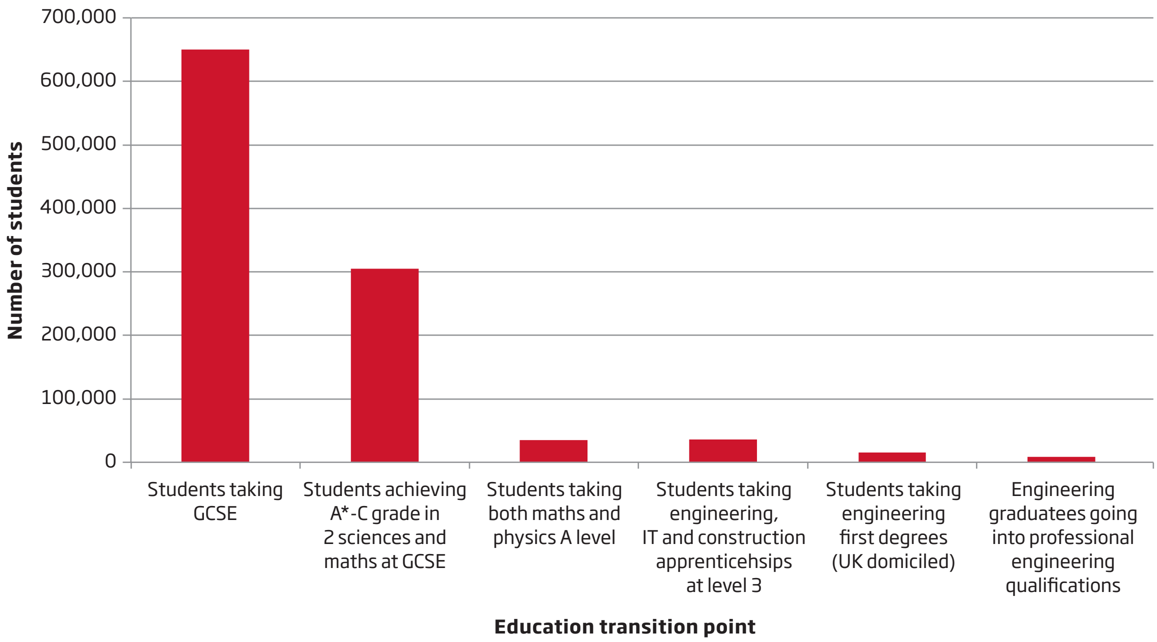
The CBI reports that around 40% of employers already find it difficult to recruit such people and that the STEM recruitment situation will worsen over the next few years. This intensification of recruitment difficulties has been identified by, among others, the Institution of Engineering and Technology (IET)[21], Social Market Foundation[22], EngineeringUK[23] and UKCES[24].

17 CBI. Engineering our Future – Stepping Up the Urgency on STEM. 2014
18 Wright J, Brinkley I, Clayton N. Employability and Skills in the UK: Redefining the debate. Work. 2010
19 UKCES. The Labour Market Story : Skills For the Future The Labour Market Story: Skills for the Future. 2014
20 UKCES. The Supply of and Demand for High-Level STEM Skills. Evidence Report 77. 2013
21 http://www.theiet.org/factfiles/education/skills2015-page.cfm
22 Social Market Foundation. In the balance – The STEM human capital crunch. 2013
23 EngineeringUK. EngineeringUK 2015: The state of engineering. 2015 www.engineeringuk.com
24 UKCES. The Supply of and Demand for High-Level STEM Skills. Evidence Report 77. 2013

2 STEM education attainment and progression

From the age of five, children in the UK enter the formal education system and progress through a series of stages and transition points. They will remain in some form of education, or training until at least the age of 18. Throughout this period, they will travel through a formative period of education and personal development during which they will be exposed to a range of social and educational influences and experiences. At the same time, they will pass through key gateways and decision points – the choices they make will be a key determinant in their future life and career opportunities.

Figure 1: Key transition points for young people across various stages of education towards engineering[25]



At each of these main transition points, many young people either do not attain sufficiently high grades to be able to pursue further study towards engineering or they make subject choices that do not enable them to easily progress with engineering as a future career. **Figure 1** above illustrates the scale of the challenge.

25 EngineeringUK. The State of Engineering. 2015 www.engineeringUK.com

Image: Royal Academy of Engineering

GCSEs

Each year, some 650,000 students across parts of the UK (England, Wales and Northern Ireland) take GCSE exams across a broad range of subjects. Of these, around 300,000 will achieve a 'good' grade (A*–C) in maths and two sciences – usually seen as the minimum required for progression to further study in STEM subjects at level 3 (A level or equivalent vocational qualification). In reality, many schools require students to have an A/A* grade in maths and physics to allow students to progress with STEM subjects beyond 16, because of concerns about the transition from GCSE to A level and consequent impacts on school performance measures. **Figure 2** shows the trend over time for a selected group of subjects at GCSE.

The graph shows an encouraging historic upward trend of students taking individual sciences (physics, chemistry, biology) often referred to as 'triple science' up to 2013. The alternative to triple science is 'double science' which comprises of two more general science GCSEs – *core* science and *additional* science. These cover the three areas of biology, chemistry and physics but in less depth. They still provide a route to A levels in STEM; however, the triple science route is preferred by schools for progression.

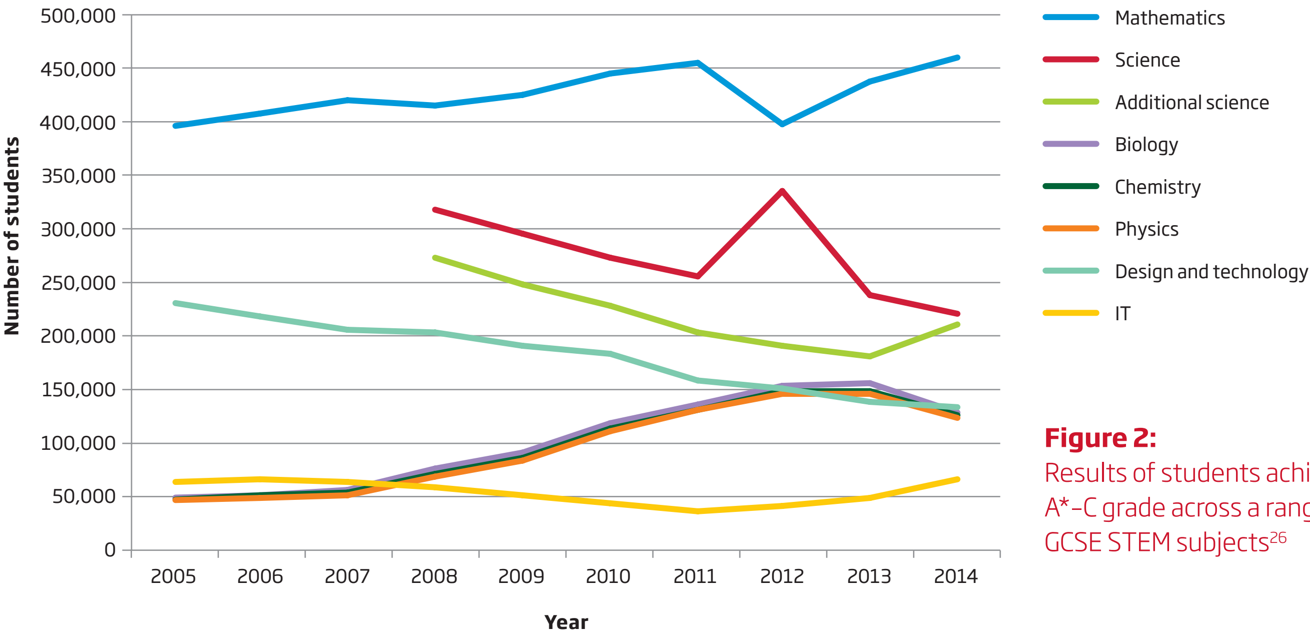


Figure 2:
Results of students achieving A*–C grade across a range of GCSE STEM subjects[26]

26 Joint Council for Qualifications www.jcq.com

There has been an ongoing decline in the number of students taking D&T since 2005/6 when it was withdrawn as a compulsory key stage 4 subject. This decline has been exacerbated in recent years – many teachers feel – because of the English Baccalaureate accountability measure on schools which focuses attention on more 'traditional' subjects at GCSE.

The Information and Communication Technology (ICT) GCSE is no longer being offered and a new computer science GCSE has been introduced. This is in line with reforms to the national curriculum in England in 2012 which removed ICT from the curriculum and introduced computing as a new subject encompassing elements of computer science, IT and digital literacy.

A levels

Of those students who do achieve good grades in maths and science at GCSE, around 90,000 now go on to take maths A level, which is an encouraging trend over recent years, as shown in **figure 3**.

Over the same period, all science subjects have also been increasing at A level; however, their growth has been relatively slow and the number of students taking physics remains stubbornly low. Only around 30,000 students will choose to pursue a combination of both maths and physics at A level – often seen as a requisite combination for entry to many engineering and physics degree programmes.

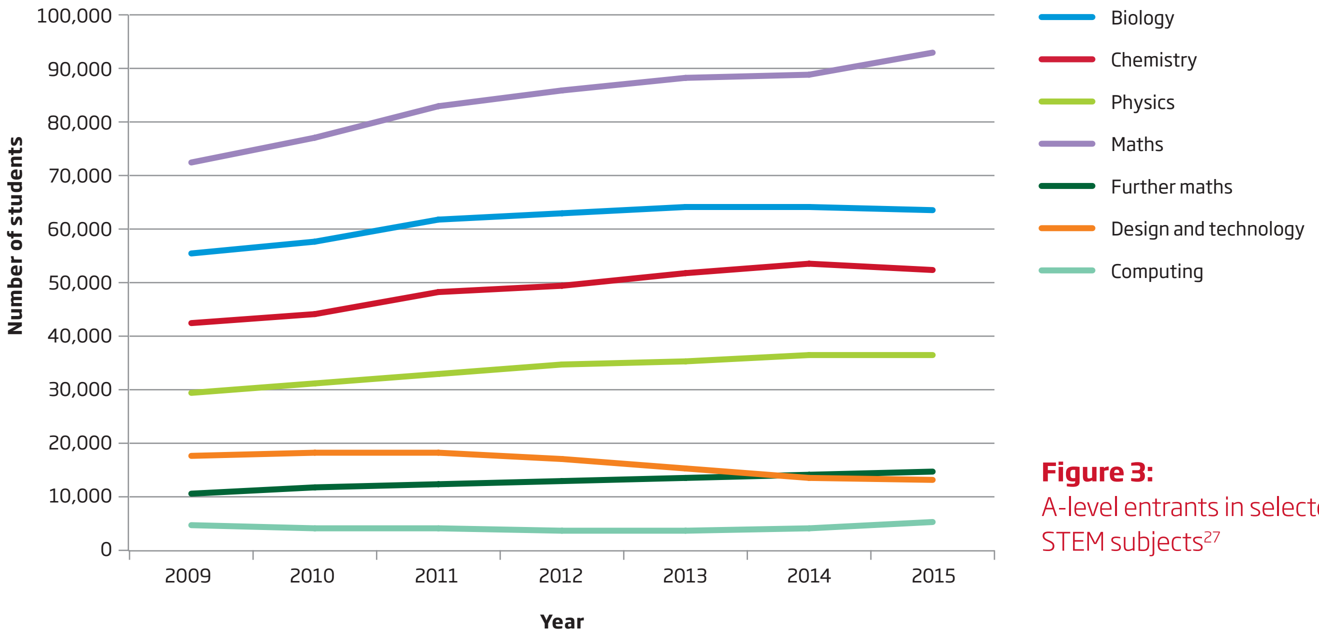


Figure 3:
A-level entrants in selected STEM subjects[27]

27 Joint Council for qualifications. www.jcq.com

Image courtesy of the Brunel University London

Scottish education system

Scotland has an entirely different qualification system to that of England, Wales and Northern Ireland. The qualifications structure is based on national awards, certificates and higher certificates. The majority of qualifications taken by students are National certificates (Scottish qualification levels 4 and 5), Highers (level 6) and Advanced Highers (level 7)[28]. Nationals 4 and 5 are roughly equivalent to GCSEs, Highers similar to AS levels and Advanced Highers approximately equivalent to A levels in the rest of the UK. These qualifications are taken between the ages of 15 and 18.

Students will typically take four or five Highers and can leave the school education system with Highers after S5 – the fifth year of secondary school (aged 17). With a range of Higher certificates, students can begin university as undergraduate programmes in the Scottish higher education sector run for four years. However, students are also able to stay on for a further year in the school system to undertake two or three Advanced Highers for increased depth of study and this is becoming a favoured route. Advanced Highers are usually requisite qualifications for those students wishing to study in English and Welsh universities as they have similar depth of content to A levels.

Those students who do not wish to follow higher education pathways can follow vocational pathways and apprenticeships at the equivalent of National level 4.

For the past few years, the Scottish education system has been in a state of flux, with the introduction of a new Curriculum for Excellence and a suite of new specification Highers being introduced for 2015. As such, it is difficult to provide any meaningful trend data. **Table 2** shows the attainment across a selection of subjects for the new Highers and Advanced Highers in 2015.

Subject	Higher		Advanced Higher	
Organisation type	Participation	Attainment (A grade)	Participation	Attainment (A-C grade)
Mathematics	10,220	2,015 (19.7%)	3,641	2,496 (68.6%)
Biology	2,572	677 (26.3%)	2,425	1,865 (76.9%)
Chemistry	4,020	885 (22.0%)	2,448	1,958 (80.0%)
Physics	3,662	862 (23.5%)	1,845	1,441 (78.1%)
Computing science/computing	1,182	190 (16.1%)	509	432 (84.9%)
Design and manufacture	2,224	416 (18.7%)	-	-

Table 2:
Attainment in selected STEM Higher and Advanced Higher qualifications (2014-15), Scotland[29]

28 Note, the Scottish qualification framework levels do not map directly on to the qualification levels used in England, Wales and Northern Ireland
29 EngineeringUK annual report 2016. www.engineeringuk.com

Apprenticeships and other vocational pathways

Alternative pathways at age 16 include apprenticeships. There has been a clear increase in the number of apprenticeships over recent years, but there is concern that much of the growth has been in retail, healthcare and business apprenticeships. Also, the growth has mainly been at level 2 (GCSE equivalent) and not at the more advanced level 3 (A level equivalent) often seen as required for a high value-added economy. **Figure 4** shows the trends for apprenticeships across a range of sectors, while **figure 5** shows the apprenticeship starts at different levels for engineering, construction and IT. Over the last three years around 35,000 students have started advanced apprenticeships across engineering, construction and the built environment, and IT sector skills areas.

