"WE THINK IT'S IMPORTANT BUT DON'T QUITE KNOW WHAT IT IS"
THE CULTURE OF ENGINEERING IN SCHOOLS.

Institution of MECHANICAL ENGINEERS

Improving the world through engineering

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Broadly speaking, industry, parents and pupils have differing expectations of school. Employers want skills for a productive workforce, parents seek a secure foundation for their children, while young people are trying to imagine themselves in meaningful and fulfilling careers.

Elevating the profile of engineering in schools offers a way to connect these disparate ambitions. A new narrative around engineering in schools could present fulfilling opportunities for young people, and deliver the skills desired by industry and the occupational agility that will be an essential element of working lives in the coming decades.

Peter Finegold
Head of Education & Skills
Institution of Mechanical Engineers

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FOREWORD

We are already suffering from a shortfall of highly skilled engineers. According to the CBI, over the next five years the engineering, science and high-tech sectors of industry expect a 90% increase in employer demand for people with these skills – with more than three quarters of businesses expected to have more job openings for people with higher-level skills as they look to the future. At the same time, efforts to attract more women to the industry have so far had only a very limited effect, and it is a similar story for other groups who do not fit the engineering archetype.

Too few young people are aware of its value, but modern engineering has the power to change the world for the better. It also promises economic growth for our nation, creative career opportunities and sound financial rewards.

Political efforts to raise the profile and parity of engineering apprenticeships and technical training are warmly welcomed, but these are at risk of failure if they do not attract sufficient interest through lack of knowledge of the sector. Our schools therefore need to support pupils to discover the range of engineering opportunities, and provide a firm grounding that can lead to lifelong and fulfilling careers.

But it is not simply future engineers who would benefit from an education system better attuned to engineering. This innovative study from the Institution of Mechanical Engineers extends understanding from its previous 'Big Ideas' research work to offer up engineering, not simply as a collection of jobs or products, but as a generic methodology, applicable to all sorts of challenges: "Engineering as a verb, not just a noun".

This report highlights the lack of visibility of the subject in our education system and calls on the Government to place engineering in schools at the heart of its industrial strategy, while at the same time imploring the engineering community to present engineering as creative and people-centred to broaden its appeal. It also acknowledges how we need to prepare all future citizens to thrive in a world of continuous technological change, where those with the best chance of succeeding will possess technical know-how, problem-solving and communication skills.

The Institution of Mechanical Engineers has developed this thought-provoking and timely report and recommendations, which I strongly support and endorse.

Andrew Churchill
Managing Director
JJ Churchill Ltd

EXECUTIVE SUMMARY

Engineering contributes some £486bn to the UK economy each year, and the sector accounts for one-fifth of the country's workforce – about 5.7 million jobs. Even so, employers report a constant struggle to recruit staff with the appropriate skills, and Engineering UK estimates that the UK needs to produce 182,000 engineers and skilled technicians a year, though currently there is an annual shortfall of 69,000.

As part of a wider effort to address the UK's skills shortage, the UK Government is exploring ways to implement more coherent routes into technical education. However, alongside such 'supply-side' activities, it is also important to consider the 'demand-side' – stimulating young people's interest in and desire for engineering and technical careers. Central to this issue are students' perceptions of engineering and their experience of engineering in the classroom, as well as the views of teachers and school leaders on engineering and the potential role of schools in preparing students for technical careers.

Given the long-standing failure to attract sufficient numbers of students (particularly female students) into engineering and technical careers, previous Institution of Mechanical Engineers' reports highlight the need to consider more carefully the interests and values of different types of young people, how engineering is perceived by them, and the roles of formal education, informal learning and family exposure in shaping such perceptions.

To gain deeper insight into how engineering is experienced and conceptualised within schools, the Institution carried out two complementary pieces of work:

- A school-based study, using interviews, discussion groups and online surveys to explore the perceptions of key stage 3 students (ages 11–14), parents and key school stakeholders in 11 English schools of varying types in three cities.

- A research study derived from participation in three engineering-themed debating competitions, designed to engage 16–19 year olds in deeper consideration of questions about engineering and society.

Engineering is seen as a force for good – but is rarely encountered in schools

Both projects found very positive attitudes to engineering, but students generally had little early exposure to engineering in school and did not feel well informed about engineering – perhaps best summarised as "We think it's important but we don't quite know what it is". There was a common view that engineering is taken for granted and undervalued: it is omnipresent in modern society and seen as central to societal 'progress', yet seldom actively considered.

This lack of exposure leads to a hazy and varied understanding of engineering among students

As a result of this low visibility in schools, students often had a vague understanding of engineering, and came up with a multiplicity of ways of thinking about it. Designing and making things was widely seen to be at the heart of engineering, but several other ways of perceiving engineering were apparent, including repair and maintenance, the ill-defined application of physics and mathematical knowledge, problem-solving, and engineering as a career outcome.

Notably, these conceptions do not add up to a coherent, integrated view of engineering. They are also of limited appeal to groups without an existing strong interest in engineering products (such as many girls or more creatively minded students).

Girls feel particularly poorly informed and do not see engineering as relevant to their own lives

The school-based study found that girls in particular felt poorly informed about engineering, and that they had learned little about engineering in the early stages of their secondary education. They were also less likely to identify how engineering could contribute to fields such as medicine or environmental protection.

Strikingly, although they were just as likely as boys to see the general social benefits of engineering, they were much less likely to agree that engineering was personally important to their lives. They were also less likely than boys to want more engineering in schools or more information about engineering careers.

Young people are able to see engineering as a 'socially beneficial, people-focused activity', but only when prompted

The Institution's 'Big Ideas: The Future of Engineering in Schools' report concluded that, to engage greater numbers of young people, more attention should be given to portraying engineering as a socially beneficial, people-focused activity. Notably, this message resonated with all groups – suggesting that there is a 'latent' understanding that could be shaped into a more coherent and positive conception of engineering.

Young people see engineering as a creative problem-solving activity

There was widespread agreement that engineering is a creative problem-solving activity, based on specific ways of thinking and team working. These aspects of engineering could underpin engaging educational experiences for all young people.

Socially rooted engagement projects can help the full spectrum of students, to see the relevance of engineering

Deeper engagement achieved through participation in an engineering-focused debating competition encouraged students to reflect on the nature of engineering, its social impact and personal relevance. The unorthodox approach to engineering engagement was popular among participants, who felt that it enhanced their understanding, and it promoted more favourable opinions of engineering.

Hence, while engineering engagement activities often focus on technical skills, processes and products likely to inspire the natural enthusiasts, more broadly conceived activities could appeal to a wider range of young people. This could boost general engineering and technological literacy, and potentially deepen the pool of students considering an engineering or technical career.

Parents and teachers (and to a degree young people) want to see more engineering in schools

There was strong support among all stakeholders for schools to place more emphasis on the made world and engineering specifically. Engineering is rarely taught as a specific subject, but is an extension of much that is studied in science and mathematics, has obvious resonance with design and technology, and is of potential relevance to other subjects. However, the school science curriculum is currently tilted in favour of teaching about the natural world.

Several schools expressed a desire to integrate more engineering into their curriculum offering, but several factors make this challenging, including limited flexibility within the curriculum, school performance measures, the primacy currently being given in England to English Baccalaureate subjects, and lack of staff expertise in the discipline. There are few if any incentives for schools to include engineering. When schools do focus on engineering it is often as a result of the passion and commitment of individual subject teachers, with senior leadership backing.

Schools are generally positive about highlighting engineering career options, but identified a number of constraints

Teachers, school leaders and governors generally felt that schools had an important role to play in preparing students for the world of work, including highlighting employment opportunities in engineering. Subject teachers, as well as careers professionals, were thought to be an important conduit of careers advice, by contextualising learning and drawing attention to career opportunities related to concepts taught in the classroom. Time pressures, lack of knowledge and insufficient resources were highlighted as limiting constraints, while closer links with local industry and additional professional development were identified as potential enablers.

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RECOMMENDATIONS

Engineering in schools – clarifying the vision

Collectively, the findings suggest that very low levels of exposure to engineering in the majority of schools leave young people with a poor appreciation of the nature and scope of engineering, leading to a diversity of perceptions and no coherent overarching vision of the discipline. As a result, many feel little if any connection with engineering, and many make early subject choices that rule out engineering or technical career paths.

On the other hand, there exist positive attitudes towards engineering and a widespread appetite for more engineering in schools, particularly among parents and students. Yet, despite this positivity, relatively few secondary schools are integrating engineering into their offering. Engineering-specific qualifications have not taken off, and, despite major investment by the engineering community over many years, extracurricular enrichment and enhancement activities are unlikely to be able to achieve the required sea change on their own.

The answer may instead lie in raising the profile of engineering within existing curricula – with a strong focus on providing an engaging experience of engineering across the full range of abilities and interests, and emphasising the socially beneficial, people-focused, problem-solving aspects of engineering. By enhancing young people's exposure to engineering in the classroom – and providing greater clarity of the nature of engineering and its world-changing potential – the UK schools sector could both have a significant impact on the UK's skill gap and enable more young people to benefit from stimulating, rewarding and worthwhile careers.

1. As part of its industrial strategy, Government should situate engineering at the heart of schools education by:

   - Setting up a working group of leading educationalists and other stakeholders to review and report on innovative ways to integrate engineering into young people's education

   - Appointing a nationally respected Schools Engineering Champion to provide a channel of communication between schools, Government and industry, and to advocate the wider cultural value of greater technological literacy alongside the economic rationale for investing in skills to prepare for the Fourth Industrial Revolution

2. National Education Departments should begin this process by ensuring that engineering is integral to classroom learning by:

   - Advocating curricula that better reflect the importance of the made world to modern society, and make explicit reference to the engineering applications of science, mathematics, and design and technology

   - Promoting approaches to teaching that emphasise and value engineering 'thinking skills' and problem-based learning

3. Individual schools should adopt an engineering vision and strategy, with support from local employers and national governors' associations, which would include:

   - Appointing a member of the school senior leadership team as an Engineering & Industry Leader to establish and communicate a vision for the school and to drive change

   - Appointing a dedicated Industry School Governor to work alongside and advise the Engineering & Industry Leader, and to embed employer relationships in school governance

   - Implementing a robust careers strategy such as the benchmarks set out in The Gatsby Foundation's Good Career Guidance report, with special emphasis on embedding careers awareness in the curriculum

4. The engineering community should present a unified narrative around engineering that will be attractive and relevant to a wider range of students by:

   - Stressing the creative problem-solving nature of engineering, its social benefits and relevance to individuals

   - Providing opportunities for students to take part in activities that explore the political, societal and ethical aspects of technology.

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INTRODUCTION

Engineering currently accounts for one-fifth of the UK economy – contributing £486bn to an annual GDP of £2.3trn. The sector is also responsible for one-fifth of all employment, amounting to 5.7 million jobs.

The UK's future national prosperity is widely believed to be dependent on a highly skilled workforce. Indeed, 'developing skills' was recently identified as one of the ten pillars of a draft industrial strategy[1]. Yet UK industry is dogged by skills shortages and many parts of the country are characterised by low-wage/low-skill employment opportunities. It is estimated that the UK needs to be generating 182,000 skilled engineers a year.

Notwithstanding the importance of training and lifelong learning, schools play a critical role in the acquisition of knowledge and development of skills required in the modern workplace. With industry continuing to experience considerable difficulties recruiting suitably qualified and skilled employees, it is clear that the education system is not meeting national needs. In particular, insufficient numbers of young people – particularly girls – are choosing to study STEM (science, technology, engineering and mathematics) subjects and pursue technical and engineering careers.

In 2015–16, motivated by the UK's engineering skills shortage, the Institution of Mechanical Engineers, supported by the Royal Academy of Engineering, led the 'Big Ideas' project, to explore radical new approaches in school-based education[2]. It identified a range of factors contributing to the dearth of students opting for technical and engineering career paths. In particular, the near-invisibility of engineering in schools was suggested to lead to poor understanding of what engineering entails and what engineers do.

Big Ideas drew upon earlier work identifying attitudinal clusters that could be used to group students according to their perceptions of STEM. The Five Tribes report[3] identified 'STEM Devotees' as a group most likely to pursue engineering-related careers (and the target of most engineering promotional activities). However, students in the other groups might, given the right encouragement and opportunities, also have the capabilities and motivation to follow engineering and technical career paths.

Indeed, the Big Ideas project suggested that, rather than focus on a narrow, mostly self-selecting group, engineering engagement should cast its net wider and promote greater engineering and technological literacy across all student groups. This would not only widen the pool from which future engineers might arise but would also provide all young people with valuable skills and knowledge to enable them to be active and informed citizens of a technologically advanced society.

To broaden the appeal of engineering, Big Ideas recommended the promotion of engineering should focus less on its products and more on its potential to make the world a better place, and to be an engaging problem-solving activity, drawing on a range of generally useful transferable skills.

These ideas led the Institution of Mechanical Engineers to question how engineering is currently perceived by young people and how it is contextualised by schools. At the heart of Big Ideas is the notion that engineering should be communicated as a socially beneficial, people-focused, problem-solving activity. It is therefore important to understand whether this reflects how students currently perceive engineering, how schools present engineering to students, and whether the Big Ideas 'model' is one that resonates with students, parents and teachers.

To explore this question, the Institution carried out two complementary pieces of work. The first was an investigation of perceptions of engineering among students in England aged 11–14, their parents, teachers, school leaders and governors. Interviews and surveys were conducted at 11 varied schools, including a subset that had taken steps to incorporate engineering into their formal teaching.

The second strand of work was more experimental. In partnership with the Institute of Ideas – an organisation dedicated to promoting independent discourse on a wide range of political and social matters – an engineering-focused Debating Matters competition was organised in England, Wales and Scotland, based on debate motions with a strong engineering theme and social context. Participants in the competition contributed to discussion groups and completed online follow-up surveys. The aim was twofold: first, to use the competition as a vehicle for exploring the perceptions of mainly post-16 students, and particularly how they were affected by the more immersive exposure to engineering and how it relates to everyday life, through research and discussions during the course of their preparation; and secondly, to explore the potential of this type of project to kindle interest in and knowledge of engineering.

SCHOOL-BASED RESEARCH

The research study was undertaken by the Vector STEM Partnership, a STEM and education consultancy with expertise in research, development and evaluation.

Overview of project

To explore perceptions of engineering, 11 secondary schools were selected in London, Manchester and the Sheffield region (**Appendix**). A subset of these schools ('engineering-incorporating schools') had chosen to include engineering in their curriculum offering, for example by adopting a key stage 4 (ages 15–16) learning programme based on construction engineering.

Structured interviews were undertaken with key school stakeholders: members of senior leadership teams; heads of department and teachers of science, mathematics or design and technology; schools careers staff; and governors. Key school stakeholders also completed open-ended questionnaires. Students provided views during activity sessions and through online surveys, while parents also completed similar questionnaires.

Perceptions of engineering

Responses to open-ended questionnaires and comments in discussion groups with secondary school students revealed considerable diversity in perceptions of engineering (**Figure 1**). The most common response was that engineering was about 'designing, creating or making things'. The products of engineering were also commonly referenced. A significant minority referred to 'fixing, improving, mending or maintaining'.

Teachers were more likely to mention that engineering involved problem-solving – a key aspect of engineering that, unprompted, few parents or students identified. Teachers were also more likely to draw out connections between engineering and school subjects – something few students did.
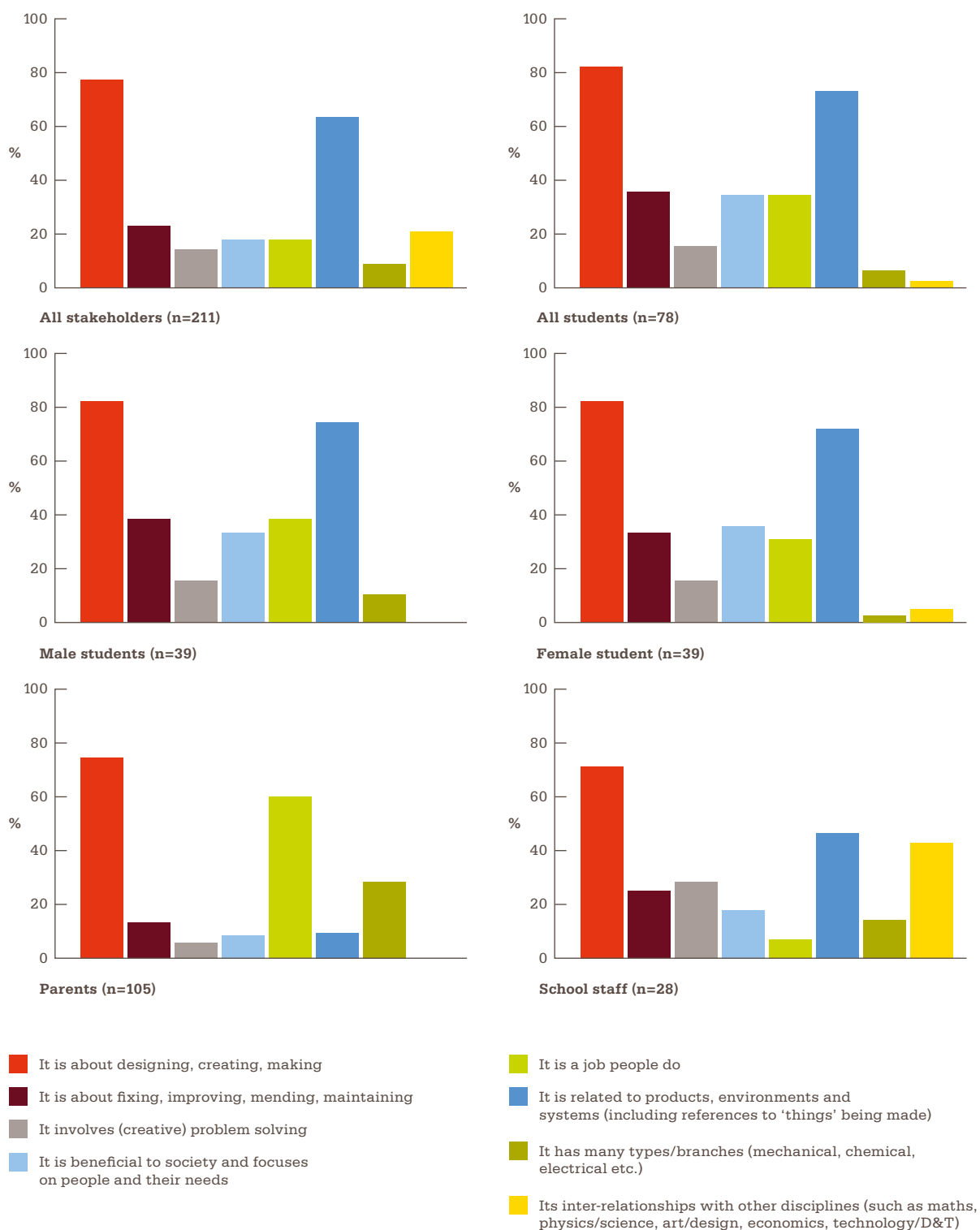
Notably, students were much more likely than the other groups to describe engineering as an occupation; they may therefore already be attuned to the idea of engineering as a possible career option. Unprompted, students were also more likely to talk about engineering in terms of its social benefits. However, they were also more likely to highlight 'mending and maintaining' perceptions of engineering; this perception was also more common among school staff than parents.

There were only relatively small differences in the responses of girls and boys, although girls were slightly less likely to mention engineering as a job opportunity or the range of different types of engineer.

The responses suggest that there is considerable variation in how engineering is perceived. There is a general perception that engineering is about making things and physical products, an idea that also strays into areas of technical maintenance, but also a variety of other complementary or competing conceptualisations.

Figure 1: Perceptions of engineering (unprompted):

Percentage of respondents mentioning particular aspects of engineering.