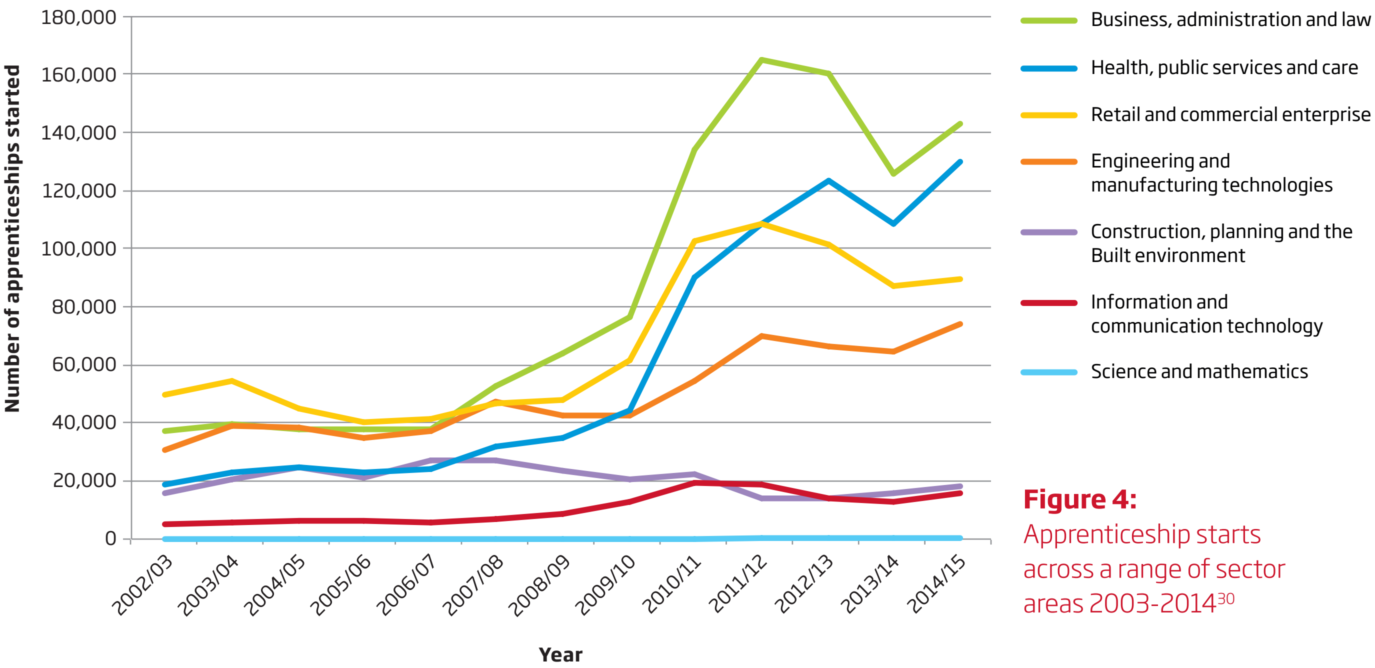


Figure 4: Apprenticeship starts across a range of sector areas 2003-2014[30]

30 FE Data library https://www.gov.uk/government/collections/fe-data-library

Image courtesy of the University of Birmingham

The number of full- and part-time students taking vocational qualifications who are not undertaking an apprenticeship is difficult to ascertain. Estimates based on survey data carried out by the Royal Academy of Engineering and the Gatsby Charitable Foundation (not yet published) suggest the following numbers of students:

- 75,000 full-time students taking level 3 engineering qualifications.
- 10,000 part-time students taking level 3 engineering qualifications.
- 27,000 students taking level 4+ engineering qualifications.

More work is being done to assess the accuracy of this survey data against FE data sets. However, if correct it shows that the FE sector makes a very significant contribution to the engineering skills pipeline, which is, at present, significantly undervalued.

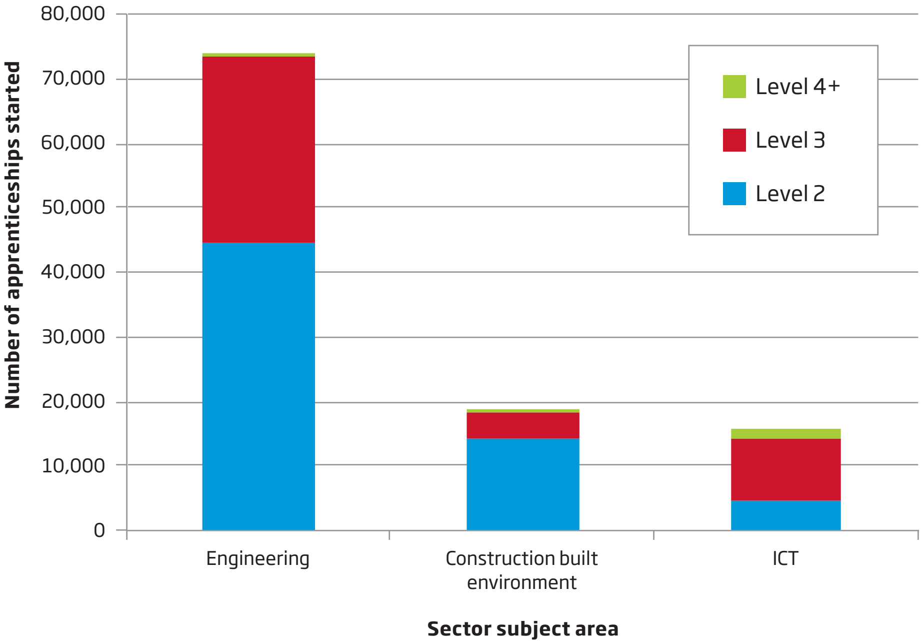


Figure 5:
Apprenticeship starts in engineering and manufacturing, construction and built environment, and IT sector subject areas by level of apprenticeship 2014/15 [31]

In 2010, the JCB Academy in Staffordshire heralded a new form of provision as the first University Technical College (UTC). This new form of provision was created by former education secretary Lord Kenneth Baker and the late Lord Ron Dearing.

UTCs take in students at age 14 until age 19. They have strong connections with universities and with employers. There are currently 39 UTCs open with a range of engineering specialisms. A further 16 are due to open by 2017. They are an exciting new form of provision for developing engineering skills but they are unlikely to have any significant impact on skills supply for the short or medium term because of the current numbers of UTCs in existence.

31 FE Data library https://www.gov.uk/government/collections/fe-data-library

Image courtesy of the University of Leicester

University degree programmes

Beyond A levels and level 3 vocational study, the number of UK students entering engineering degrees is around 14,000 per year. This figure has remained largely static for the past ten years, falling in the early 2000s, as shown in **figure 6**. However, in 2011/12 the number of UK domiciled students returned to 2003/4 levels and has been increasing steadily since. Overall, the number of people taking engineering degrees has been increasing throughout the period, and this has been largely due to the significant growth in the number of non-EU students coming to study in UK universities.

Disciplines such as mechanical and civil engineering and chemical engineering in particular, have seen significant growth over the last ten years, while subjects such as electronic engineering, production and manufacturing engineering have seen steady decline over a sustained period, as shown in **figure 7** on the following page. There is now concern that applications to some disciplines are falling. Civil engineering in particular has seen applications reduce over recent years.

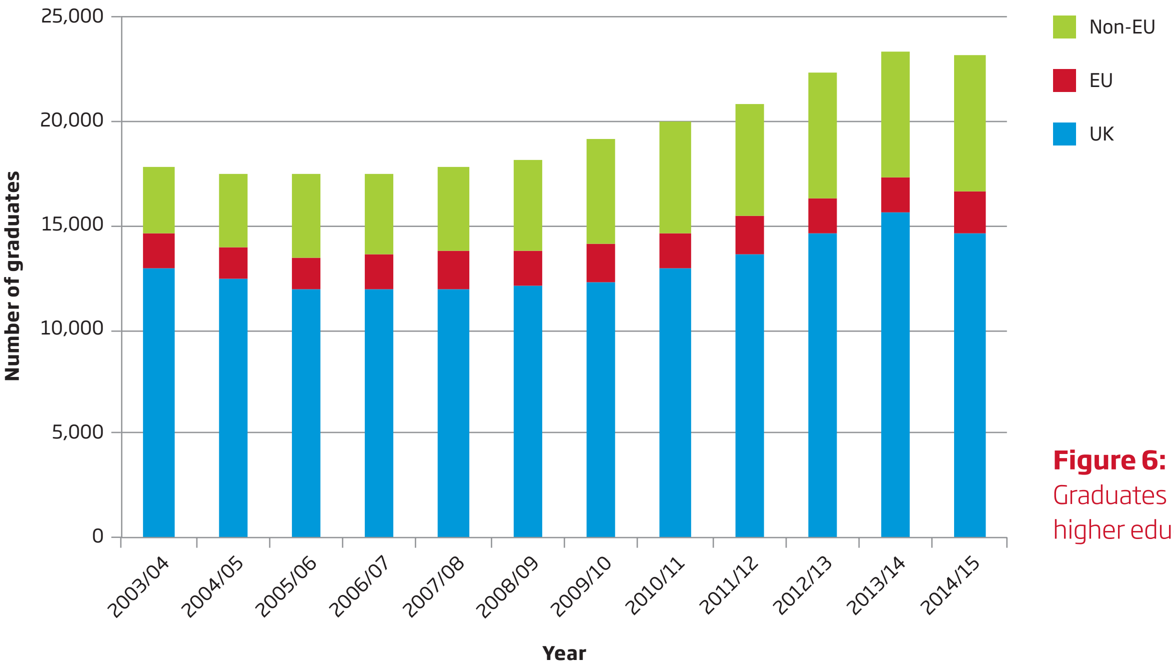


Figure 6:
Graduates in engineering higher education[32]

32 EngineeringUK annual report 2015 www.engineeringuk.com

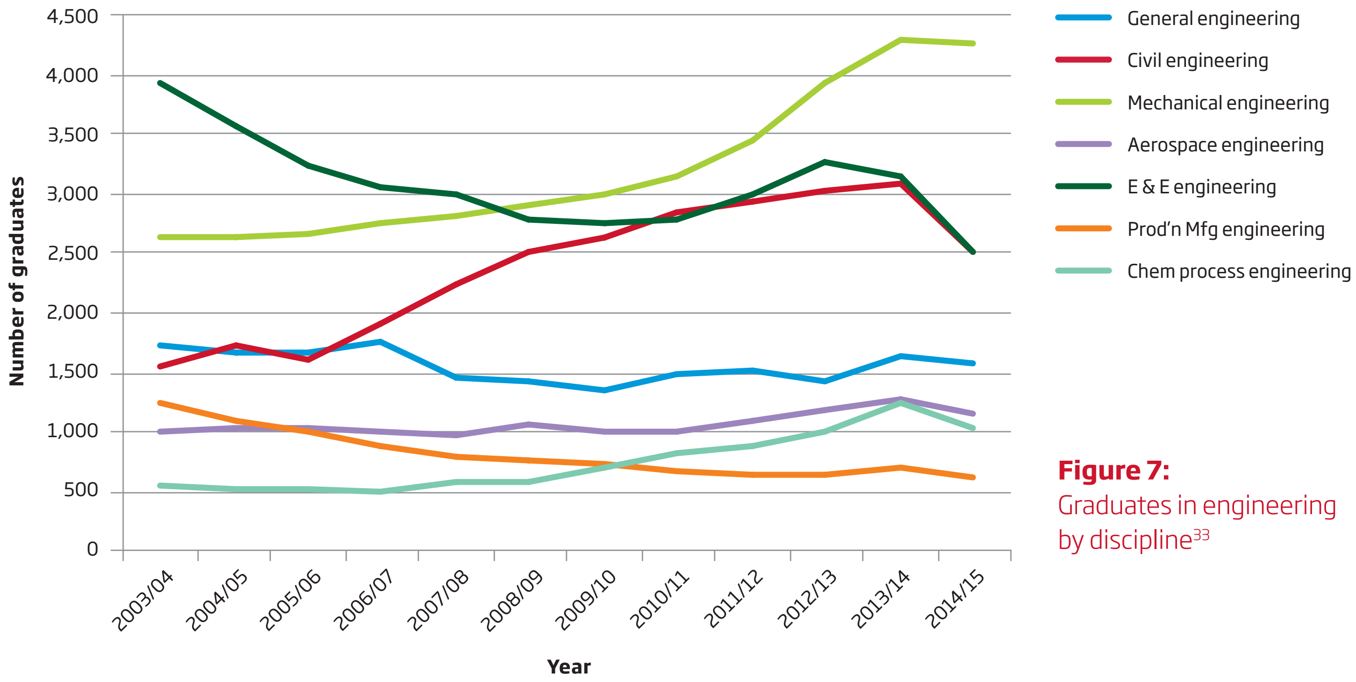


Figure 7:
Graduates in engineering by discipline[33]

Employment destinations of graduates

On leaving higher education, fewer than half of UK domiciled engineering students enter into professional engineering occupations. **Figure 8** illustrates the flows of engineering graduates into employment and other destinations. While the largest single destination of both male and female graduates is into professional engineering roles, as a proportion of the whole cohort, they account for only 40%. Further analysis by the Academy has shown that students from Black, Asian and other minority ethnic groups are more likely to be in non-engineering jobs or unemployed six months after graduation[34].

Employers are dealing with shortages of engineers in their own way and are recruiting individuals from a wide range of subject areas in higher education to go into engineering roles and occupations[35]. **Figure 9** shows the most popular subject areas from which graduates are employed into engineering jobs. While of course it is expected that employers recruit from engineering, computing, maths and physical science subject areas, it is interesting to note they are also recruiting from subject areas such as biological sciences, business and administration, and creative arts and design. Other subject areas not included in the graph from which employers are also recruiting graduates include modern foreign languages, historical and philosophical studies, social sciences and law.