All stakeholders (n=211)

All students (n=78)

Male students (n=39)

Female student (n=39)

Parents (n=105)

School staff (n=28)

- █ It is about designing, creating, making
- █ It is about fixing, improving, mending, maintaining
- █ It involves (creative) problem solving
- █ It is beneficial to society and focuses on people and their needs
- █ It is a job people do
- █ It is related to products, environments and systems (including references to 'things' being made)
- █ It has many types/branches (mechanical, chemical, electrical etc.)
- █ Its inter-relationships with other disciplines (such as maths, physics/science, art/design, economics, technology/D&T)
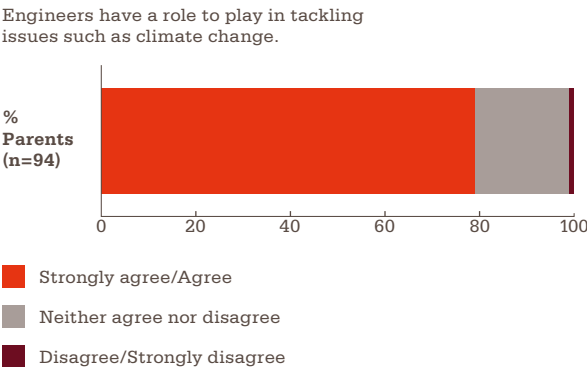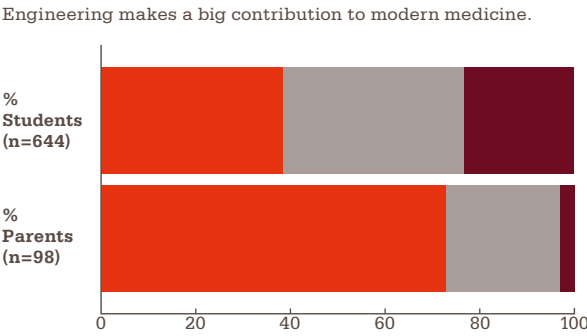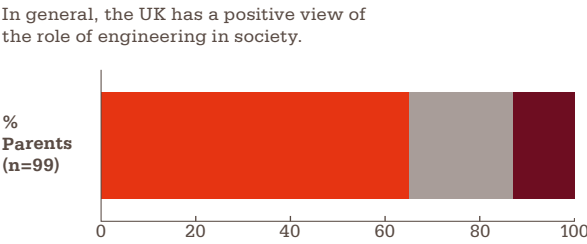
Strikingly, however, when presented with statements about engineering, there was a high degree of uniformity in responses from parents and students. Solving problems and developing ideas were widely seen as central to engineering (**Figure 2**). Perceptions about engineering were also very positive. Engineering was felt to be viewed positively by society and to make an important contribution to medicine and in solving global challenges (**Figure 3**).

Figure 2: Perceptions of engineering (prompted):

Solving problems is key to engineering

Developing ideas is important in engineering.
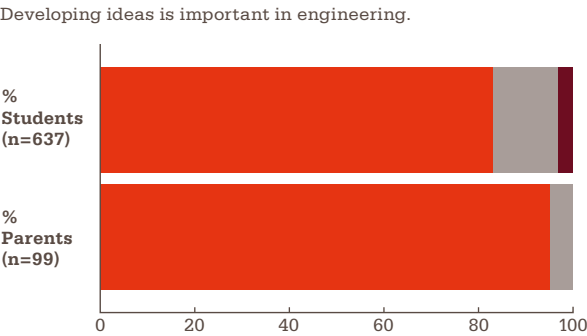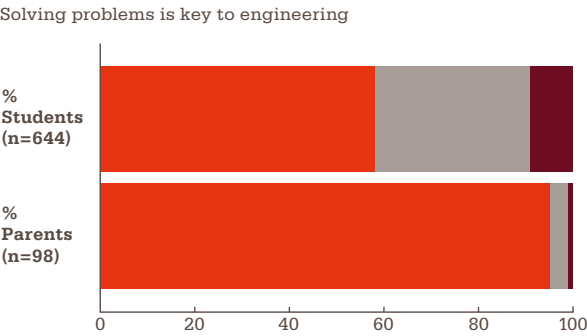
■ Strongly agree/Agree

■ Neither agree nor disagree

■ Disagree/Strongly disagree

Figure 3: Value of engineering in non-traditional domains (prompted):

In general, the UK has a positive view of the role of engineering in society.

Engineering makes a big contribution to modern medicine.

Engineers have a role to play in tackling issues such as climate change.

■ Strongly agree/Agree

■ Neither agree nor disagree

■ Disagree/Strongly disagree

There was very strong support from students and parents that engineers contribute a lot to most people's lives and help to make the world a better place (**Figure 4**). Parents also backed the idea that engineers of the future needed to place people at the heart of everything they do.

These sentiments were echoed in responses given in interviews and free-form questionnaire responses. Several respondents also suggested that engineering was largely taken for granted and not given the credit it deserves given the social benefits it delivers.

Figure 4: Value of engineering:

Engineers help to make the world a better place
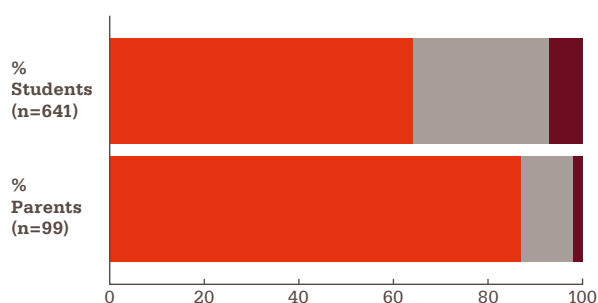
Engineering contributes a lot to most people's lives.

- ■ Strongly agree/Agree
- ■ Neither agree nor disagree
- ■ Disagree/Strongly disagree
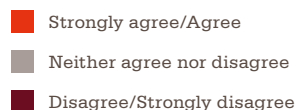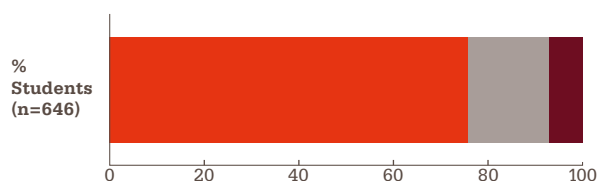
" I think the work of engineers and a career in engineering have tended to be undervalued in our society, particularly by parents of students, in comparison to doctors, dentists, lawyers, bankers etc. **Teacher**

" Many people take for granted the work of engineers. It is 'behind the scenes' and not widely understood or appreciated. **Careers Professional**

" I think that we are naive and slightly ignorant of the impact that engineers have on our daily lives. **School Governor**

" I don't think we do value engineers – our educational system nationally and locally does not foreground the need for engineers, or the skills that engineers need. Oddly enough, we celebrate our ingenuity nationally, but there is an unwritten coda which implies that we believe these triumphs are achieved against the odds. If engineering is important, it should be part of a national strategy, not a reliance on talented individuals simply emerging. **Senior School Leader**

Notably, however, students did not feel well informed about engineering – only one in four felt they knew a great deal or quite a lot about engineering. Strikingly, this figure fell to 8% for girls (**Figure 5**). Almost half of boys but just 23% of girls felt they had learned a great deal or something about engineering in years 7–9 (**Figure 6**).

Furthermore, when asked about the contributions of engineering in various domains (eg medicine, environmental protection, agriculture), engineering was seen by many students to play an important role, but many responded 'don't know', with girls again more likely to be unable to provide an answer (**Figure 7**). These results suggest there is a high degree of uncertainty about what engineering entails, particularly among girls.

Figure 5: Students' knowledge of engineering.

How much do you think you know about engineering?

- A great deal/Quite a lot
- A little/Nothing at all

Figure 6: Students' exposure to engineering in school.

How much do you think you learned about engineering in your lessons in years 7–9?

- A great deal/Some
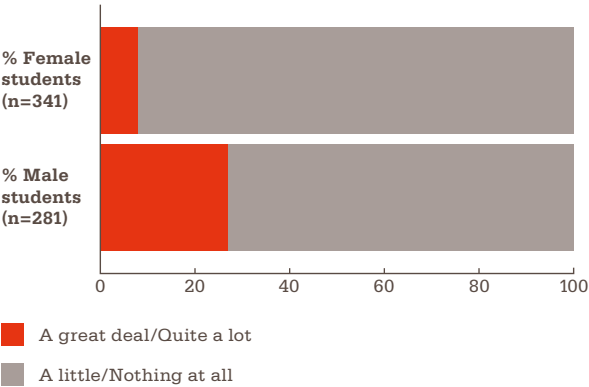- Very little/None
- Can't remember

Figure 7: Students' understanding of applications of engineering.

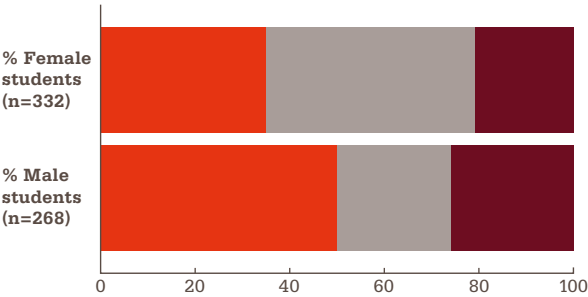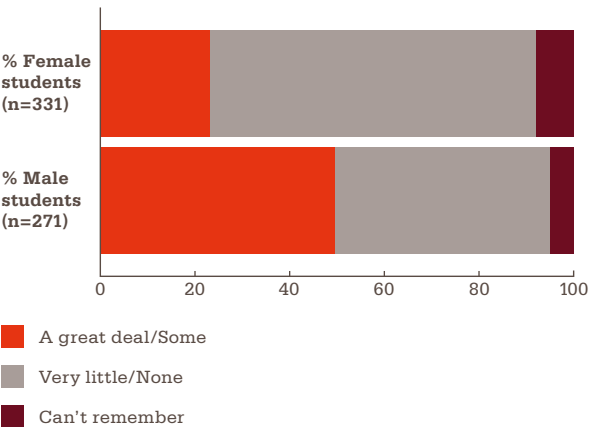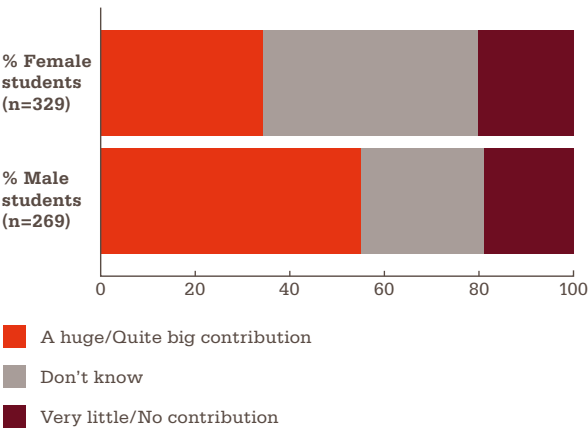How much can engineers contribute to the early detection of cancer?

How much can engineers contribute to increasing agricultural productivity?

- A huge/Quite big contribution
- Don't know
- Very little/No contribution

While the societal benefits of engineering were, in general, perceived equally strongly by boys and girls, there was a striking difference in how relevant engineering was perceived to be to individuals. Some 49% of boys agreed that engineering was important to them as individuals, compared with 24% of girls; only 17% of boys but 34% of girls disagreed with this statement (**Figure 8**). These results suggest that, while girls are equally likely to appreciate the social value of engineering, they are less likely to see it as relevant to their own lives.

In addition, when asked to select three descriptions of engineering, girls were more likely to choose 'dirty', 'challenging', 'complicated' and 'boring' and were less likely to choose 'innovative', 'exciting' and 'interesting', further indicating that perceptions of engineering are less favourable among girls.

Figure 8: Relevance of engineering to individual students.

Engineering is important to me.

- Strongly agree/Agree
- Neither agree nor disagree
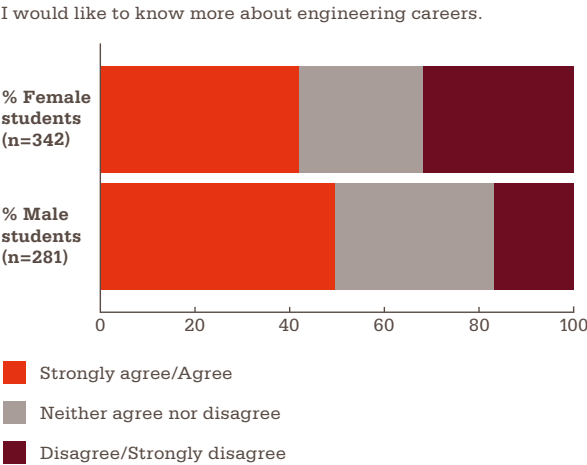- Disagree/Strongly disagree
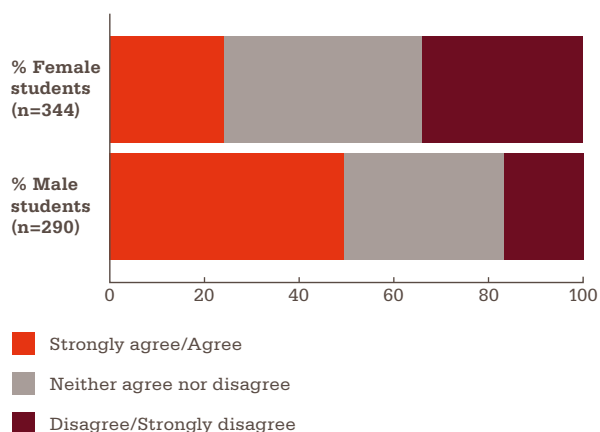
Experience of engineering in schools

Engineering currently has little visibility in the early years of secondary education. Most students (58% overall, but 68% of girls) believed they had learned little or nothing about engineering in years 7–9. On the other hand, more than half of students (54%) responded that they would like to learn more about engineering at school. However, this desire was not shared equally between boys and girls – 66% of boys but just 44% of girls were in favour. Similarly, while about half of students expressed a desire to know more about engineering careers, boys were markedly more likely to want such information (**Figure 9)**.

Some students may have been more exposed to engineering because they attended schools that included some engineering programmes that the research team described as 'engineering incorporating schools'. Students at such schools were slightly more likely to want to learn more about engineering at school (59% vs 50%) and to want to learn more about engineering careers (55% vs 45%).

Figure 9: Students' desire for more information about engineering careers.

I would like to know more about engineering careers.

- Strongly agree/Agree
- Neither agree nor disagree
- Disagree/Strongly disagree

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However, gender differences were even more pronounced in such schools – just 33% of girls in engineering-incorporating schools wanted to learn more about engineering, compared with 64% of boys. In comparison with girls in other surveyed schools, girls in engineering-incorporating schools were actually less likely to want to learn about engineering (33% vs 54%) and less likely to want to discover more about engineering careers (30% vs 52%) (**Figure 10**). This might suggest that the way engineering is being presented in such schools may actually be discouraging girls from pursuing the subject. These findings emphasise the importance, not just of promoting engineering in schools, but also of promoting it in the right way, to make it appealing to a large constituency of students.

Overwhelmingly (96%), parents agreed that it would be beneficial for young people to develop greater engineering and technological literacy at school. Some 73% agreed that their child's school should do more engineering activities, 82% were in favour of engineering being taught as a separate subject, and 85% approved of the idea of using practical engineering examples to illustrate scientific and mathematical principles. Nearly all (95%) said they would encourage their child to consider a career in engineering if they were interested. However, only 32% agreed that their child learned about the impact of engineering on people's lives in school. Hence, it is likely that parents would be supportive of moves to increase the emphasis on engineering and technology in school education.

Most members of the school community acknowledged that engineering had very little presence in the school classroom. It was suggested that engineering concepts were sometimes incorporated into STEM classes or other subjects (such as design and technology), although this was often dependent on the interests of specific teachers. Generally, even when these concepts were introduced, an explicit link to engineering was not made. School staff identified a range of other approaches used to raise student awareness of engineering, such as curriculum enhancement and enrichment activities including off-timetable days, STEM visitors and participation in third-party schemes. Outside engineering-incorporating schools, these were generally arranged on an *ad hoc* basis rather than as part of an overall strategy.

Figure 10: Female students' desire for more information about engineering careers in engineering-incorporating schools (A) and other schools (B).

I would like to know more about engineering careers.

- Strongly agree/Agree
- Neither agree nor disagree
- Disagree/Strongly disagree
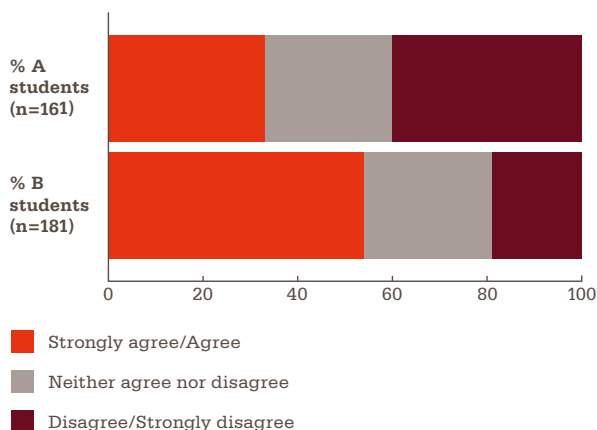
Some respondents suggested that curriculum content pressures added additional challenges. It was felt that inclusion of engineering would add still further to a crowded science curriculum. It was also suggested that performance measures such as the English Baccalaureate and the school success metric, Progress 8, were applying pressure to creative subjects such as design and technology where the profile of engineering could be raised. Financial pressures on schools may also have contributed to a recent marked drop in the numbers of students taking design and technology courses, with savings being made in equipment and materials budgets, and design and technology departments being vulnerable to staff reductions.

On the other hand, some schools felt that engineering was being successfully incorporated into STEM teaching and in other subjects (and in some cases it was being taught as a separate subject).

The study also examined the thinking skills and competencies associated with engineering. As well as technical knowledge, employers also highly prize these skills and competencies. Furthermore, it has been argued that there are specific mental processes associated with 'thinking like an engineer' – known as 'engineering habits of mind'[4]. Specific pedagogical approaches, such as problem-based learning, may be particularly effective at developing these habits.

When presented with versions of engineering habits of mind, many school staff felt that they recognised the skills being described and attempted to cultivate such skills in their classrooms, even if they were not familiar with the engineering habits of mind terminology. These results suggest that teachers might be receptive to the inclusion of problem-based approaches to learning, and an emphasis on developing students' engineering thinking skills.

Overall, despite generally positive views about the desirability of teaching engineering in schools, relatively little is actually happening – suggesting the existence of a significant 'implementation gap'. Some specific obstacles were identified, and it remains true that schools as a whole have little incentive to make engineering a major element of students' learning experience.

" "
We do not use engineering as a phrase – no direct ref to engineering – do refer to physics applications eg ultrasound. **Head of Department/Teacher**

" "
At my last school we had a collapsed timetable day for science and D&T every half term, and students learned all sorts of things to do with the interconnections. But after I left they stopped doing it because it was thought the students needed to spend more time on the science curriculum.
Head of Department/Teacher

The participating schools varied in the extent to which they promoted engineering. Location and proximity to manufacturing industry appeared to have relatively little impact on whether a school promoted engineering. A more important factor appeared to be the presence within a school of an 'engineering advocate' who took the lead in raising the profile of engineering in schools. However, advocates also needed to secure the support of the school's senior leadership team in order to have cross-school impact. The reliance on specific individuals raises questions about the sustainability of engineering promotion in schools, as the emphasis on engineering could be diminished or lost if that individual leaves a school and an engineering strategy has not been fully embedded into the school's work.

Role of schools in careers planning

Schools could help to develop a deeper appreciation of engineering and promote the teaching of the knowledge and skills applied in engineering. Potentially, schools could also play a more explicit role in raising awareness of and preparing students for technical or engineering careers.

School staff, including careers advisers, were generally supportive of the idea that subject lessons should include careers guidance. It was suggested that this could be achieved by contextualising learning and by pointing out career-related implications of concepts taught in the classroom. Linking curriculum learning to careers is one of eight benchmarks for successful careers provision presented in the widely supported Gatsby Charitable Foundation Good Career Guidance report[5]. Extracurricular activities, such as visits by engineers to schools, were also identified as a potential mechanism for exposing students to careers information.

A range of constraints were identified that limited scope to introduce careers-related information. These included teachers' lack of knowledge, the demands of a content-rich curriculum that leaves little time for wider discussions, and a lack of resourcing.

On the other hand, some schools were wary about seeing school education purely as a service for employers, or about guiding students toward specific career destinations.

> Students should be given as much information about all careers available to them as possible.
> **Head of Department/Teacher**

> The school should provide opportunities and experiences which enthuse children and develop their curiosity and understanding of aspirations and possible careers. Students should learn about subject specific careers and how careers utilise and require cross curricular skills.
> **School Governor**

> To some extent, but we must also instill a love of learning for the sake of it and for future further learning. School is not directly vocational in the main although it can lay the groundwork and ensure appropriate qualifications are gained that will open doors in the future. It is helpful for students to have considered future pathways to ensure the right choices are made when available to not cut off certain routes, but also students should choose to study subjects they enjoy to maximise engagement and therefore success, this is the best way to keep doors open.
> **Member of Senior Leadership Team**

> I think that seeing teachers as the answer here is misguided. Neither the skill base nor the funding exists to make that possible, if we are talking about engineering specifically. There are things (the school) does to prepare its students for transition to workplace and further education, but it can't all be about school.
> **Member of Senior Leadership Team**

> Every teacher is a teacher of careers. Ideally they should make links between their subject and careers, or with well-known people who have studied it, or interesting things resulting from the study of this subject. It doesn't have to be all the time! **Careers Professional**

EXISTING MODELS OF ENGINEERING EDUCATION IN SCHOOLS

CASE STUDY 1: ENGINEERING AS DESIGN & TECHNOLOGY

To date, engineering has not gained a strong foothold in the UK school education systems. Nevertheless, schools have adopted a range of approaches to enhance the presence of engineering. The following case studies illustrate three contrasting approaches that have been adopted with some success by individual institutions, and highlight some of the obstacles and enablers associated with each approach. These exemplars have been included to provide further food for thought to inform discussions about sustainable long-term strategies for embedding engineering in our schools.