33 EngineeringUK annual report 2015 www.engineeringuk.com
34 Improving the employment changes of engineering graduates. CRAC. http://www.raeng.org.uk/publications/other/improving-the-employment-chances-of-engineering-gr
35 Engineering occupations are identified through the standard occupation classification (SOC) list

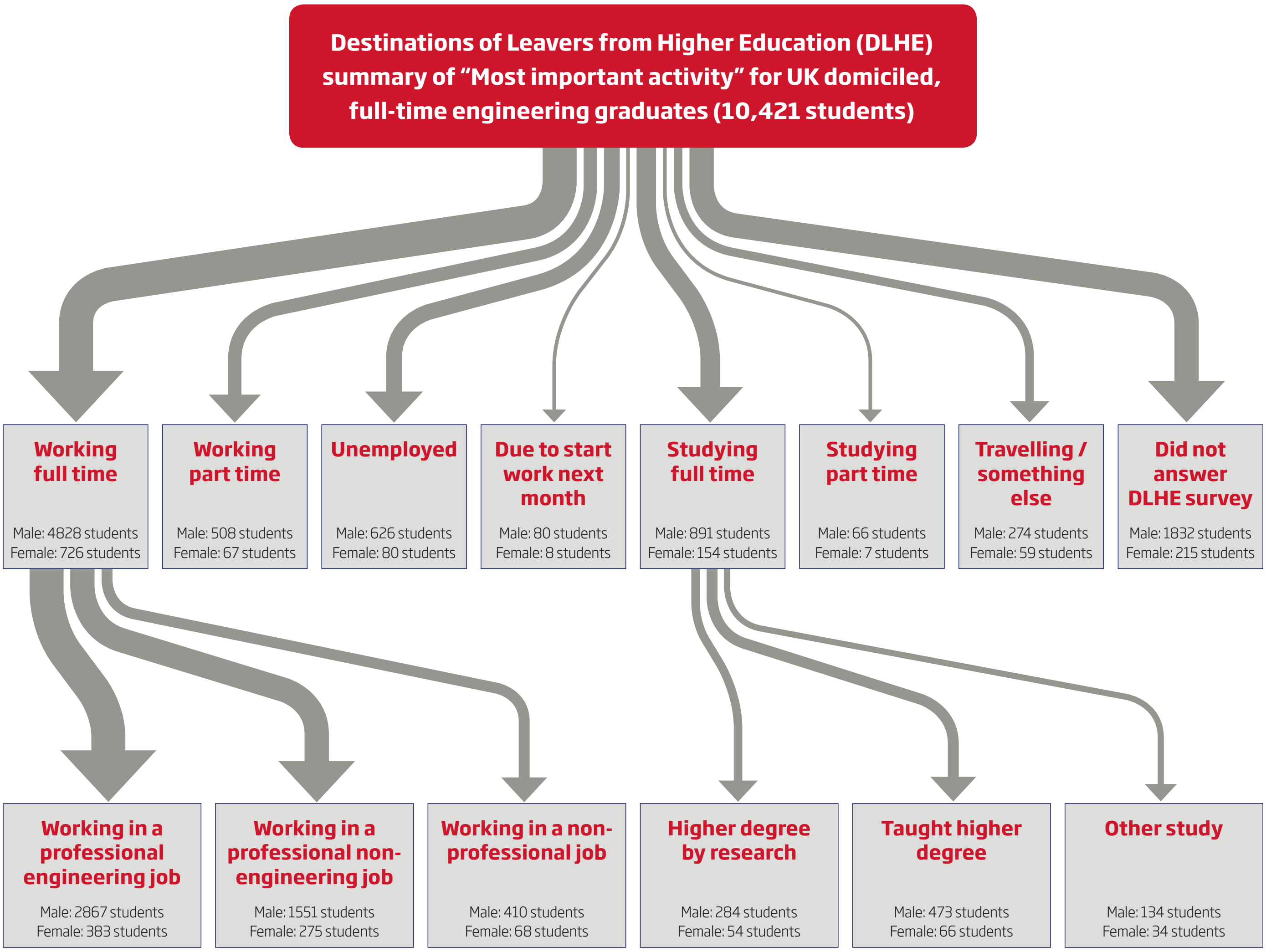


Figure 8:
Destinations of graduates from engineering higher education first degree programmes (2011) [36]

36 Taken from 'Pathways to progression for engineering degrees and careers' report. Royal Academy of Engineering. 2014

All this data on STEM subjects in education shows that from around 650,000 students each year taking GCSEs, the number of professional engineers produced is around 7,000 or approximately 1% of the cohort (excluding those entering engineering from other subject areas).

It is clear then that there is still substantial work to do to attract young people towards engineering and more broadly STEM careers, but also ensure that students are assisted in making appropriate choices and attaining well at each stage to enable them to progress readily to further study and employment.

However, there are significant barriers that appear to be reducing the number of young people looking to pursue the appropriate subjects and engineering careers. These are explored further in the next section.

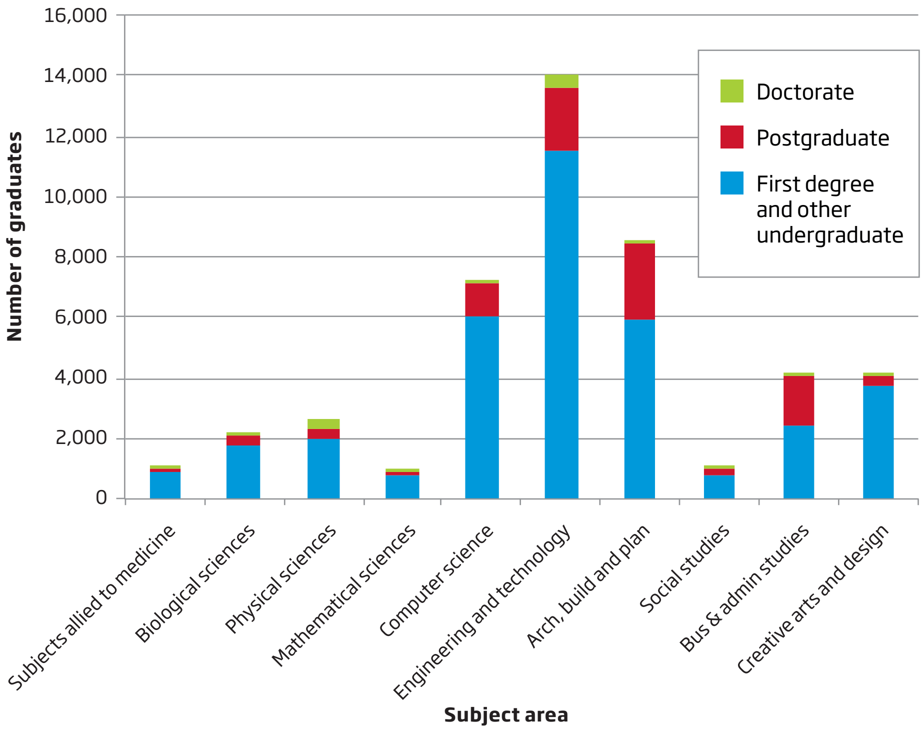


Figure 9:
Higher education subject areas from which employers will take on graduates in engineering occupations (2013/14)[37]

37 EngineeringUK. The State of Engineering 2015. www.engineeringuk.com

3 Key issues affecting engineering skills supply

The issues that affect the proportion of people who pursue STEM subjects towards engineering careers are complex, and have been the subject of numerous reports. Often multiple factors compound the challenge and there is clearly no single thing which can alone address the 'engineering skills crisis'.

Figure 10 illustrates the key issues that the Royal Academy of Engineering believes, if addressed, would make a significant impact in the number of young people following engineering career pathways.

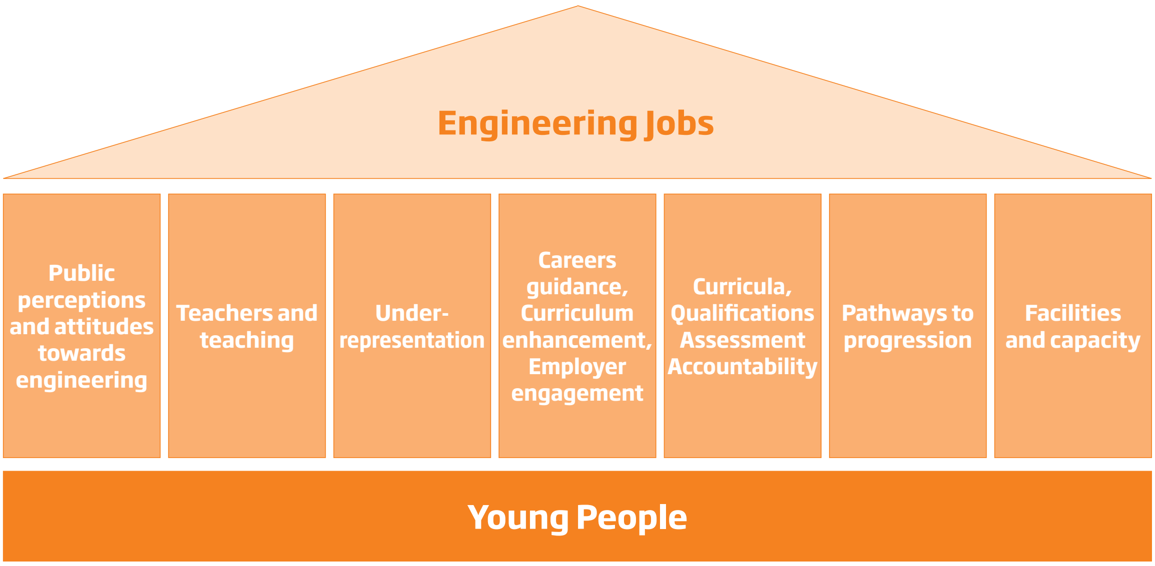


Figure 10:
Key issues affecting the proportion of young people continuing with STEM study and following engineering careers


Image: Royal Academy of Engineering

Public perceptions and attitudes towards engineering

There is generally a very positive perception of engineering and science in the UK. Many people acknowledge the benefits both disciplines bring to society. The latest Engineers and Engineering Brand Monitor, a survey of attitudes towards engineering undertaken by EngineeringUK, shows the public generally view the profession in a favourable and improving light[38]. More generally, the Wellcome Trust's monitor shows young peoples' attitudes towards science in school is also favourable. However, the data presented earlier in this report showing uptake of STEM subject pathways highlights the considerable disconnect between the recognised value and interest in science and engineering, and the number of young people pursuing subjects and pathways suitable for careers in these fields.

There is still a longstanding and ongoing concern among the engineering community that many people perceive engineering as manual and of low status – a set of occupations more readily associated with repair, such as car mechanics, washing machine and domestic gas boilers. The concern is that these perceptions extend beyond young people to include their influencers, such as parents, peers and teachers. For example, the Engineers and Engineering Brand Monitor for 2014 showed that only 57% of STEM teachers felt that a career in engineering was desirable to their pupils[39]. An earlier engineering brand monitor survey found that one in five STEM teachers actively discouraged their pupils from pursing engineering as a career[40].

There is an increasing sense that public perceptions of, and attitudes towards, engineering need to be changed to address skill shortfalls and meet increasing demand for engineers. Efforts to encourage young people into STEM subjects have been successful in increasing participation over the last ten years, but the scale of change required to address the forecast shortages is significant and long term.

Outdated views of engineering are seen by many to be a key part of the problem. At the request of a consortium of national UK engineering companies, the Academy is currently developing a national campaign to reposition engineering in the public mindset.

Teachers and teaching

Specialist teacher shortages

An influential report by McKinsey consultancy stated that "no education system can exceed the quality of its teachers"[41]. Yet across all STEM subjects leading to engineering, there are ongoing, critical shortages of specialist teachers – defined as having graduate-level qualifications in the subject or a cognate discipline.

38 2014 Engineers and Engineering Brand Monitor, Engineering UK www.engineeringuk.com
39 2014 Engineers and Engineering Brand Monitor, Engineering UK www.engineeringuk.com
40 2011 Engineers and Engineering Brand Monitor, EngineeringUK www.engineeringuk.com
41 How the world's best-performing schools come out on top, McKinsey, 2007 http://mckinseyonsociety.com/how-the-worlds-best-performing-schools-come-out-on-top/

Specialist teachers are particularly important in secondary schools, where a teacher's deeper understanding of, and confidence in, the subject can be instrumental in stimulating interest and engagement among the students. At the same time, it is also important that primary schools provide an appropriate, accurate and inspiring STEM education to children from an early age, through ensuring those coordinating science or with responsibility for science are appropriately trained even if themselves not science specialists. Currently, only 5% of primary school teachers have a qualification at A level or above in mathematics or science[42].

Teacher recruitment and retention is becoming a key issue, particularly for STEM subjects as the economy improves and those with STEM skills have more opportunities than ever before. The government has recognised the challenge and put in place a system of bursaries for graduates to take up teaching in a range of 'shortage subjects' including mathematics, sciences and computing[43]. It has also made a manifesto commitment to creating 17,500 more maths and physics teachers over its term of office. However, of these, it appears only 2,500 new specialist teachers will be recruited and the remaining 15,000 will be current teachers re-trained to teach mathematics[44] and thus are unlikely to have the deep understanding that comes with having studied the subject to higher level.

Programmes such as Teach First have done much to attract new teachers to disadvantaged schools, particularly in large cities. However, despite the popularity of this route with high-achieving graduates, there are still widespread shortages for teachers of STEM subjects, particularly maths, physics, D&T and computing.

Figure 11 shows the percentage of under- and over-recruitment of teachers for a range of subjects for 2014/15. The chart shows that initial teacher training for D&T is only recruiting just above 40% of the necessary rate. In physics, Initial Teacher Education (ITE) recruitment is over 30% lower than required. Some commentators feel that the new model for ITE favoured by government – Schools Direct, where schools themselves are responsible for recruiting and training new teachers – is at least partly responsible for the lower numbers of teachers being taken into training overall, with specific issues around STEM subjects[45].

Teaching

Like any professionals, all teachers, regardless of their subject specialism, should have ways and encouragement to engage with career-long continuous professional development (CPD) in the subject(s) they teach. For STEM subjects, where there is a significant pace of development in new scientific knowledge and understanding and also in the practice of teaching, it is particularly important that teachers update their skills.

There are a number of organisations providing STEM-specific teacher CPD across the UK, some of which are highlighted in this report.

42 Building expertise – the primary science specialist study. Wellcome Trust, 2013
43 Get into teaching bursaries, Department for Education, www.getintoteaching.education.gov.uk/bursaries-and-funding
44 www.gov.uk/government/news/major-push-to-get-more-maths-and-physics-teachers-into-our-classrooms
45 Times Education Supplement www.tes.com/news/school-news/breaking-news/school-direct-causing-shortage-maths-and-science-teachers-report

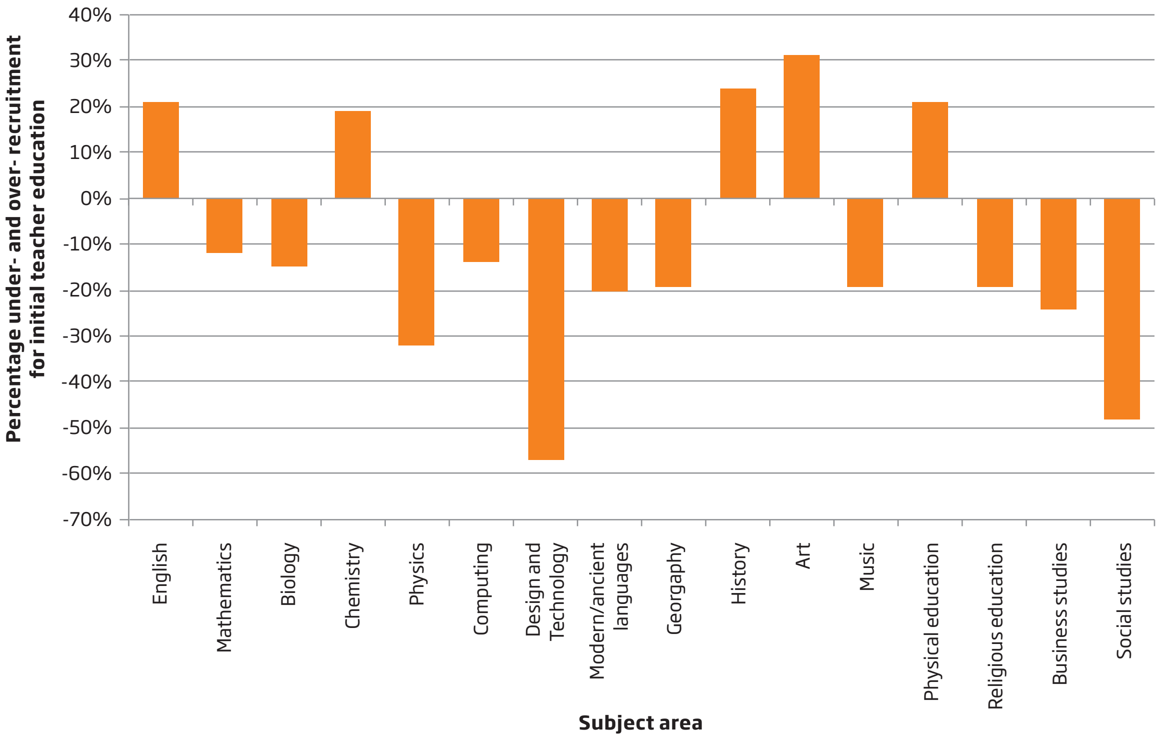


Figure 11: Percentage of under- and over-recruitment for teachers of subjects in schools in England 2014/15

National Science Learning Network and Project ENTHUSE

The single largest provider of STEM-specific professional development for teachers and support staff in schools in the UK is the National Science Learning Network. The network comprises the National STEM Learning Centre in York[46] – a purpose-built, state-of-the-art facility providing laboratory facilities and residential training opportunities – along with a network of Science Learning Partnerships across England, with other third-party partnerships in Scotland, Wales and Northern Ireland.