UCL Academy: A dedicated engineering department

The UCL Academy offers all students an experience of engineering, achieving a high take-up of the subject by students of both genders as well as excellent results in engineering qualifications.

Design and technology (D&T) has been suggested as one route by which students' exposure to engineering could be enhanced. However, the subject is struggling to maintain its position within schools. When it opened in 2012, the UCL Academy chose to establish a dedicated engineering department rather than a conventional D&T department, part of a faculty that now also includes computer science.

Students at the UCL Academy receive three hours engineering teaching a week in year 7 and two hours a week in years 8 and 9. Engineering is the most popular option in year 10, taken up by 83 students in 2016/17 (out of a year group of about 180) – a figure that has been steadily rising. The school offers a GCSE in engineering, a vocational qualification at level 2, and an A-level in D&T (previously in engineering, until the specification was withdrawn).

A-level results in 2016 were the highest in the school, with 89% of students achieving A*–B. In 2017/18, the first cohort of UCL Academy students, who have been exposed to engineering throughout their secondary education, will be entering its sixth form. Encouragingly, the number of students opting for an engineering-related A-level has leapt from eight to 30. Sixth-form entry requirements are high, emphasising that engineering is seen as a rigorous course.

Uptake of engineering shows a significantly less marked gender split than is seen nationally. Girls typically make up 30–35% of GCSE classes and its 2016/17 A-level class was evenly split between girls and boys. The school is, however, keen to increase participation by female students, with the ultimate aim of achieving gender parity at all stages of education.

Engineering courses are seen as natural choices for medium- and high-achieving pupils, with students potentially able to go on to undergraduate engineering courses or into technical training. The school is also keen to increase its provision of careers-related information into its teaching. Parents have been extremely positive about the opportunity children have to study engineering – use of the specific term 'engineering' and the association with a well-respected academic institution in UCL may have played an important role in reinforcing the status of engineering in the school.

About UCL Academy

Opened: 2012

Student numbers: 1,150 (inc. 250 in sixth form)

Specialisms: STEM, foreign languages

Recruitment: Non-selective

Student mix: More than 50% from disadvantaged backgrounds

Staffing and resourcing

The engineering department has a staff of 4.5 FTE, plus two technicians who make a highly valued contribution to classroom activities, including working directly with students. Notably, three teaching staff undertook a combined engineering and education degree course run by the University of Limerick, Republic of Ireland. The head of department has a background in D&T and has spent time working in the automotive industry. He suggests that, with a flexible attitude and willingness to learn, many D&T teachers would readily be able to transition into teaching of engineering specifications – particularly with the practical support of suitably skilled technicians. He also cites the benefits of a gender-balanced staffing complement.

The UCL Academy's senior leadership team is strongly committed to the subject, and the school's facilities are well resourced. The department has two workshop spaces, an additional area for practical work and an iMac suite for computer-aided design/manufacturing. Per-student running costs are in line with those of an established D&T department.

Approach to engineering

The UCL Academy's approach to teaching includes open-ended 'design-and-make' projects alongside guided practical projects. Courses include mathematics and physics content, and attract students from across a range of abilities, including high achievers. Where possible, teaching draws upon real-life examples and highlights the social value of engineering, such as an anaerobic digester project raising awareness of food waste and sustainable energy generation.

The engineering department has links with other STEM departments in the school (for example working with the science department on a project based on building an anaerobic digester), and is exploring opportunities for greater collaboration. It has also worked with non-STEM departments, including a joint project with the drama department, using role-play to explore the use of empathy in product design. The department is also interested in developing stronger links with secondary and primary schools, and acting as a hub to build capacity in engineering teaching in additional schools.

The Academy's sponsorship by UCL adds distinct features to the department, and links with UCL Engineering are strong. The school hosts visits by academic engineers and draws on the technical expertise of UCL engineering staff; teachers also spend time at UCL as part of their continuing professional development. It also has contact with local industry, primarily through the STEM Ambassadors scheme.

A potential model for engineering in schools

The UCL Academy model suggests that engineering can be integrated as a discrete subject into secondary schools and that it is a popular choice, attracting a wide diversity of students. The model relies on strong support at an institutional level, but is one that would be practicable to implement as an alternative to a traditional D&T department.

Engineering in schools: Key enablers of a D&T to engineering transition

- A supportive senior leadership team and governing body

- A strategic decision to brand activities as 'engineering' and to enhance the technical aspects of teaching

- Appropriate resourcing

- Skilled and valued technicians contributing to teaching as well as providing technical backup

- A focus on stimulating curiosity and practical problem solving

- An emphasis on social context in teaching

- Flexible and adaptable teaching staff

- A particular focus on medium- and high-achieving students

- Links to local industry and higher education institutions

CASE STUDY 2: A UNIVERSITY TECHNICAL COLLEGE

Aston University Engineering Academy

Aston University Engineering Academy aims to provide an intensive grounding in engineering, with a particular emphasis on contextualised learning and student professional development.

The University Technical College (UTC) model was developed in response to the UK's technical and practical skills gap, providing an option for students from year 10 onwards. The first UTC opened in 2010, and by mid-2017 about 50 had been established, many with a focus on engineering.

Aston University Engineering Academy, specialising in engineering and science, opened in 2012. It takes students from across the whole Birmingham metropolitan area. It is now operating at full capacity, being oversubscribed at both year 10 and year 12 intakes. It has excellent destination outcomes: more than 80% of the Academy's students go on to STEM-related degrees and apprenticeships, far higher than the national average. In 2017, just two leavers ended up not in education, employment or training.

About Aston University Engineering Academy

Opened: 2012

Student numbers: 615 (inc. 345 in sixth form)

Specialisms: Engineering, science

Recruitment: Non-selective, intakes at year 10 and year 12

Student mix: 13% pupil premium students

The engineering offer

All year 10 students undertake a BTEC in engineering and a level 2 technical award (GCSE equivalent) in smart product design. Students also have the option of a separate GCSE in product design (or in computer science), alongside core GCSE subjects (triple science, mathematics and English).

A range of pathways are offered at year 12. The most common option is a BTEC extended diploma in engineering, equivalent to three A-levels, often combined with a physics or mathematics A-level. A triple distinction in the extended diploma generally secures entry into undergraduate engineering courses. (Some universities have more proscriptive entry requirements, and the Academy discusses likely destinations with prospective students, to ensure that it offers the best option given their longer-term educational aspirations.)

The Academy tries to ensure that it offers a welcoming environment for female students. Girls made up about 25% of 2017's year 12 intake, a significant increase on previous years. The Academy has worked with partners to develop specific activities for female students, including a women in the rail industry module, as well as with the Women's Engineering Society and partners such as BMW, that are keen to improve female representation. Girls have the opportunity to be mentored by female engineers working in industry.

Contextualising learning

The Academy has a strong focus on contextualising learning and the practical application of knowledge. It has established strong links with local industry and other partners, including higher education institutions and the Armed Forces. In recognition of this partnership building, the Academy's Vice-Principal received the Most Innovative Contribution to Business–Education Collaboration at the West Midlands 2017 Education Awards.

Local businesses help to develop projects for students and contribute to classroom teaching. Projects include work on an RAF skeleton bobsleigh and building a plane. The Academy also offers multiple extracurricular activities, such as the Jaguar Maths Challenge, Bloodhound and Formula 1 in Schools. It also has links with RAF Cosford, home to aeronautical engineering in the Armed Forces, and the British Army's Royal Electrical and Mechanical Engineers.

Contextualisation is also promoted in the classroom. The Academy is organised around curriculum areas, including science, engineering and mathematics, but teaching is integrated across these areas. For example, teachers in the mathematics department teach the mathematical components of engineering courses. Furthermore, teaching in science and mathematics classes has a strong emphasis on the practical application of knowledge.

Several teachers have experience of engineering in industry or the Armed Forces, and there are plans for teachers to undertake work experience in local companies. Given that UTC teachers have longer teaching days and longer terms, and organise many extracurricular activities and visits, it is important that staff have a strong commitment to the UTC model.

Students' professional development

A second key theme for the Academy is students' professional development. This can include the development of specific technical skills (such as certification in use of CAD/CAM technology), as well as work experience and participation in general initiatives such as the Duke of Edinburgh and Duke of York schemes or the Combined Cadet Force.

One day a week is devoted to professional development. For year 10 students, this is based on project work, while year 11 students can choose between project work and work experience. Year 12 and 13 students have similar options, but can also study for professional qualifications.

A potential model for engineering in schools

UTCs can provide an intensive foundation in engineering for those who have already identified this area as one in which they have an interest. Some 40% of the Aston Academy curriculum is devoted to engineering.

A recent review identified a range of challenges facing UTCs[6]. Many have struggled with recruitment (as do most new schools), leading some to close, although others – including Aston Academy – have established strong local reputations and are significantly oversubscribed.

UTCs tend not to fare well in GCSE league tables. However, they are non-selective, and some students may be choosing UTCs for negative reasons (because they are disaffected with their current school or their current school is keen for them to leave). UTCs also have just 14 months to prepare students for GCSEs. Finally, GCSE results do not capture the added value of UTCs – professional and personal skills development and enhanced employability. Destination statistics may be a better metric for assessing their success.

UTC model for schools engineering

Benefits

- Clear institutional focus on engineering
- Strong links to local industry and involvement of industry in teaching
- Emphasis on project-based learning and contextualisation of knowledge
- Focus on professional development and employment-related skills

Challenges

- Need for change in school at unconventional time (year 10); recruitment challenges
- UTC choice not always made for positive reasons
- Appealing mainly to those with existing interest in engineering
- Current emphasis on GCSEs/English Baccalaureate does not recognise UTC's other educational contributions

CASE STUDY 3: EMBEDDING ENGINEERING

Sutton Grammar School

In time and with enough commitment, it is possible to embed engineering into the culture of schools.

In 2017, 28 out of 110 sixth-form students at Sutton Grammar School chose to study engineering at university. Two girls joined the school's sixth form specifically because they wanted to do engineering degrees. Its students have won Young Engineer of the Year Awards, and in 2016 the school won the national UK Space Design Competition. These facts and figures illustrate how engineering is woven into the fabric of the school.

This situation owes much to the vision of the school's head of faculty, who joined the school in 2010 (and who won an Institute of Physics Teacher of Physics Award in 2012). The school has a strong focus on academic achievement and is a science specialist school. However, as well as pursuing a strong STEM-wide agenda, the head of faculty has also attempted to instil a particular focus on engineering.

Engaging activities

In the absence of a specific engineering course, raising the profile of engineering has relied heavily on extension and enrichment activities. This began with a high-altitude ballooning project. Now, use is made of the many activities offered by professional bodies, companies and others. The school is a regular entrant in the annual Big Bang Competition run by Engineering UK, and hosted regional Big Bang Fairs in 2014 and 2016.

To accommodate this project work, a regular weekly slot has been set aside for STEM-related extracurricular activities, and is attended by about two-thirds of year 10 and year 11 students. There are opportunities to study for a GCSE in electronics or to undertake activities linked to the British Science Association's CREST awards, as well as to take part in engineering-themed projects.

The school also arranges external speakers, often from less obvious fields of engineering, making use of the STEM Ambassadors scheme of by calling local companies directly – most have been more than willing to help out. In addition, Sutton Grammar is a hub for the Institute for Research in Schools – many of whose projects have a strong focus on engineering.

About Sutton Grammar School

Opened: 1899

Student numbers: 938 (inc. 289 in sixth form)

Specialisms: Science

Recruitment: Selective; boys only years 7–11; mostly boys in sixth form with girls able to join when places are available.

Student mix: 4% pupil premium students

Motivating students

Students are also exposed to workshop spaces, including work-in-progress and half-finished models, rather than just finished products in isolated display. Furthermore, older students are allowed to work on projects (quietly) while lessons are taking place in the same space.

None of the activities has required a significant investment of resources, and most should be feasible within a typical secondary school environment. (The only exception is the school's involvement in the Greenpower initiative, where a new shed was built to house an electric car; this was funded by a donation from a school alumnus.)

Students may not have a good understanding of what engineering is, so it is actively promoted as a career option. Helpfully, several of his colleagues have some background in engineering.

Notably, experience with films from the Born to Engineer website suggests that the use of engineering to solve social and medical problems strikes a chord with young boys. With idealistic young people, stressing how the application of mathematics and physical sciences in engineering can make the world a better place may be a powerful motivator.

A potential model for engineering in schools

The experience of Sutton Grammar School suggests that engineering can be made visible and relevant in schools without being afforded specific curriculum time and space. However, it takes time and commitment, and inevitably relies heavily on extracurricular activities; it may also take several years before engineering is truly embedded. Also critical has been the active support of senior school leaders and governors, particularly the school's headmaster, who has recognised the importance of addressing the UK's technical skills gap.

Embedding engineering in a school's culture

Factors that can promote the profile of engineering in a school

- Strong commitment from a specialist teacher

- Support from senior school leaders

- Extensive use of resources provided by professional bodies, companies and others

- A willingness to devote time to activities outside normal school hours

- Young students' exposure to engineering activities carried out by older students

- Explicit referencing of engineering and application of science and mathematics knowledge and skills

- Participation in and exposure to practical activities

- A focus on the potential of engineering to deliver social benefits

Magnus Riley

INSTITUTE OF IDEAS
DEBATING

DEBATING MATTERS

OVERVIEW OF PROJECT

The Debating Matters study was a more experimental strand of work that sought to explore the perceptions and experiences of older (post-16) students. In partnership with the Institute of Ideas, the Institution of Mechanical Engineers commissioned a bespoke version of the well-established Debating Matters competition (see **Box 1**) with debate motions based on engineering topics with a strong social dimension. These motions were:

- "All vehicles should be automated"

- "Technological progress will not solve society's environmental issues"

- "Constant monitoring of our health does more harm than good"

- "Engineers are born and not made" or "Anyone can become an engineer"

The project had two key aims. The first was to use the debating events as a vehicle to explore students' perceptions of engineering, engineers and their role in society, and their exposure to engineering in schools. Uniquely, the project offered a way to compare the perceptions of both STEM and non-STEM students (and those combining STEM and non-STEM subjects) and of girls and boys. It also provided an opportunity to examine how participation in the Debating Matters competition affected perceptions of engineering.

The second aim was to explore the impact of a non-traditional engineering engagement exercise. Debating activities allow students from any background to engage with engineering-related issues. Furthermore, they provide ample scope to draw out the social connections and implications of engineering. Schools were encouraged to involve all their students with an interest in debating, not just those studying STEM subjects. The project therefore had several notable features:

- It was deliberative, providing an opportunity for students to engage with engineering-related issues over an extended timeframe

- It was non-directive, making no attempt to persuade students of any particular point of view

- It was inclusive, engaging both STEM and non-STEM students

- It was socially contextualised, framing engineering-related issues in a social context.

Box 1: Debating Matters and the Institute of Ideas

The Debating Matters competition, developed and run by the Institute of Ideas since 2002, provides sixth-form students with opportunities to develop their debating skills. The focus is on contemporary issues, often with a scientific or technical dimension, and resources are provided to enable debating teams to dig beneath the headlines and research topics in depth.

Each year, a national competition is organised, with schools pitting their wits against each other in qualifying rounds, regional finals and a national final. Expert judges provide constructive feedback to participants and collectively decide who 'won' each debate.

In addition, the Institute of Ideas works with partners to develop themed debating competitions, as in the partnership with the Institution of Mechanical Engineers. Four motions were developed, each exploring an engineering/technological issue in a social context. With input from the Institution of Mechanical Engineers, the Institute of Ideas produced stimulus materials for each of these four motions. Schools had several weeks in which to carry out research, using the stimulus materials and resources they identified for themselves, to prepare themselves for the debating event.

At each event, four schools competed against each other in front of specially selected judges, with two students representing their school in each debate. The two best-performing schools in round robin stages met in a grand final to determine the day's overall winner. School teams were were typically 12–20 strong, drawn mainly from sixth forms, and included students who were not studying STEM subjects.
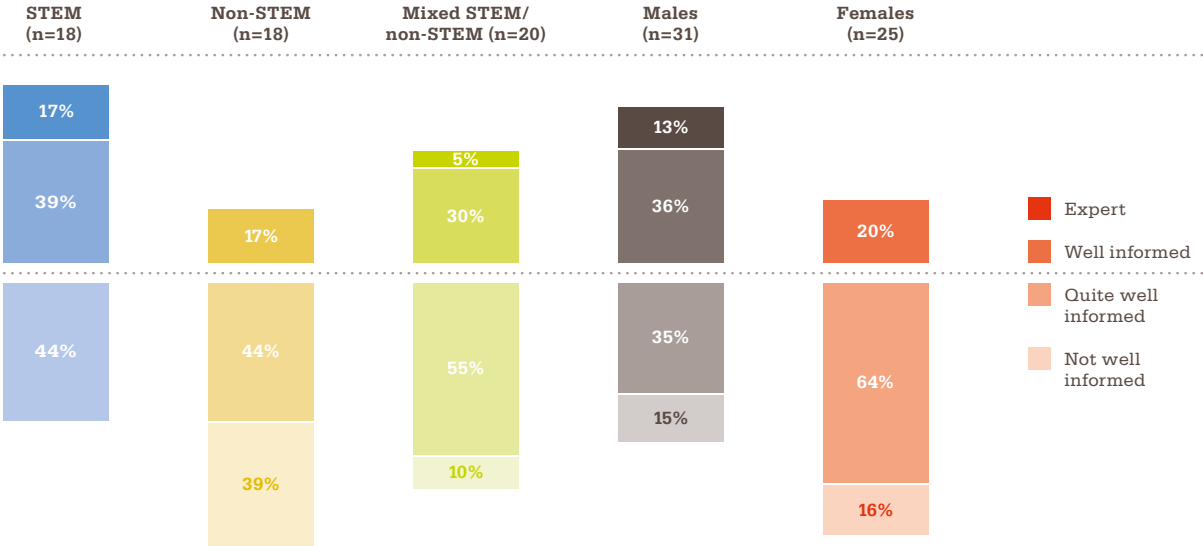
debatingmatters.com

Twelve discussion groups were held during breaks at competition venues in London, Cardiff and Glasgow, with groups ranging in size from three to 15 students. Key themes from these discussions (and other relevant questions) were then explored further in online surveys sent to participants. Survey data was disaggregated to allow quantitative comparisons between students studying primarily STEM subjects, those not studying STEM subjects and those combining the two ('mixed' groups), and between girls and boys, (although results of these subgroup analyses should be treated with caution because of the relatively small sample sizes).

Understanding of engineering

Mirroring the results from younger age groups, most students did not feel well informed about engineering, particularly girls and those not studying STEM subjects (**Figure 11**). Nevertheless, students generally held very positive views of engineering – including girls and those not studying STEM subjects; some 95% of students considered engineering to be essential or very important to the modern world (**Figure 12**).

Across groups there was good agreement that engineering benefits people and helps to make the world a better place; the importance of engineering to medicine was widely recognised. There was also a strong consensus that engineers had an important role to play in solving important social issues and, to a slightly lesser extent, environmental and medical challenges.

In discussion groups, students expressed highly positive views of the benefits of engineering. Students recognised that engineering and technology underpinned modern life, and equated engineering with societal 'progress' in general terms.

" "
We can't really function without engineers.
Glasgow

" "
The point of engineering is to make a change for the better. **London**

" "
Our whole culture in the developed world is based around engineering. **Glasgow**

There was strong agreement across all groups that engineering is pervasive in society (a view markedly reinforced by participation in the Debating Matters project) and relevant to people's lives. Ethical and social issues were seen as central to engineering, particularly by non-STEM and mixed STEM/non-STEM students, and by girls.

The discussion groups strongly suggested that participation in the Debating Matters projects had led students to think more deeply about the role of engineering in everyday life and its connections with ethical and social issues, the relevance of which to engineering had rarely been considered.

Figure 11: How well informed do you feel about what engineering is?

STEM (n=18) · Non-STEM (n=18) · Mixed STEM/non-STEM (n=20) · Males (n=31) · Females (n=25)

Legend:
- Expert
- Well informed
- Quite well informed
- Not well informed

STEM: 17%, 39%, 44%
Non-STEM: 17%, 44%, 39%
Mixed STEM/non-STEM: 5%, 30%, 55%, 10%
Males: 13%, 36%, 35%, 15%
Females: 20%, 64%, 16%

There was a sense that engineering is taken for granted. While students recognised the importance of engineering and technology, only when they stopped to reflect did they realise just how pervasive it is and how much influence it has on their everyday lives.