The network, supported by a range of funders including Project ENTHUSE, provides subject-specific training and support to over 15,000 teachers and other staff each year. It does this through a range of routes including ENTHUSE-bursary supported residential training at York, local training and networks including after-school 'twilight' sessions, in-school intensive support, development of school partnership projects, and online CPD.

The network's activity is underpinned by evaluation and impact measurements along with educational research. The focus is on seven key outcomes:

Improving teachers and school and college leaders:

- subject, pedagogical knowledge and awareness of STEM careers
- confidence, motivation and competence
- leadership within STEM
- quality of teaching
- retention and career progression within STEM.

So leading to increased pupil:

- engagement, achievement and STEM literacy
- pursuit of STEM subjects and careers post-16.

46 https://www.sciencelearningcentres.org.uk/

Over its ten years of operation, the network has collected a substantial body of evidence showing positive impacts of its support on all of these areas[47] with independent evaluations of specific aspects of the network's support also available[48].

The National STEM Learning Centre at York provides support across the range of STEM subjects and includes an eLibrary containing over 10,000 quality-assured curriculum-linked resources, which are freely available for teachers to download at no cost. While the focus of the centre's activities has historically been on science it is providing an increasing portfolio of professional development activities to teachers of design and technology, computing and mathematics.

Scottish Schools Education Research Centre

SSERC is a long-standing provider of professional development and support to science and technology teachers in Scotland. Its activities support teachers in over 90% of Scotland's schools. The core training programme provided by SSERC reaches approximately 1,800 teachers, student teachers, and technicians each year. It includes residential courses for secondary subject teachers, provision of science and technology teaching resources, and a range of e-learning sessions. SSERC also provides an information and advisory service to schools, including advice on health and safety.

SSERC works closely with the National Science Learning Network and teachers are able to use ENTHUSE bursaries to assist with costs for their professional development and training. Professional development courses include support for newly qualified teachers, subject specific courses for teachers in primary and secondary schools including science, design and manufacturing. In addition there are courses to support technicians and training for curriculum leaders and heads of faculty.

Stimulating Physics Network

The Stimulating Physics Network (SPN) is a support network for teachers managed by the Institute of Physics on behalf of the Department for Education, and delivered in partnership with the National Science Learning Network[49]. Its aim is to improve the uptake of A-level physics among young people. It provides teaching and learning coaches, physics network coordinators, gender diversity support and an online community for teachers. The teacher CPD workshops run by the SPN report that more than 92% of teachers report increased confidence in physics teaching, and over 97% of teachers report a positive impact on classroom practice. Schools that take part in the SPN have been shown to increase their number of pupils progressing from GCSE to AS-level physics at more than twice the national rate, and have also doubled the increase in girls continuing to study physics post-16.

Computing At School

Computing At School (CAS) provides leadership and guidance to all those involved in computing education in schools with a strong focus on computer science within the wider computing curriculum[50]. CAS is a collaborative partnership with BCS, the Chartered Institute for IT, through its Academy of Computing, and has formal support from other industry partners. Membership is open to all interested parties and is very broad, including teachers, parents, governors, exam boards, industry, professional societies and universities. CAS directly supports ICT and computing teachers with teaching material, training, local hubs, newsletters and the opportunity to meet with like-minded colleagues, as well as acting as the subject association for computer science teachers. Professional development schemes such as *Barefoot Computing*, a primary schools teacher CPD programme, are organised through CAS.

47 www.sciencelearningcentres.org.uk/impact-and-research/impact/10-years-impact/
48 www.sciencelearningcentres.org.uk/impact-and-research/research/research-reports/
49 http://www.stimulatingphysics.org/
50 http://www.computingatschool.org.uk/

Image: Royal Academy of Engineering

Design and Technology Association

The Design and Technology Association (DATA) is the subject association for D&T, and runs a range of activities for teachers – working groups, local branch meetings and CPD events on specific topics (such as electronics, computer-aided design, 3D printing)[51]. CPD sessions are run by trained experienced individuals and consultant members. DATA employs expert consultants, executives, fellow members and a dedicated events team to ensure the events are of high quality and on current and relevant topics.

National Centre for Excellence in the teaching of Mathematics

The National Centre for Excellence in the teaching of Mathematics (NCETM) works to ensure that all teachers of maths, including all primary school teachers and non-specialist maths teachers, have easy access to high-quality, evidence-based maths-specific CPD at every point of their careers[52]. It achieves this through:

- Its website, where individual teachers can improve their subject knowledge and pedagogy, access classroom-based research, and exchange views and experience with colleagues.
- Support (face to face and online) for all schools, colleges, organisations and individuals with a professional development role as providers of CPD for teachers of maths in all settings, and in providing a framework for quality assurance of that provision.
- Identifying aspects of maths teaching where additional CPD support is needed, and trialling new programmes to address these needs, which may then be disseminated more widely.
- Disseminating research-based papers and summarising current thinking in key areas of mathematics education, aimed at the whole maths education community, including classroom teachers.

Royal Academy of Engineering – Connecting STEM Teachers programme

The Royal Academy of Engineering runs a large-scale secondary school teacher support programme creating geographically based networks of teachers across the STEM subject areas working together[53]. Some 600 schools are currently involved in the activity. The programme is built around 40 local teacher coordinators who organise local network meetings and collaborative projects across schools in their area. The professional development activity is based on the notion of 'communities of practice' with teachers sharing ideas around good practice. The CPD activity is designed to draw on engineering contexts that provide real-life applications to maths and science, using D&T and computing as vehicles for active, practical hands-on learning in the classroom. As such it is the only teacher support programme that combines all elements of STEM in a coherent manner, which is essential for developing engineering skills.

The programme is in its fourth year and continues to grow and attract more schools into the network. The Academy provides resources to schools in the programme, which are also freely available to download from the Academy's website, the National STEM Centre eLibrary and other teacher websites.

Despite all this activity being provided by many organisations at no cost to schools, there is still a significant challenge to many schools releasing teachers from their teaching duties to upskill and develop their teaching practice. This is due to a variety of factors including a continuous focus by school senior leadership teams on government accountability measures and inspection regimes, and a cost of providing supply cover while the teachers are away from their classes.

51 https://www.data.org.uk/
52 https://www.ncetm.org.uk/
53 http://www.raeng.org.uk/education/schools/education-programmes-list/connecting-stem-teachers

Improving teaching and learning in further education

As with schools, the FE system can only be as good as the teaching workforce. Many FE lecturers will have come into teaching from working as engineers or technicians, but they may have been in the FE sector for many years and are not able to keep up to date with current industry practice. There is a particularly strong need for FE lecturers teaching vocational, practical qualifications for the future technician workforce, to have professional development.

There have been some notable reviews and reforms of the FE sector to improve the system, most recently the Commission on Adult Vocational Teaching and Learning[54]. However, with little funding for CPD in the FE sector, few organisations offer any subject-specific support for advancing teaching and learning. The Academy has, for several years, been providing professional development training across a range of engineering subject areas for FE lecturers. This has been on topics such as composite materials, programmable logic controllers, programming and microprocessor control, contextual maths for engineers, mechanical engineering principles and smart materials.

Under-representation

A key theme across many existing STEM support opportunities and challenges is highlighting and tackling issues around under-representation of specific groups, both in the current engineering workforce and those young people studying subjects leading to engineering. There is a significant amount of activity being undertaken to address these challenges.

Only 8% of the UK's engineering workforce are women – the lowest number across the whole of Europe[55]. The statistics for engineers from minority ethnic backgrounds are also poor at around 6%, despite the fact that those from ethnic minorities account for 14.1% of the England and Wales population (Census 2011) and around 20% of the higher education cohort.

There are a significant number of organisations involved in encouraging women to consider and progress into engineering careers. The most notable of these are WISE (Women in Science and Engineering) and WES (Women's Engineering Society). Yet more organisations are also focusing on other aspects of diversity, such as low participation among Black, Asian and minority ethnic (BAME) groups, lesbian, gay, bisexual and transgender (LGBT) groups, and socially disadvantaged groups.

54 It's about work...excellent adult vocational teaching and learning. http://cavtl.excellencegateway.org.uk/
55 Women Engineers Society http://www.nwed.org.uk/uploads/2/6/1/1/26111168/women_in_engineering_statistics_on_a_page_february_20142.pdf

Image: Royal Academy of Engineering

Similarly, there is no shortage of research to understand the issues around diversity and STEM subjects – though it is mostly focused on gender. Particularly important work includes the *Aspires*[56] project by Professor Louise Archer of King's College London. This was a very large-scale project that interviewed some 19,000 students aged 10-14 to understand their career aspirations and, in particular, the influences that were likely to aspire towards science-related careers. This research is continuing with Aspires 2, which will examine the young peoples' perceptions and attitudes towards science over the crucial decision-making years.

Another recent important study is *Not for people like me*[57] by Professor Averil MacDonald for the SEPNET physics network. The Institute of Physics has published regularly on the issue of girls in physics with reports such as *It's different for girls* and *Closing Doors*. The Institute of Mechanical Engineers published its study *Five Tribes*[58] in 2014, which undertook a segmentation analysis of young people based on their interests and attitudes towards STEM. The report highlighted that a blanket approach to STEM engagement of young people is unlikely to be effective and a more targeted and nuanced approach is required if maximum impact is to be achieved.

The Royal Academy of Engineering and the Royal Society have been appointed by government to lead on diversity for the engineering and science sectors respectively. The Academy's diversity programme covers all aspects of diversity including gender, ethnicity, disability, sexual orientation and social disadvantage and has two main strands. The first (Diversity Leadership Group) is a senior industrial leaders group working together to drive improvements in workplace cultures and practices. The second (Concordat group) brings the professional engineering institutions together to share good practice around increasing the membership and registration of a more diverse set of engineers. Both groups have built positive momentum, with numerous outputs for industry and the profession[59].

56 http://www.kcl.ac.uk/sspp/departments/education/research/aspires/index.aspx
57 https://www.wisecampaign.org.uk/resources/2014/11/not-for-people-like-me
58 https://www.imeche.org/knowledge/themes/education/five-tribes-personalising-engineering-education
59 http://www.raeng.org.uk/policy/diversity-in-engineering

Careers guidance, curriculum enhancement, employer engagement

Careers guidance

The 2011 Education Act removed the statutory duty of local authorities in England to provide careers information, advice and guidance to young people, placing that duty instead on individual schools and colleges. At the same time, the Department for Education did not provide any additional funding for schools – expecting them to provide careers information, advice and guidance (IAG) within existing budgets. The department has regularly updated guidance on provision of careers IAG since the change[60]. However, while schools and colleges are aware of the guidance, it is unclear how focused many of them are on this, at a time of significant change also in accountability measures, curricula and assessment.

The results of this change have been the subject of widespread disquiet over the last two to three years, including critical reports by Ofsted, the CBI and the Commons Education Select Committee. Key concerns centre around the 'patchiness' of provision and fragmentation of the service, with some schools doing IAG extremely well, but others – often those working with more vulnerable young people – not providing the level of support required.

Existing organisations and activities continue to work hard to support the careers agenda through a variety of routes, with new initiatives and organisations emerging to try and address gaps. However, ensuring effective careers IAG for all young people – particularly around STEM and for those who need most support – remains vital if we are collectively to both fulfil their potential and help employers meet their skill needs.

Professor Sir John Holman has produced a detailed report on effective careers guidance in school following an investigation of careers provision across a number of international jurisdictions. The report, published by the Gatsby charitable foundation, highlights eight benchmarks to ensure world class careers guidance.

A particular challenge for engineering is the myriad entry routes to the complex engineering domains. Unlike law, medicine or finance, which have relatively simple access routes and recruitment processes, engineering, because of its diversity across many sectors, is often difficult to navigate. As such there is a specific need for young people to understand the progression pathways, the value of work experience and industrial placements and the types of personal and professional characteristics that engineering employers are looking for in technicians and graduate entry roles.

Employer engagement

Employer engagement in education is a powerful tool for influencing young people's career aspirations. Student engagement with employers will reduce their likelihood of being NEET (not in education, employment or training). The Education and Employers Taskforce found that students who had four or more interactions with employers while in education were five times less likely to be NEET than those who did not recall such activities[61].

However, better coordination of employer engagement to ensure that it reaches all schools is critical if we are to ensure that all students can benefit. In England, the government has established the Careers and Enterprise Company to undertake such activity and the Tomorrow's Engineers programme, led by EngineeringUK, is now developing employer engagement as a major strand of activity. As part of that work, it has developed an online map of all schools in the country and the engineering employer engagement activities that have taken place. It is intended this should improve coordination, reduce duplication of effort and ensure that as wide a range of students as possible benefit from appropriate support.

60 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/440795/Careers_Guidance_Schools_Guidance.pdf

61 It's who you meet. Dr Anthony Mann. Education and Employers Taskforce http://www.educationandemployers.org/wp-content/uploads/2014/06/its_who_you_meet_final_26_06_12.pdf

STEMNET is the largest provider of volunteer ambassadors across England, with currently over 30,000 practising scientists and engineers visiting schools to provide talks, support activities, STEM clubs and provide careers information. Through the STEM Ambassadors programme, STEMNET has a coverage of 95% of secondary schools in England.

Strong employer links with FE and HE institutions is also highly beneficial. It provides real-life contexts for teaching and learning, helps students to see the direct line through education to employment and also provides teaching staff with access to latest up-to-date industry practice. The Royal Academy of Engineering has, for many years, run schemes in both FE and HE to place practising engineers in the classroom to support teaching and learning and real world examples of the engineering subject matter being delivered.

Curricula, qualifications and accountability

Curriculum in England

In the UK, the curriculum for young people is set by the appropriate devolved government. In England, pupils in local authority controlled schools follow a national curriculum across most subjects up to age 14, after which they study towards external examinations (GCSEs at 16; A levels at 18). External examination criteria are set by government but are provided by awarding organisations based on a free-market model.

Schools and colleges that have become academies do not have to follow the national curriculum although many continue to do so. Over 60% of English secondary schools are now academies with a growing percentage of primary schools following suit. The government is committed to every school being an Academy by the end of the current Parliament in 2020.

It has been argued by some in education that the current national curriculum in England is too broad, with each individual subject such as mathematics or the sciences covering too many topics – particularly in the primary phase of education. The large amount of material to cover and the fixed number of hours for delivery of material thus causes young people to have only a surface level of understanding and learning. Some commentators and educationalists have argued for a smaller amount of content for each subject that pupils can master[62].

The national curriculum review in 2012 did however provide an opportunity for substantial redevelopment of the D&T and computing curricula. In both instances the Department for Education worked with the engineering community, through the Royal Academy of Engineering and other bodies to develop substantially improved subjects. These were introduced for first teaching in 2014.

Accountability

Schools are held to account for their performance through a series of measures and through the independent schools regulator Ofsted.

Primary education

At primary, school performance is measured through examinations of pupils leaving school at the end of key stage 2 (year 6, for children aged 10 or 11). There are two assessments, in English and in mathematics. The focus of these examinations has a significant impact on the rest of the curriculum in schools. Typically, schools will spend over 50% of teaching time focusing on English and maths. All other subjects, such as art, history, science, D&T, computing, geography, languages, physical education and music, are squeezed into the remaining time available.

62 http://www.toomuchtoosoon.org/national-curriculum-proposal-responses.html

There is concern among the science community that despite science being categorised as a core subject, many primary schools are spending less time than prior to 2010, when it was also assessed with an end of key stage 2 SATs examination. Anecdotal evidence suggests that some schools are providing only one hour of science teaching a week or, in some cases, compressing all science into a science week once or twice a year. The same is true for other STEM subjects such as computing and D&T. Despite this, few in the science community support a return to science key stage 2 SATs as this was seen to limit science teaching in other ways.

Secondary education

For secondary schools, attainment of pupils in GCSEs and equivalent vocational qualifications at key stage 4 are a key performance indicator. The measure has historically been the number of students achieving five or more GCSEs, which include maths and English with passes at A* to C grade. However, new measures are also being used to assess school performance against national and regional averages.

English Baccalaureate

In 2010 the coalition government introduced the English Baccalaureate (EBacc) performance measure for schools, which was created to incentivise schools to promote study of certain 'academic' subjects. While the EBacc is a measure of school performance rather than individual pupil performance, it is assessed by examining pupil grades in a set 'basket of qualifications' with relatively little flexibility or personalisation. Key subjects for the EBacc include – English, maths, two or more sciences (including physics, chemistry, biology or computer science), history or geography, and a modern or ancient foreign language.

The current Conservative government in 2015 announced that no school will be able to achieve an outstanding Ofsted rating unless it offers all pupils the opportunity to gain the 'EBacc'.

Attainment 8 and Progress 8

In 2016, a new set of measures will be introduced (based on 2016 exam results) that require schools to demonstrate students' attainment and progress in a suite of eight subjects, consisting of English and maths, three additional EBacc subjects and three other subjects of the individual's choosing. However, in many instances pressure on schools to simultaneously achieve the EBacc measure is creating an unintended consequence of schools limiting students' options to EBacc subjects only, rather than a wider set of options.

Attainment 8 measures student achievement in such a 'basket' of subjects. Progress 8 is a variant on this, whereby schools are measured on the progress that pupils make over the time spent at secondary school rather than solely on whether they achieve a C grade or above. This measure is intended to prevent schools from focusing only on students who are at the D/C grade boundary.

Assessment

There has been ongoing reform to qualifications in England, in particular GCSEs and A levels. A concern for the science and engineering community is the removal of practical assessment in science qualifications. Science is inherently a practical subject and the removal of experimentation from the assessment risks fundamentally undermining this critical element of the subject.

Curriculum for excellence – Scotland

The Scottish government introduced the new Curriculum for Excellence in 2010 – the most significant reform of the Scottish education system since the second world war. It is designed to provide a more flexible and enriched curriculum for all students from age 3 to 18. Its aim is to ensure that all children and young people in Scotland develop the attributes, knowledge and skills they will need to flourish in life, learning and work. There are four key purposes of the curriculum – to

Image courtesy of the Brunel University London

nurture and develop the knowledge, skills and attributes in learners to be successful learners, confident individuals, responsible citizens and effective contributors.

The intention of the curriculum for excellence in Scotland is to promote interdisciplinary learning, through providing space for students to learn beyond the traditional subject boundaries. This provides opportunities for students to apply skills and to contextualise knowledge in a way that cannot be offered through discrete subject teaching.

While critics have argued that the new curriculum is vague in terms of its intended learning outcomes and lacks clarity of its guiding principles, there is still a significant amount of goodwill towards the new model, with many arguing that it is a considerable force for good. It may however take an additional number of years before the impact of the curriculum on engineering skills is fully realised.

Wales

The Welsh Assembly Government is introducing a new curriculum for Wales following an independent review undertaken by Professor Graham Donaldson. The programmes of study specify what learners should be taught for each subject and the expected standards of learners' performance at key stages 2 and 3.

The new curriculum will have six areas of learning which will combine core and non-core subjects. The areas of learning will include; mathematics and numeracy, science and technology, literacy and communication, humanities, health and well-being and finally expressive-arts. However, particular attention will be paid to digital competence, as the Welsh Assembly Government recognises the importance of digital skills to the economy in the years ahead. Therefore there will be cross-curricula responsibilities of teachers, to ensure digital competence along with literacy and numeracy is worked into all pupils learning.

The assessment regime will introduce more informal progression steps which will relate broadly to expectations of children's abilities at a series of key ages. The intention of the approach is to recognise that children develop at different rates, and therefore assessment is less of a judgement and more of an indicator or 'staging post' for the educational development of the students.

Again, it is too early to comment on how the new curriculum will affect STEM skills supply in Wales.

Northern Ireland

In Northern Ireland, the curriculum is managed and maintained by the Council for the Curriculum, Examinations and Assessment. The curriculum has historically been based on that of England and Wales. In 2007, the curriculum was revised with the intention of developing a broad range of skills and competencies in students. The new structure removed many of the statutory requirements relating to subject content and provided more autonomy to teachers to choose the content appropriate for their students.

The curriculum in the primary phase is grouped into seven broad areas; the arts, language and literacy, the world around us, maths and numeracy, religious education, physical education and finally personal development and mutual understanding. Science education in the new curriculum has been amalgamated with geography and history into the 'world around us' programme of study. As a consequence, and with the new autonomy for teachers, there has been concern from the science community that this has enabled teachers who are not comfortable with teaching science to reduce the content of science delivered to students as there is no duty on teachers to spend an equal amount of time on the individual components of the working around us subject grouping (history, geography and science).

In the secondary key stage 3 curriculum, science and technology are joined together as an area of learning. However, unlike the other UK devolved education systems, in Northern Ireland science is not compulsory at key stage 4.

Pathways to progression

There are multiple pathways to progression in engineering. Many students will take an academic route, through A levels to higher education undergraduate degrees. Other students will take a vocational route, studying full time in a post-16 education establishment, which provides a more applied learning approach. Others will take on an apprenticeship and learn while at work. These different pathways enable young people to make different choices about progression to engineering careers that suit their learning needs. However, there are a number of challenges that reduce the effectiveness of these multiple routes.

Early specialisation

One of the key distinctions between the UK and other countries is early specialisation. Students are required to make decisions on which subjects to pursue at age 14 for GCSEs and vocational qualifications. Measures introduced by the Department for Education, such as the EBacc and Progress 8/Attainment 8, have been an attempt to ensure pupils are encouraged to focus on what are perceived to be 'academic' and 'high value' subjects at GCSE. However, these measures themselves have created perverse incentives, encouraging some schools to focus pupils on a narrow set of subjects rather than a broad and balanced offer. As a result, students may be missing out on opportunities to study subjects that can support a move towards engineering, such as D&T.

By age 16, students are making very firm decisions around subjects that will have implications for their future career choices and directions. In many instances, a clear science/humanities divide is created with students opting for one route likely to be cut off from easily accessible opportunities to study subjects in the other route. This is particularly the case in engineering and physical sciences, where studying mathematics and physics to 18 are often cited as prerequisites for university degree study, particularly in pre-1992 institutions. These subjects are also often specified by engineering companies for subsequent employment into many engineering roles.

In 2014, the Royal Society set out its vision for an education system where all young people study mathematics and science up to the age of 18. The *Vision for Science and Mathematics Education* report[63] also called for the development of rigorous new post-16 courses and qualifications in STEM to engage students who are studying non-STEM subjects at school or who are training in the workplace, ensuring these meet the changing needs of employers. The government has made no firm commitments to progress in these areas.

Low status of non-academic progression pathways

The UK has long suffered from an apparent public perception that vocational pathways are less valuable than academic routes. This has given rise to a historic lack of investment in apprenticeships and further education provision, poor recognition of the important role of technicians across a range of industries and the inevitability of an ageing workforce and expected shortages in future technicians. In addition, the FE system has been denuded of resources while at the same time expected to support a wide range of participants with vastly varying levels of ability.

63 https://royalsociety.org/topics-policy/projects/vision/

The government is now working to address the issue with a renewed focus on apprenticeships and has committed to creating three million new apprenticeships over the course of the Parliament. This will include a substantial drive towards a new form of degree apprenticeship, where employees will undertake a work-based training route towards undergraduate and postgraduate degrees. Some commentators have raised concern that the government's focus on the number of apprentices is misplaced and the emphasis should be on quality rather than quantity[64].

The government has also recently commissioned an independent review of a new curriculum for post-16 education. The review of Technical Professional Education, chaired by Lord David Sainsbury, is examining the potential for a number of 'routes'. These are study programmes aligned to clusters of occupations, such as engineering, care or retail and business services. The review is examining what the routes should comprise of and how many there should be. The findings are expected in late Spring 2016.

Increasing progression in FE

Across all post-16 provision (school sixth forms, sixth-form colleges and FE colleges) students require sufficiently high grades at GCSE to progress to higher qualifications – whether A level or vocational alternatives. For progression in sciences, maths and engineering, schools and other providers now regularly require GCSE grades of A* or A with some schools accepting B grade for progression. Those students with a C grade are not expected to be able to cope with the additional challenge in the subjects at the next level.

From the perspective of the school or college, if students do not achieve well at A level, this will reflect badly on the provider's performance measures, and if they drop out of a high-level qualification, colleges are punished financially. There is therefore no incentive, and indeed many disincentives for schools and colleges to be proactive in driving up progression in STEM subjects despite calls from employers and government for higher skilled workers to improve productivity in the UK.

Students entering the FE sector may not have sufficiently high grades in maths and sciences to progress to higher level qualifications. As a consequence, they are likely to be placed on GCSE equivalent courses for a further two years – effectively re-sitting GCSEs but in a different set of subjects (often vocational such as car maintenance etc.). The FE sector needs to have incentives put in place to drive up progression to more challenging material. It also needs considerable additional maths support and resources to ensure students can keep up with the material being presented to them.

Experience-led learning and innovative teaching

Over the last few years there has been increasing recognition of the importance of practical, hands-on learning for students in engineering at degree level. The active learning pedagogical approach enables a deeper understanding of theory and principles. However, the approach requires a change of focus from lecture-based teaching to more active learning environments. These environments tend to be open spaces that allow students to create, build and test designs, structures and prototypes.

There are few organisations committed nationally to improving teaching and learning in higher education. Often, it is left to academics themselves and there is a developing community of interested academics wishing to improve the student learning experience. The Academy continues to work across the academic community to provide support and guidance on teaching engineering. It is also developing a new website focusing on engineering teaching at HE to provide a single place for the academic community to find resources and materials for teaching and provide a home for the recently established Engineering Education Research Network.

64 Fixing a broken training system: the case for an apprenticeship levy. Professor Alison Wolf. Social Market Foundation http://www.smf.co.uk/publications/fixing-a-broken-training-system-the-case-for-an-apprenticeship-levy/

4 Mapping the engineering education landscape

The Academy has undertaken a detailed mapping of the STEM education support landscape and has identified over 600 organisations that are in some way involved in STEM education. Organisations include learned societies and professional bodies, education enrichment providers, science discovery centres, field study centres, subject associations and teacher support organisations. The mapping does not include employers that also provide a significant amount of support to the education system.

Support from these organisations covers the full spectrum of learners, from early years foundation stage and key stage 1 through to key stage 5, apprenticeship and vocational education, and university programmes.

The analysis suggests that activity is mostly undertaken in schools by organisations focusing on enrichment and enhancement of the STEM curriculum. This enrichment activity plays an important role in providing careers awareness and inspiring young people to see the opportunities afforded by careers in engineering/ STEM. The majority of provision is targeted at 11–14 year olds – often cited as a key age before GCSE subject choices are made.

The most common type of activity is ‘talks and presentations’, followed by hands-on extra-curricular activities. Providers are distributed across the UK with particularly high numbers in the North West and South East. However, it is difficult to understand fully how widespread activity is, since national organisations have a wide reach across many regions. In terms of subject areas, organisations are providing support across the whole range of STEM, but ‘general science’ is identified as the most common subject focus.

Image: Royal Academy of Engineering

One of the key issues that the mapping study has identified is the lack of consistent evaluation across providers. Evaluation is often limited to brief feedback forms completed by students or teachers directly after an activity or event (often called 'happy sheets'). While this form of evaluation is a useful tool in assessing the immediate impact of an activity, it does not help with understanding the longer-term impact of interventions on student perceptions, attainment in STEM and decision making. This is an area that should be examined further to ensure good practice is identified and more widely used.

Development of the STEM landscape map

To undertake the mapping, the Academy has developed a database of over 600 relevant STEM organisations. This does not capture the totality of the STEM organisation landscape and it is questionable whether this would ever be possible, given the number of small formal and informal providers and volunteers offering very local, discrete support to schools. Also, the mapping does not include employers that provide substantial support to schools directly through their workforce.

Throughout the mapping process, the Academy has shared information on the development of the database with a range of relevant potential users and beneficiaries. These are listed in annex A.