"
(I) realised that engineering makes up the human world and I wouldn't have thought that before. **London**

"
It's broadened my perception of the huge range of things we use engineering for. **Glasgow**

The social and ethical dimensions of engineering were an eye-opener for many students, as engineering is often conceptualised in terms of products and the physical properties of those products, rather than their use by people. Once highlighted, the social and ethical context of engineering was seen as real and important and not a contrivance to support a debating project. Notably, the focus on social and ethical issues clearly attracted the interest of those who would not have engaged with traditional engineering activities.

"
It's the first time I've talked about engineering… I've been stimulated to think. **Cardiff**

"
I always thought of it as something completely separate from society for some reason, even though it's practically integrated in every single bit of it. So I don't really know where that idea came from… I thought it was something that didn't really have an effect on me when it really does. **Cardiff**

"
I was surprised to see the ethical side and the moral side, which you can relate to professions like medicine and doctors and you wouldn't consider that for engineers. **London**

"
There's a lot more aspects to solving problems than just equations and formulae… There's moral issues and social issues and economic issues that you have to take into account. **Glasgow**

Figure 12: How important do you think engineering is in the modern world?
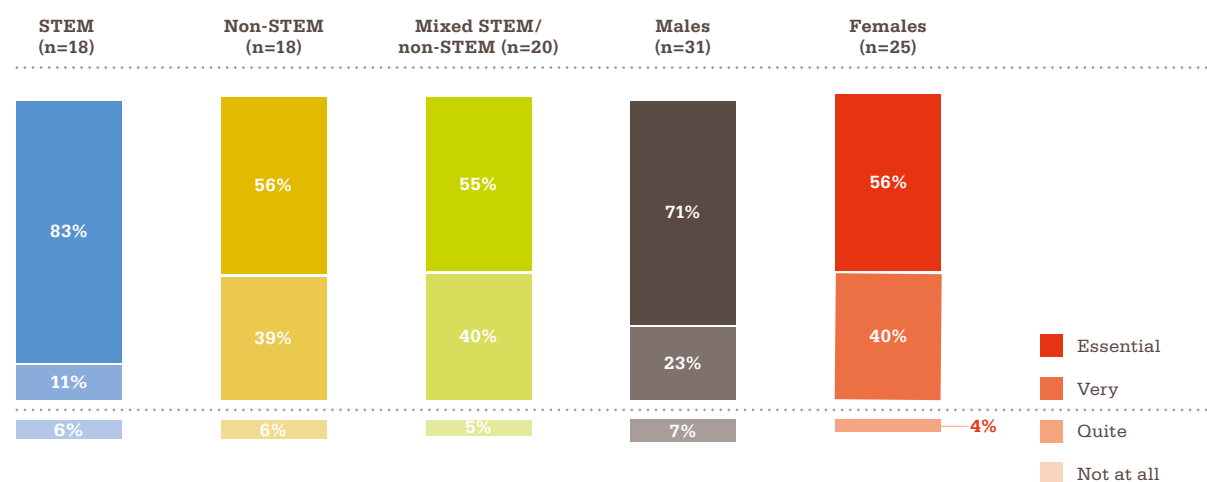
Problem-solving was seen as central to engineering. Despite often associating engineering with practical activities and physical products, students emphasised the importance of more abstract concepts, such as developing ideas, over practical skills. Creativity was also seen as essential to engineering, by all groups. The importance of working in teams was also widely recognised, as were soft skills such as communication and, to a lesser extent, empathy and listening skills.

Discussion groups identified a range of ways in which engineering is conceptualised, not always consistent with one another. For many, engineering is strongly associated with the products of engineering – cars, aircraft, bridges. It was often suggested that engineers were typically viewed as people working manually with mechanical products.

" (Engineers are people who have their) heads down working on an engine. **Cardiff**

" (An engineer is) someone who gets their hands dirty. **Cardiff**

" They build roads and bridges and stuff like that. **Cardiff**

Notably, having to research engineering-related themes led many students to develop a deeper appreciation of what engineering is and what engineers do. Students often came away with a stronger sense of engineering as a process associated with a particular skill set rather than a set of products.

" Initially at the very beginning I thought that engineering was about working with machines but there's a lot to do with developing ideas. It's not just the end output. **London**

" It's not just a vocation, it's the way people think and act. **Glasgow**

" I think there is a misconception that engineers are people who fix things manually, like a mechanic. I think an engineer is more about developing a hypothesis about how to fix something and they're not physically implementing it themselves – it's about how they plan it, how they design it, how they imagine it. **Glasgow**

The exercise also helped students appreciate the breadth of engineering. Often this was expressed in terms of different types of engineering disciplines but many students also expressed surprise at the range of spheres in which engineering could be applied, such as medicine or the environment.

Perhaps because of their involvement in the project, students had a keen sense of the skills associated with engineering. Problem-solving was seen to be core to engineering, and an attractive feature that would appeal to large numbers of students. Students also saw creativity as important to engineering – identifying solutions to problems was felt to require creative approaches. Allied to this was a focus on meticulousness and an analytical mindset, which distinguished engineering creativity from artistic creativity. The importance of team-working was also widely recognised. Mathematics and physics were acknowledged to be important, but students were often more equivocal about the need for practical skills (often highlighting instead the important role played by new technology).

" Without creativity you can't come up with something new. **London**

" I imagined them on their own, coming up with ideas, writing all these algorithms. It's not something I would have imagined would be a team career. Now I've researched it I realise you can't do stuff by yourself. **London**

On the other hand, engineering was also conceptualised in a school setting as a career destination for the brightest STEM students, and as the practical application of knowledge learned in physics and mathematics lessons. This can be appealing to STEM students, but is excluding of other students. As a result, from an early age, engineering can be perceived as 'not for me'. As well as discouraging further engagement with engineering, because of early specialisation, students also find career options have been closed off.

" You associate (engineering) with physics and maths, the really hard A levels, 'ooh you have to be really clever to do those'. **Cardiff**

" It's for the sciency people. **Cardiff**

> "" Things have been closed off to us. **Cardiff**

> "" People say engineering is to do with maths so it's going to be like maths lessons, so it's in a box. **Glasgow**

Overcoming disincentives to participation in engineering

When asked about possible disincentives that might make girls or other under-represented groups less likely to follow a career in engineering, students highlighted a range of possible reasons. Lack of awareness of what engineers do and of possible careers was seen as significant, as were social factors such as the influence of family (seen as particularly important by STEM students), peer pressures and the perception of engineering as a boy's thing. Other possible influences included the absence of engineering as a separate subject, a focus on machines and engines, and on facts rather than creativity.

In terms of potential solutions, there was widespread support for a diversity of measures. Non-STEM students particularly highlighted the importance of emphasising how engineers can make the world a better place, while STEM students were especially keen on group-based problem-solving activities. Girls were more supportive of most suggested solutions, particularly more exposure to engineering and engineers (role models, online mentors, visits by engineers to schools, trips to engineering companies), and were strongly in favour of more group-based, problem-based learning and better communication of how engineers can make the world a better place.

In discussion groups, students identified a wide range of reasons why girls and other under-represented groups are discouraged from pursuing engineering study and careers, echoing the results of many other studies. Lack of exposure to engineering at school and a poor understanding of what engineering is were widely felt to be major issues. Engineering-related activities at school tended to focus on core groups who already showed a strong interest in physics and mathematics, again excluding those who could potentially develop an interest in aspects of engineering.

Other suggested contributory factors included a lack of suitable role models, an over-emphasis on physics and mathematics at the expense of problem-solving or creativity, too much reliance on engines and machinery to stimulate interest, and the competitive 'macho' culture in the classroom. In some cases, teachers were felt to be promoting stereotypical attitudes.

Potential solutions frequently focused on raising awareness of engineering and engineering careers, particularly at early stages of secondary education, focusing on problem-solving and group activities. Communicating better the social relevance and value of engineering was thought to be a way to engage wider groups of young people. However, it was also recognised that the under-representation of women in engineering reflected wider social challenges.

> "" There's maybe people who would have an interest if they understood a bit more what it was about. **Glasgow**

> "" Try and show the other facets of engineering, rather than just going into physics and maths, going in at different angles. **Cardiff**

> "" …(if) it's all about cars, that can put some people off, but if you open it up and say you can also create all these different things that you might find more interesting, that might make people more interested and see the opportunities that engineering can give people. **Cardiff**

> "" Being here today, it's like 'wow, engineering's so cool, what cool things they do', whereas before it was 'hmm sounds a bit boring'. **Glasgow**

> "" It brings people who do different subjects into the discussion and they realise they might have an interest in it and it's easier to think about things when they apply to your lives. **Cardiff**

> "" If the school showed it not just as you're going to be a grease monkey underneath a car as an engineer then maybe it would attract more women into the profession. **London**

> "" The problem-solving side is more important. Even if people don't pursue it (engineering), they'll still take something away from it. **London**

Experience of engineering in schools

Students reported low levels of exposure to engineering in schools. In discussion groups, students generally felt that engineering had little presence in schools. Engineering-related activities happened only if particular teachers at a school had an interest in engineering.

Some activities, particularly in early years, were felt to be relevant to engineering but were rarely labelled as such. There were some suggestions that design and technology could be used to introduce engineering concepts, although also concerns that extra physics and mathematics in such lessons could be off-putting. In later years, activities tended to be focused on small numbers of students identified as potential future engineers, and once such groups were established it could be difficult to join them.

❝❞
Once there's a group identified who enjoy doing these things, then that's the group that will continue to do the same projects. **Glasgow**

❝❞
They'll introduce it to certain people, they won't introduce it to everyone. **Glasgow**

Views of Debating Matters: The Future of Engineering and impact on participants

The competition proved highly popular with participants of all groups, including non-STEM students (**Figure 13**). Girls showed slightly higher satisfaction levels than boys. Students, particularly non-STEM and mixed STEM/non-STEM students and girls, felt that participation had led to improvements in their understanding of engineering (**Figure 14**).

Participation led to markedly more positive views of engineering, particularly among non-STEM and mixed STEM/non-STEM students and girls, and also had some impact on the likelihood that students would consider a career in engineering (even though this was not one of the main aims of the project); this was most noticeable in non-STEM and mixed STEM/non-STEM students and girls, but was also seen in STEM students and boys (**Figure 15**).