The feedback from stakeholders has been very clear; the database has considerable potential value as an aid to research and analysis, and could provide "a signposting service with real day to day benefits". With further development the database has the potential to influence the shape of the STEM landscape – where the organisations within it understand their position and their relationships with others and change their strategic direction to maximise their own impact. One specific proposal from a stakeholder was for the Academy to prepare publicly available 'standard' data sets and analysis on key issues, with the possibility of publishing, perhaps every two to three years, a full analysis of the data with an emphasis on changing trends.

It should be noted that other databases currently exist for the STEM community.

Stem Directories

The Royal Institution hosts and maintains the STEM Directories, an online facility that allows users (mostly schools) to identify specific STEM enrichment and enhancement (E&E) providers against a range of fields such as age group (key stage) and specific subject area. The STEM Directories provide links and contact details of providers for schools to contact directly.[65]

65 www.stemdirectories.org.uk

Tomorrow's Engineers

Another database that has recently been developed is held by EngineeringUK for the engineering profession's Tomorrow's Engineers programme. The database contains information on all secondary state-funded schools in England, their science and maths attainment data, and information on STEM enrichment or employer engagement activity in which they have participated. The database also includes information on primary schools and FE colleges.

At the time of writing, the database is not currently freely accessible as it is still under development. It will eventually be open to employers and other bodies to use to identify schools within range of a specified postcode, which can be contacted for Tomorrow's Engineers activities. The database will be very useful to minimise duplication of effort by organisations as they target schools to engage with.

STEMNET

A significant database is held by STEMNET, which includes information on over 30,000 STEM ambassadors and almost all secondary schools across England. The database holds information on schools that have participated in STEM ambassador activities or after-school STEM clubs supported by STEMNET. However, this database is not accessible because of data protection rules.

Data fields within the STEM mapping database

The Academy's STEM has been developed to categorise organisations by a range of specific fields or variables in which they support STEM activity. These include the type of organisation (professional body, STEM enrichment provider, subject association etc.), the age range of their activity (5–7, 7–11, 11–14 etc.), the type of activity (careers talks, hands-on activity workshops, presentations, teacher training workshops, field trips etc.), the subject matter (general science, computing, engineering, physics, chemistry, biology, D&T etc.) and also by region. An illustrative map of the data fields is shown in **figure 13** while the complete list of the data fields is provided in annex B.

The data collected for each organisation across the different data fields are not exclusive and all variables may be selected for any individual body. For example, a professional association might be involved in producing policy output, undertaking STEM enrichment activities at different age ranges and funding of third-party activity. All this different activity has been captured within the database where possible.

The database also enables the different data fields to be searched individually or filtered through different variables. For example, it is possible through the database to examine the organisations that provide: 'chemistry activities for 11–14 year olds in southwest England'.

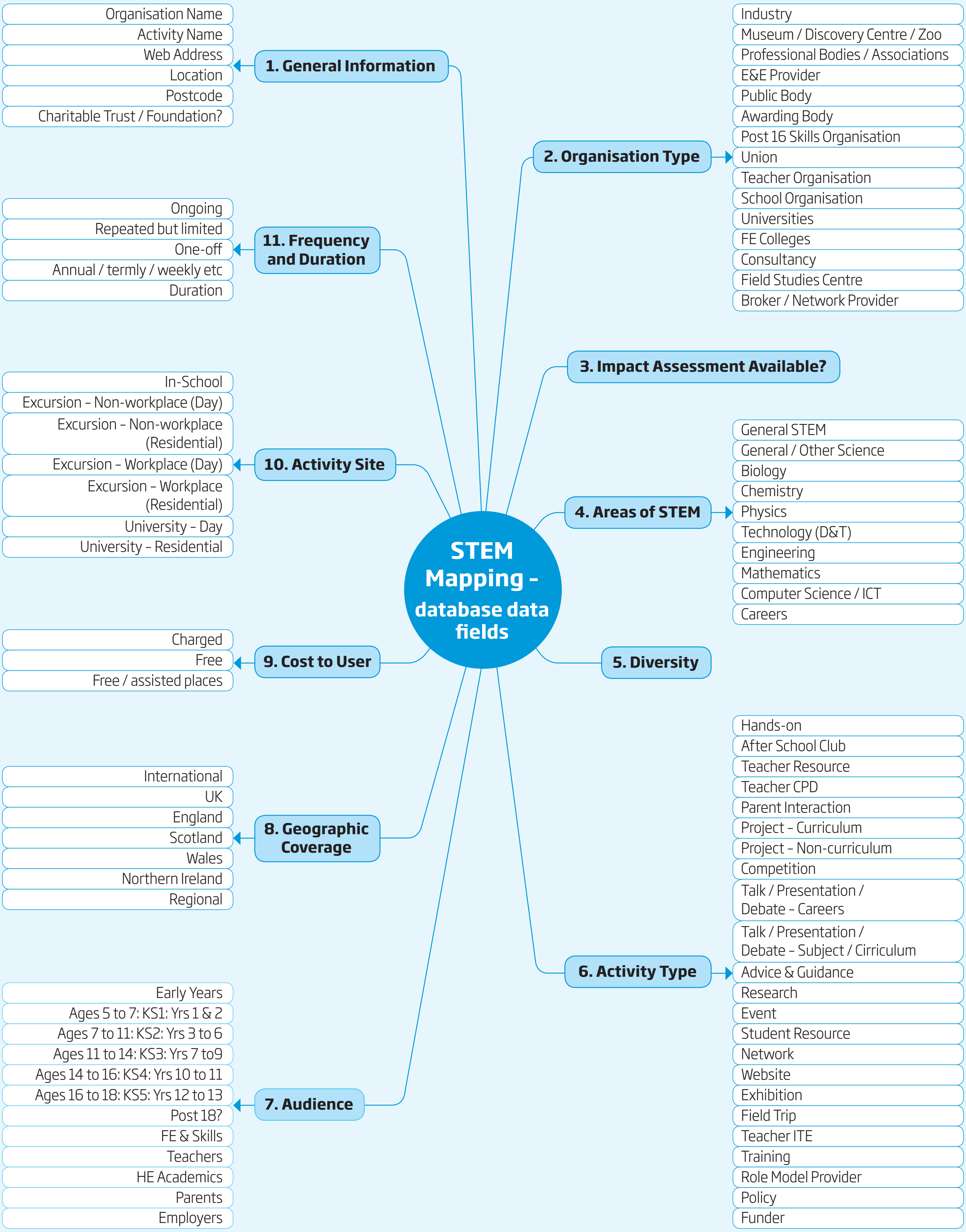


Figure 13:
Illustrative data fields map for the STEM Mapping database

Image: Royal Academy of Engineering

STEM enhancement and enrichment activities

A wide range of organisations and individuals provide these experiences and resources in STEM, which are intended to help young people understand and be enthused about science and engineering and encourage them to consider STEM-based careers. Although a spectrum of provision exists, two useful broad categories of activity can be identified[66]:

i. Provision from external organisations that seeks to enhance formal science learning and takes place in a formal educational environment (usually schools, but could include field study centres etc.). This does not include some of the very effective curriculum enrichment activity undertaken by teachers themselves.

ii. A broader category of informal provision accessed on a voluntary basis and taking place in a range of setting (such as museums, the home, community centres).

In creating the database, the Academy has taken a broader view of STEM education support, including, for example, support for teachers and other educators through CPD. This reflects the view that STEM E&E should be seen as part of a spectrum of support and services, aimed at increasing ongoing engagement with STEM, and ultimately raising the quantity and quality of STEM qualified people in the UK.

How is STEM E&E provided?

The results of the mapping process highlight the range of ways through which STEM enhancement activities are made available to. and engaged with by, schools, colleges and young people. For example, some organisations are national, providing their services and resources across the UK. Others are regional covering large areas, including one or more of the UK national regions. Still others are small, providing very discrete offerings to local schools. Some promote STEM in the round; others specialise in one or more areas of STEM, such as chemistry; while others specialise in very specific aspects of one of these areas, such as aerospace engineering.

It is worth noting that there is evidence to suggest that some types of E&E are provided to selected or self-selecting groups of pupils. One survey[67], for example, found that the majority of science clubs, STEM clubs, STEM ambassador interactions and STEM competitions are provided to students who either volunteer or are selected. This does not undermine their value in feeding interest in STEM and stimulating further curiosity and development. But it does raise the question of how the STEM community might consider reaching young people who do not self-select for such activities.

66 Lloyd R, Neilson R, King DS, Dyball M. Review of Informal Science Learning. 2012
67 Hutchinson J. School organisation and STEM career-related learning. 2013

Who provides STEM enrichment activity?

A wide range of organisations provide E&E in the UK, either as their main or secondary area of business. These include suppliers of STEM services, museums, science discovery centres, zoos and aquaria, universities, theatre and arts groups, professional bodies and industrial/commercial companies.

E&E providers are also:	
Organisation type	**%**
E&E provider *only*	80.5%
Museum/discovery centre/zoo	5.8%
Professional bodies/associations	2.5%
Broker/network provider	1.6%
Post-16 skills organisation	1.4%
Field studies centre	1.4%
Public body	0.5%
Consultancy	0.5%
Awarding body	0.3%
School organisation	0.3%
FE colleges	0.3%

Table 3:
Analysis of E&E providers in the UK STEM landscape database

Organisations can appear in more than one category

Source: UK STEM Landscape Database

Where 'E&E provider' is listed as a discrete organisation type, this is to capture those organisations whose prime role is to deliver E&E. Organisations can appear in more than one category; so, for example, a museum might appear as 'museum/discovery centre/zoo' and as 'E&E provider' if they are also undertaking outreach activity. The data gathered so far shows that the vast majority of E&E providers are organisations focused solely on E&E provision (**Table 3**).

What STEM enrichment is on offer?

The wide range of services and support matches the range of providers. Larger organisations, such as museums and science and discovery centres, may combine centre-based delivery with outreach provision. Smaller providers often deliver their services directly to schools. Some provide support designed to dovetail with school curricula and to be delivered as part of the formal learning process, sometimes by the provider and sometimes by teachers. Others provide activities and/or resources that are used in school but outside classroom settings, such as after-school clubs and projects.

The Wellcome Trust reports that the key motivations for those providing informal science learning are 'raising awareness' and 'understanding of and interest in science'[68]. This can be broadened to represent the motivations of E&E providers across all STEM disciplines.

The key target audience for E&E provision is young people of school age. Alongside this, there may be provision aimed at helping teachers with STEM education and, albeit limited, engaging parents in their children's experience of STEM.

68 Lloyd R, Neilson R, King DS, Dyball M. Review of Informal Science Learning. 2012

Work by the Science Communication Unit at the University of the West of England[69] that focused on identifying key gaps in provision of national found that teachers would like to see more E&E activities that cover skills such as 'problem solving', 'creativity' and 'group work or collaboration'.

The Academy's study shows that the subjects in which E&E providers offer support is dominated by general science, followed by a group comprising mathematics, technology and engineering shown in **figure 14**. Note that providers can be active in more than one area of STEM.

Figure 15 shows that most STEM E&E is provided within the school or college setting. This is perhaps not surprising as this is where most children spend considerable time including, importantly, those who do not self-select to engage in STEM E&E through other routes. It is also where a valuable link can be made between curriculum content, real-world applications and careers pathways.

The database indicates that "activity talks, presentations or debates with a focus on a particular aspect of the curriculum" (e.g. computing, biology) are the most frequently offered; the next most frequent are 'hands-on activities' followed by 'teacher resources' (**Figure 16**).

It is increasingly clear that interaction with employers at an early age are important for young people – particularly in raising their awareness of opportunities beyond their own experience, and also in addressing stereotypes[70]. Research points to the benefits for young people who have more contact with working people (often as STEM ambassadors) while they are at school[71]. In 2011, EngineeringUK research found that young people could not remember having had much interaction with employers when at school; with the exception of work experience, only 40% of those surveyed had benefited from any employer engagement activity. However, where young people had met and interacted with employers at school, they reported that these experiences had been useful in helping to get a job following full-time education.

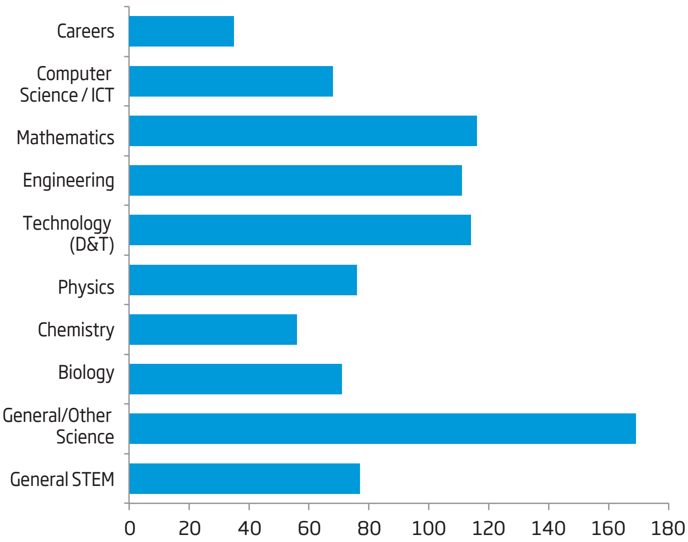


Figure 14:
E&E providers by STEM subject areas

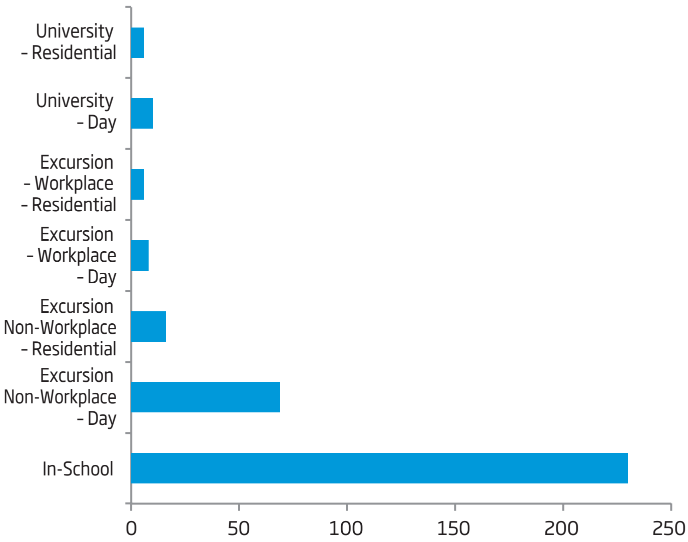


Figure 15:
E&E providers by activity site

69 Bultitude K, Featherstone H, Wilkinson C. The STEM Directories Phase 3 Gap Analysis: Final Research Report. 2010
70 Engineering UK. Engineering UK 2015: The state of engineering. 2015 www.engineeringuk.com
71 Straw S, Hart R, Harland J. An evaluation of the impact of STEMNET's services on pupils and teachers. 2011

Findings showed that young people from independent and grammar schools were more likely to have taken part in a greater number of employer engagement activities than their peers at comprehensive schools. Much like 'science capital', access to employer engagement activities is not distributed equally[72].

Young people's experiences of employer interactions vary (careers talks, mock interviews etc.), as do the benefits they receive from them. However, the underlying message was found to be, "one is good, but more is better"[73].

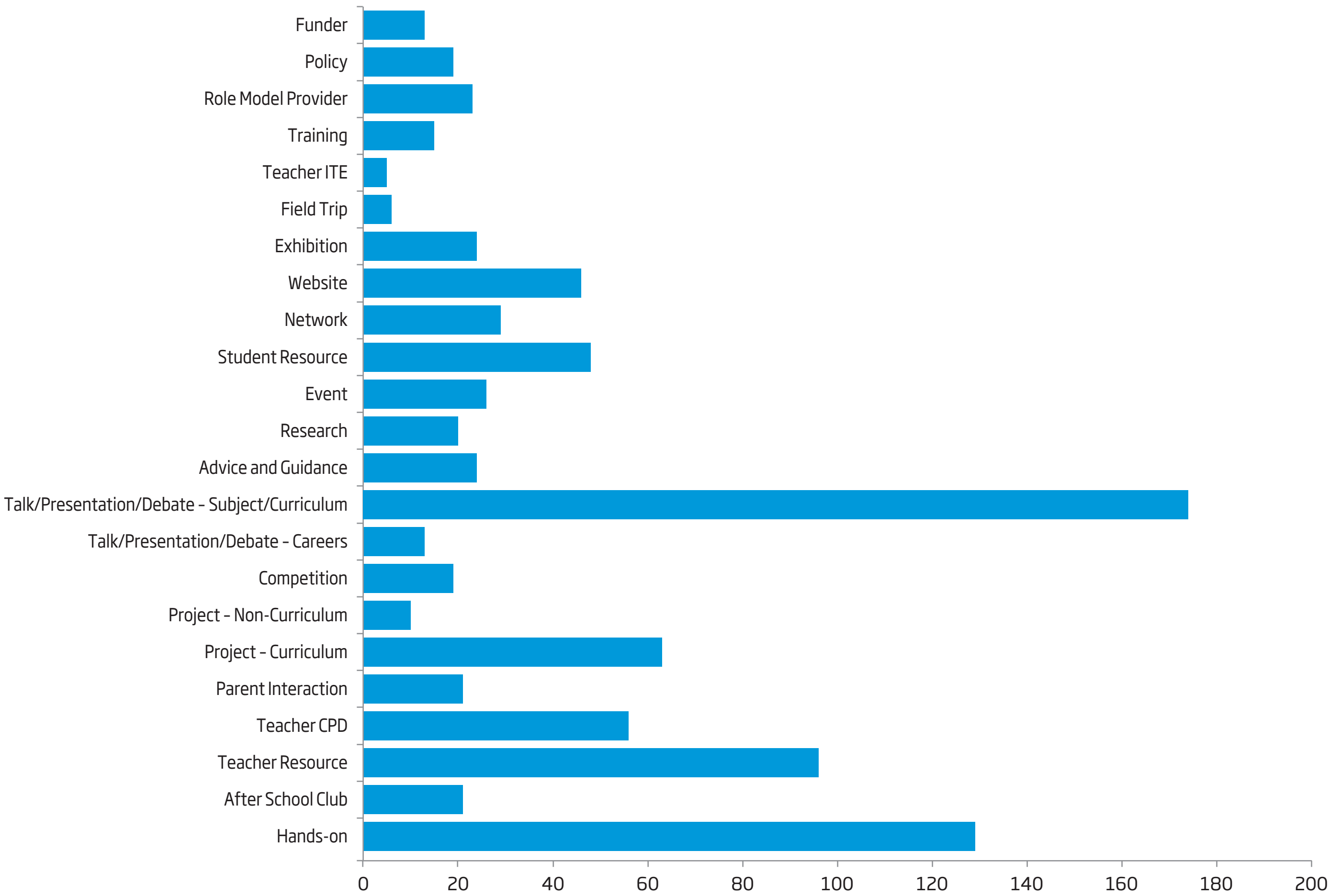


Figure 16:
E&E providers by activity type

72 Engineering UK. Engineering UK 2015: The state of engineering. 2015 www.engineeringuk.com
73 Engineering UK. Engineering UK 2015: The state of engineering. 2015 www.engineeringuk.com

Where are E&E providers active?

Many E&E providers are active throughout the UK, some operate in specific UK regions while others are highly localised. The database suggests that about 70% of E&E providers active in the UK operate across the UK. Around 15% do so in England *only*, 8% *only* in Wales, 4% *only* in Scotland and 2% only in Northern Ireland. The percentage active within each of the four major UK regions is shown in **table 4** and a more detailed breakdown presented graphically in **figure 17**.

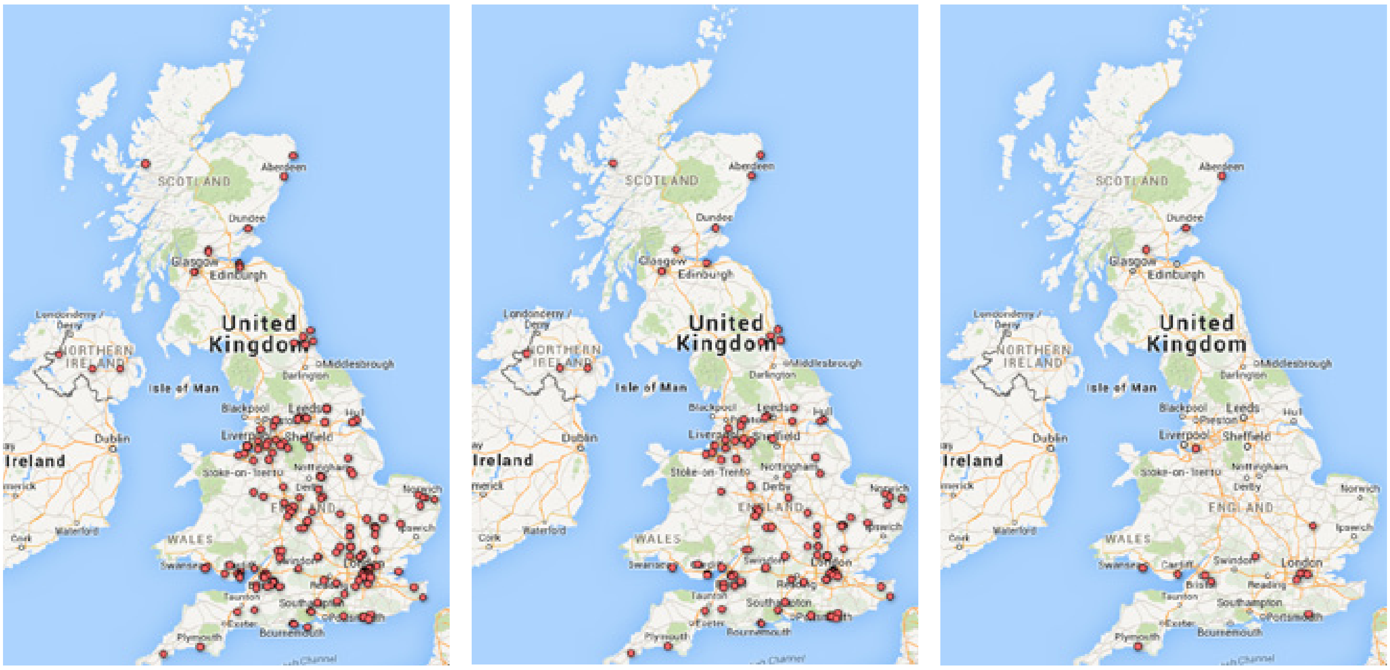
UK Region	Percentage of all E&E providers active within region
England	85%
Wales	78%
Scotland	74%
Northern Ireland	72%

Table 4:
Percentage of organisations in the UK STEM Landscape database that are active in the UK regions

Source: UK STEM Landscape Database

Figure 17:
E&E providers across UK regions and population of 5-18 year olds across regions

The distribution of the enrichment providers can also be presented on geographic maps. **Figure 18** presents postcode maps of STEM enrichment providers, and further examples of providers who have been filtered by audience type. This method of presenting the data could potentially be beneficial in enabling schools and providers to understand the extent of provision in their area.



E&E providers in UK

E&E providers - audience age range 5 to 7

E&E providers - audience ages 5 to 7 and parents

Figure 18:
Postcode mapping of STEM Enrichment providers

How is STEM enrichment activity organised?

There is no formal or central coordination of STEM E&E within the UK. Organisations and individuals are free to establish and offer the services they consider best to any school, youth organisation or group of individuals who see potential value in what is being offered. Similarly, with the current emphasis on school autonomy and the growth of academies, schools and colleges are free to determine which form of support they engage with, how often and through what means.

However, there are two key organisations that provide some measure of coordination of E&E activity, although engagement with them is voluntary.

STEMNET is the largest coordinator of STEM engagement activity in England. It delivers three core national programmes to schools:

i. *STEM Ambassadors*: a UK-wide network of over 27,000 STEM Ambassadors who volunteer their time and support freely to promote STEM subjects. Of these, 40% are women and 13% describe themselves as from Black and minority ethnic backgrounds. Ambassadors age from 18 to 70 years of age, with almost 60% under 35 years of age.

ii. *STEM Clubs Programme*: STEMNET provides free and impartial advice and support to schools that want to set up or develop a STEM club.

iii. *Schools STEM Advisory Network*: free advice and networking aimed at enhancing the STEM curriculum in schools. This is delivered through 45 coordinated regional and local organisations.

Image: Royal Academy of Engineering

The second organisation, EngineeringUK, delivers the Tomorrows Engineers programme. It does this with strategic support from a number of additional bodies including the Academy. The Tomorrows Engineers programme works to coordinate activites which promote engineering careers to key stage 3 students. It's main focus is direct employer engagement, but the programme also works with third-party providers such as Smallpeice Trust, EDT and Young Engineers to deliver activities in schools.

How is quality of provision assessed?

There is little robust evidence of the long-term impact of informal science learning activities in the UK. Indeed, given the trend data on STEM progression shown in section two, it is arguable that there has in fact been limited impact over the last ten years in increasing the number of people studying engineering, despite considerable effort made by the community. This may be due to a lack of understanding of what works. Evaluations of programmes are therefore essential in measuring and understanding the effectiveness of interventions.

The National STEM Centre published a STEM evaluation flowchart[74] provided as part of the STEM cohesion programme. This offers providers a process by which to set up an evaluation process. It does not, however, provide or suggest metrics against which to measure impact – unsurprising as metrics will depend on the context, purpose and scope of any intervention.

Structural, methodological and financial reasons have so far militated against the creation of generic metrics, which could be applicable across a wide range of E&E activities. They would, for example, need to be widely applicable to a range of E&E activities and audiences, be simple to use, independently measured and/or verified and comparable. They would also need to take account of the wide range of provider intents and intended outcomes; for example, one provider might seek to change an audience's subject choices and/or career intentions while another might simply wish to create a sense of wonder or promote engagement in learning in school. The cost of obtaining a meaningful evaluation – particularly for larger-scale activities – is also a key consideration.

Known evaluations

In 2012, the Wellcome Trust commissioned a study to review the value of informal science learning in the UK[75]. This found that evaluation of interventions by providers of informal science learning is commonplace with as many as 87% of providers evaluating their activities. The extent and nature of the evaluation largely depends on the resources available to the provider. It tends to focus on "delivery processes, audience satisfaction and attempts to identify the immediate or short-term impacts of interventions, most commonly in terms of impacts on views of and attitudes towards science and potential future engagement with STEM learning or careers". It is worth noting that much of the evaluation effort reported focuses on informing improvement in their services and resources.

Evaluation studies were most commonly conducted by provider staff, followed by a combination of internal and externally commissioned evaluation. Solely externally commissioned studies are comparatively rare. Evaluation methods used most commonly are:

i. Surveys of users (individuals and teachers) and staff – reported by 98 per cent and 85 per cent of organisations, respectively.

ii. Participant observation.

iii. Visitor exit surveys.

iv. Group discussions with users.

v. Analysis of visitor data.

74 National STEM Centre. Does it work? Better evaluation: Better STEM. 2009

75 Lloyd R, Neilson R, King DS, Dyball M. Review of Informal Science Learning. 2012

While these methods are used by over 70% of informal science learning providers, relatively few organisations carry out surveys or consultations with individuals who do not engage with their services or activities. However, where providers have undertaken consultations with non-users, they were found to provide helpful insights into reasons for non-engagement and approaches that may be effective in future.

STEMNET is one of the few E&E providers that have used independent evaluation to any degree, including an evaluation of the impact of STEMNET's activities in 2011[76]. This found that teachers are generally positive about the impact of STEM Ambassadors on students, as are pupils about the impact on themselves. Similarly, teachers were positive about the benefits to them in their professional role. Interestingly, the research suggested that students who engage with an ambassador more than four times are more positive than those who have seen an ambassador between one and three times. Yet nearly half of students surveyed had seen an ambassador only once. STEM Clubs were also found to have positive impact in terms of students' ability to relate STEM lessons to real-world applications and in terms of personal development (attitudes and aspirations).

In terms of wider STEM careers activities, a research project undertaken for the National STEM Centre and the International Centre for Guidance Studies, found little evidence of systematic evaluation of the impact of STEM careers learning by schools[77]. Where this was undertaken it comprised mostly of student satisfaction surveys.

Tomorrow's Engineers is one of the organisations currently seeking to coordinate better activities of STEM providers and employers delivered through its programme. As part of this, a common evaluation method has been developed to enable comparisons to be made across different activities. The Institution of Mechanical Engineers and the IET have also developed an interesting model of ensuring consistent evaluation, which they are now using for all their activities and intervention projects that they fund. It would be useful to have an agreed common evaluation methodology across all engineering outreach schemes for comparability purposes.

Attempts to assess the impact on attitudes to STEM in the medium to long term are rare. Several reasons for this include the high cost of the follow-up work needed to identify long-term impact, methodological challenges and the absence of accepted indicators or measures.

76 Straw S, Hart R, Harland J. An evaluation of the impact of STEMNET's services on pupils and teachers. 2011
77 Hutchinson J. School organisation and STEM career-related learning. 2013

Image courtesy of the Brunel University London

5 Gap analysis

The detailed mapping process that has been undertaken for this report has sought to identify gaps in provision or support that – in the view of the Royal Academy of Engineering – are required to address the issues highlighted in section three.

The analysis shows that actually there are very few areas where there is no current support for encouraging young people towards engineering or improving their attainment. However, there are areas identified where the scale and pace of activity is perhaps currently insufficient or not effective enough to achieve meaningful change. However, as discussed in the previous section it is essential that robust evaluation be undertaken before increasing the scale of any particular activity.

The areas identified are presented as follows:

Addressing public understanding and attitudes towards engineering

While all the activity being undertaken is attempting to improve young people's perceptions of engineering, there is little being done at a national scale to change wider public understanding of engineering and engineering careers.

This is important as the public are important influencers of young people, particularly parents and close relatives, but also teachers and other role models. Politicians and commentators in the media also have important roles to play in shaping public opinion.

To address this issue, the Royal Academy of Engineering has already begun work on a major national campaign to reposition engineering in the public mindset and improve young people's attitudes towards engineering careers.

Increasing support for teachers of STEM subjects

The impact of supporting teachers is often underestimated, with individual secondary science teachers interacting with many hundreds of young people each year, and those coordinating primary science or STEM also able to influence the education of a whole school or even wider. While there is already significant activity in this area, there is always scope for building on existing partnerships – such as the National STEM Learning Network and Project ENTHUSE – thus creating a critical mass of activity and advocacy enabling all teachers, schools and colleges to engage.

Greater STEM support in primary schools

There is increasing evidence that children's attitudes towards science and more broadly STEM are developed in primary school. Yet, historically organisations have tended to focus on secondary as it is involves working with young people closer to the age at which they make career decisions. From the analysis in this report, there appears to be insufficient support for the primary educational phase.

Primary schools have fewer teachers who have specialist knowledge of STEM subjects – in particular in science, technology and engineering. Therefore there is a need to improve the confidence of teachers in primary schools around STEM and also a need to nurture interest in young children at this important formative stage.

Improving teaching and learning in the FE sector

There are clear and growing concerns among many observers around the support for teaching and learning for engineering in the FE sector. The data in section 2 of this report shows that the FE sector makes a significant contribution to the engineering skills landscape, with apprentices and full- and part-time students studying towards technician-level employment or progression to engineering degrees and professional careers through a professional technical route. Yet figures also show that the sector has had significant underinvestment over many years compared to schools/colleges and HE. This is clearly impacting it in many areas, not least its ability to keep pace with the rate of change in industry.

While some organisations are undertaking small amounts of activity and government support is focused on support for mathematics and English, there is a clear need for more activity in terms of professional development and improvements in teaching of engineering across FE.

Widening access to under-represented groups

Many STEM enrichment providers already work with schools in areas of high socioeconomic disadvantage and address issues such as gender or ethnic diversity, but it appears as though there are few programmes that have been specifically developed to support under-represented groups.

There are a number of programmes designed to support and encourage girls into STEM, but there are fewer supporting BAME students. Further support tends to be focused at the school-age level, where it is rightly believed that intervention at this stage can keep options open for young people. However, data presented earlier clearly shows that BAME students are less likely to be employed by engineering companies than their white counterparts. Therefore, more work could be done to support transition of BAME students from university into the engineering sector.

Socio-economic disadvantage is also a key issue that needs to be addressed and there are many areas of the country in serious need of support. For example, coastal towns around the UK have been identified as some of the poorest areas in the country with the lowest educational attainment and multi-generational unemployment, yet receive very little additional support. Some rural regions and inner-city areas in large urban conurbations also face similar challenges.

Another group that appears to have limited support is students with disabilities. Disability comes in many forms, very often unseen, and figures suggest one in six people in the UK have a disability of some sort. Many people with disabilities are currently in full-time employment, but others struggle to get jobs as employers often overlook this untapped source of potential. There appears to be very little in the way of support for disabled students to consider and pursue STEM/engineering careers.

Development of innovative teaching and increasing employer engagement methods in Higher Education

The data presented in section two also shows the substantial number of students that graduate from engineering degrees and do not go on to pursue professional engineering careers. This will be for a variety of reasons, including the attraction of higher pay from other sectors, issues around employability and so on. Increasing employer engagement and developing more innovative teaching practices where students undertake more active, practical hands-on learning are both thought to encourage engineering students to pursue engineering careers. However, since the closure of the Engineering Subject Centre of the Higher Education Academy in 2010, there has been little in the way of concerted and coordinated national effort to improve teaching and learning across UK engineering departments on a national scale. There is an opportunity therefore to establish a national programme of support for innovative teaching and learning in engineering HE.

Coordination of employer engagement

The analysis undertaken in this report shows that the greatest amount of activity in the STEM landscape is around curriculum enrichment and enhancement. Yet despite all the effort over many years, there has been limited progress in increasing the number of young people progressing to study engineering subjects beyond compulsory education.

The Tomorrow's Engineers programme is working to ensure that employers engaged in STEM enrichment activity work in a coordinated manner to avoid duplication of effort within their locality and ensure that a wider range of schools are reached through a national network of regional employer support managers.

Other organisations, such as STEMNET and the recently formed Careers and Enterprise Company, also have national networks of localised, regional support.

Provision of more specific careers information on the routes to engineering

Despite the many employer activities and interventions in schools and colleges, there is still a high degree of uncertainty among young people around how to access engineering careers. Decisions on post-16 subjects, particularly vocational subjects, of which there are many thousands are difficult for young people to make. There are also many questions around the relative merit of general degrees and later specialisation compared with undergraduate programmes in specific disciplines such as civil engineering. A further particular challenge is the application process to engineering employment post-graduation, with online recruitment forms, assessment centres and interviews all posing particular challenges, especially to those young people who do not have useful network capital to draw on.

As such there is a need for improved, specific careers advice and guidance for young people to understand the progression pathways and expectations of employers, such as experience of the working industrial environment, and particular personal attributes and professional characteristics. In addition to this, there needs to be support for students through the application and recruitment process, such that no particular group are disadvantaged.

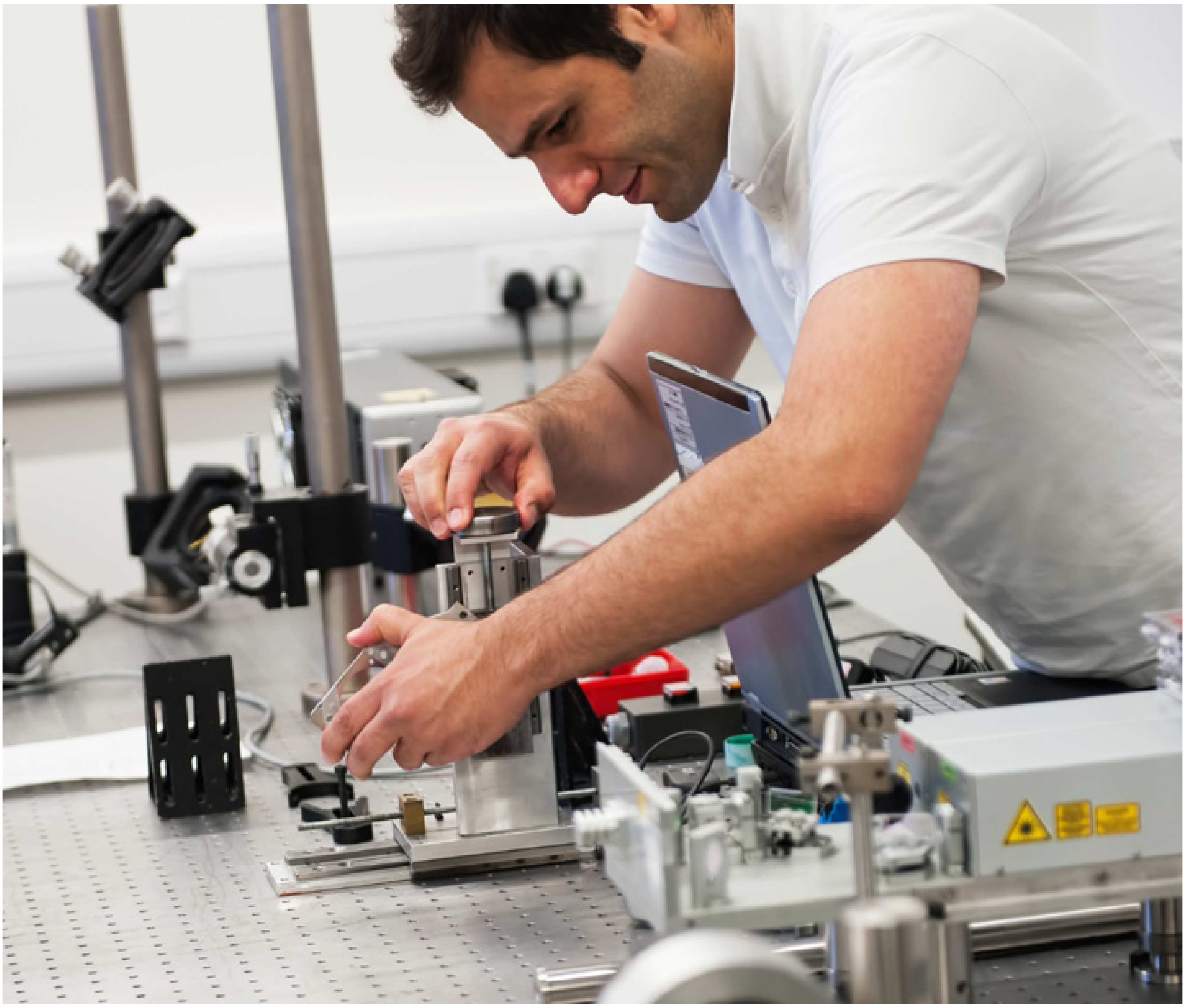


Image courtesy of IFM, Cambridge University

6 Conclusion

This report has set out to present a picture of the engineering landscape in 2015/16. The data shows that from the age of 16 onwards, there are many points at which young people can – and do – cease to study key subjects leading to engineering careers. Estimates suggest around 95% of the cohort close off access to top universities because of subject choices in post-16 education.

A wide range of factors, experiences and individual characteristics influence study choices and career decisions but there are also structural barriers that need to be addressed. These include the shortage of specialist teachers in STEM subjects and the need for appropriate incentives and levers within the school/college system to ensure that all teachers of STEM subjects are able to access subject-specific professional development throughout their careers. FE also requires significant support to enhance and improve teaching and learning in engineering subjects.

The mapping study of organisations in the STEM landscape has highlighted a substantial amount of activity. The database indicates that, perhaps not surprisingly, much of the enrichment activity currently undertaken happens in school environments. It shows that 'talks, presentations or debates with a focus on a particular aspect of the curriculum' are the activity most frequently offered; the next most frequent are 'hands-on activities' followed by 'teacher resources'. The mapping highlights an apparent lack of enrichment providers that are engaging with parents as a specific target group.

Image: Royal Academy of Engineering

The paths that some young people follow will be decided upon consciously, while others will simply follow their interests or abilities, and some will follow paths set out for them by their influencers, in particular their parents. Perceptions and attitudes of the public at large are therefore important factors that need to be addressed.

STEM E&E also has a key role to play in communicating a positive image of engineering to young people and teachers throughout their education. It can help teachers and children with academic achievement, inform them about life opportunities, and help them discover talents and interests that might not otherwise have been discovered in time to influence study choices and career paths. In particular, studies such as the *Aspires* project show how children develop personal identities and preferences at a young age. So, while curriculum enrichment and employer engagement is important at all stages of education, there may be particular long-term benefit in emphasising interaction with younger age groups.

Future work

Feedback on the map has been very positive from stakeholders who have been engaged in the development of the database. It is hoped that a successful outcome from this work would be for an online, open-access database to be established, enabling organisations to understand their position in the landscape, shape their offering to improve STEM in their local area and to maximise the impact of enrichment activities across the UK. It is hoped that the database will also be useful to other funders and to industry to help support their charitable and corporate social responsibility objectives.

ANNEX **A**

Organisations consulted in developing the database

- Advisory Committee on Mathematics Education
- Arkwright Scholarships
- BP
- British Science Association
- Design and Technology Association
- Department for Education and Skills
- Education Development Trust
- EngineeringUK
- ERA Foundation
- Institution of Civil Engineers
- The IET
- Institute of Physics
- Institution of Mechanical Engineers
- Joint Mathematical Council of the United Kingdom
- Nuffield Foundation
- Open-City
- Royal Academy of Engineering
- Royal Commission for the Exhibition 1851
- Royal Institution
- Royal Society
- Royal Society of Chemistry
- Salesforce
- Scottish Council for Development and Industry
- Royal Society of Biology
- STEMNET
- Wellcome Trust

ANNEX B STEM landscape database fields

Data Group	Data Category Name
General Information	• Organisation Name • Activity Name • Web Address • Location • Postcode • Charitable Trust / Foundation?
Organisation type	• Industry • Museum / Discovery Centre / Zoo • Professional Bodies / Associations • E&E Provider • Public Body • Awarding Body • Post 16 Skills Organisation • Union • Teacher Organisation • School Organisation • Universities • FE Colleges • Consultancy • Field Studies Centre • Broker / Network Provider
Impact Assessment Available?	• Yes / No
Areas of STEM	• General STEM • General / Other Science • Biology • Chemistry • Physics • Technology (D&T) • Engineering • Mathematics • Computer Science / ICT • Careers

Data Group	Data Category Name
Diversity	
Activity Type	• Hands-on • After School Club • Teacher Resource • Teacher CPD • Parent Interaction • Project – Curriculum • Project – Non-curriculum • Competition • Talk / Presentation / Debate – Careers • Talk / Presentation / Debate – Subject / Curriculum • Advice & Guidance • Research • Event • Student Resource • Network • Website • Exhibition • Field Trip • Teacher ITE • Training • Role Model Provider • Policy • Funder
Audience	• Early Years • Ages 5 to 7 • Ages 7 to 11 • Ages 11 to 14 • Ages 14 to 16 • Ages 16 to 18 • Post 18 • FE & Skills • Teachers • HE Academics • Parents • Employers

Data Group	Data Category Name
Geographic coverage	• International • UK • England • Scotland • Wales • Northern Ireland • Regional
Cost to user	• Charged • Free • Free / assisted places
Activity Site	• In-School • Excursion – Non-workplace (Day) • Excursion – Non-workplace (Residential) • Excursion – Workplace (Day) • Excursion – Workplace (Residential) • University – Day • University – Residential
Frequency and duration	• Ongoing • Repeated but limited • One-off • Annual / termly / weekly etc • Duration

ROYAL ACADEMY OF **ENGINEERING**

Royal Academy of Engineering

As the UK's national academy for engineering, we bring together the most successful and talented engineers for a shared purpose: to advance and promote excellence in engineering.

We have four strategic challenges:

Make the UK the leading nation for engineering innovation

Supporting the development of successful engineering innovation and businesses in the UK in order to create wealth, employment and benefit for the nation.

Address the engineering skills crisis

Meeting the UK's needs by inspiring a generation of young people from all backgrounds and equipping them with the high quality skills they need for a rewarding career in engineering.

Position engineering at the heart of society

Improving public awareness and recognition of the crucial role of engineers everywhere.

Lead the profession

Harnessing the expertise, energy and capacity of the profession to provide strategic direction for engineering and collaborate on solutions to engineering grand challenges.

The Royal Academy of Engineering promotes excellence in the science, art and practice of engineering.

Registered charity number 293074

Royal Academy of Engineering
Prince Philip House, 3 Carlton House Terrace,
London SW1Y 5DG

Tel: 020 7766 0600 www.raeng.org.uk