Notably, mixed STEM/non-STEM students showed the strongest positive responses, particularly in relation to attitudes to engineering and consideration of engineering as a possible career.

Figure 13: How much did you enjoy the Debating Matters Future of Engineering competition?

STEM (n=18)	Non-STEM (n=18)	Mixed STEM/ non-STEM (n=20)	Males (n=31)	Females (n=25)
71%	60%	71%	65%	73%
29%	30%	29%	30%	27%
0%	0%	0%	0%	0%
0%	10%	0%	4%	0%

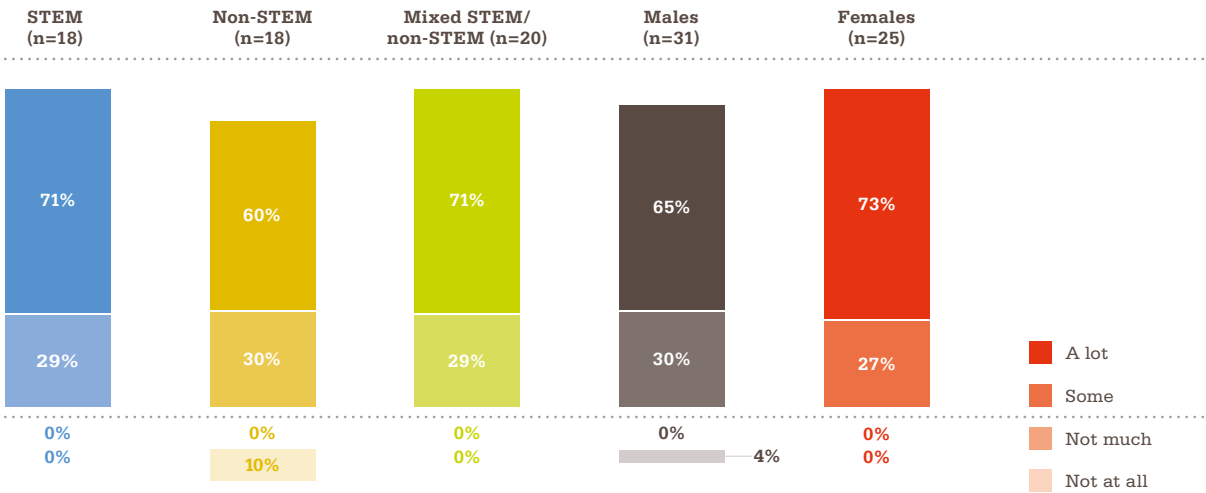- A lot
- Some
- Not much
- Not at all

Figure 14: To what extent did participating in the Debating Matters Future of Engineering competition improve your understanding of what engineering is and what engineers do?
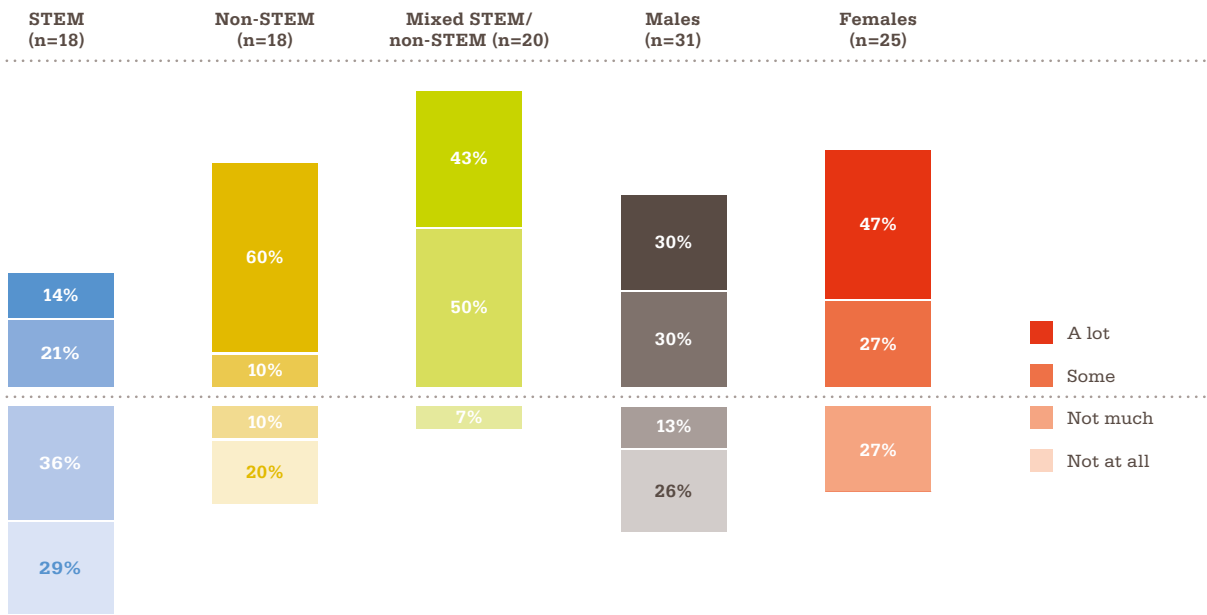

STEM (n=18)	Non-STEM (n=18)	Mixed STEM/ non-STEM (n=20)	Males (n=31)	Females (n=25)	
		43%		47%	A lot
14%	60%		30%		Some
21%		50%	30%	27%	Not much
	10%				Not at all
	10%	7%	13%		
36%	20%			27%	
			26%		
29%					

Figure 15: How has it affected your views about engineering?

STEM (n=18)	Non-STEM (n=18)	Mixed STEM/ non-STEM (n=20)	Males (n=31)	Females (n=25)	
50%	80%	100%	70%	87%	More positive
50%	20%		30%	13%	No change
0%	0%	0%	0%	0%	More negative
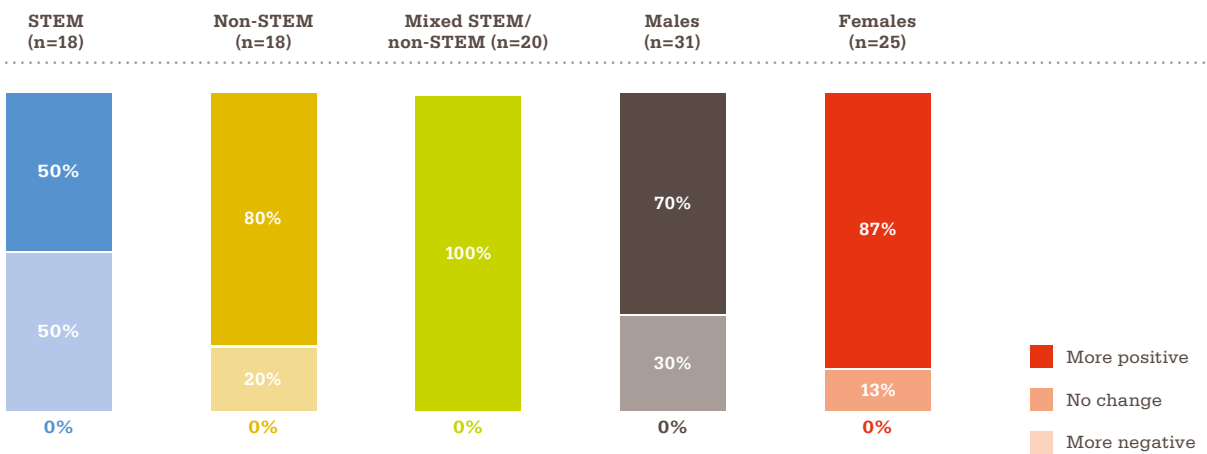
In discussion groups, students expressed enthusiasm for the subject matter. Noticeably, students from non-STEM backgrounds, although initially uninterested or sceptical, often found the topics engaging and felt able to contribute to debates.

" "

…what can you talk about as I really don't know anything about engineering, but as we discussed it and I listened to the debate, I realised there was so much to it, there's so many aspects to it I didn't really think of before. **Cardiff**

" "

The instant our teacher said there's a Techniquest engineering course I thought 'Oh well, I'll be skipping that one', but when we got together to help the speakers, I thought actually I understand what's being said. **Cardiff**

" "

I've been shown that anyone can speak about it and have different views on it, whether it's sciencey or morally. **Cardiff**

In particular, students felt that participation had given them a greater appreciation of the contribution of engineering to modern society, of what engineering entails and what engineers do. Indeed, it was often asked why engineers are not more vocal in communicating their roles and contribution to society.

Insights from the project

The engineering Debating Matters project was experimental and results should be treated with some caution; the students were relatively small in number and unlikely to be representative of the UK school population as a whole. Nevertheless, many of the themes emerging from this strand of the work echoed and reinforced the findings of the school-based research.

The popularity of the project and its apparently significant impact – particularly on students not traditionally targeted in engineering engagement activities – also suggest that reflective engineering-focused activities could be an effective way of enhancing awareness and understanding of engineering.

DISCUSSION

The two strands of work sought to explore the culture of engineering in a selection of secondary schools, through understanding current perceptions of engineering among key school groups, including teachers, senior school leaders, students and parents. Engineering is disadvantaged by not being widely taught as a discrete subject. While the same is true of other professional disciplines such as medicine and law, it could be argued that these disciplines have a stronger social and cultural presence, so students have a clearer general idea of what they entail.

The work found that engineering has minimal presence within the classroom, leading to a generally hazy understanding of engineering and multiple competing perceptions. Encouragingly, however, there were widespread positive attitudes towards engineering and a recognition of its importance to the modern world. There was strong support for a greater focus in schools on the made world in science and on engineering specifically.

The support for greater emphasis on the made world echoed views expressed in the Big Ideas report that was the impetus for this work. Big Ideas also suggested that enhancing awareness of engineering should focus on communicating engineering as a socially beneficial, people-focused, problem-solving activity.

However, despite this 'support in principle', there are few signs that the profile of engineering in schools is increasing. Schools face many competing pressures and there are currently few incentives for them to prioritise engineering. As a result, the profile of engineering in schools often depends on the efforts of individual teachers with vision and an interest or background in the subject. In some cases, schools have made a strategic decision to focus on engineering, but again this appeared to be strongly dependent on pro-engineering individuals who have mobilised the support of senior leaders in their schools. This reliance on individual drivers raises questions about longer-term sustainability.

More generally, therefore, there is a need for schools to move from a bottom-up piecemeal approach and to develop a clear strategic vision for engineering, with an assigned senior staff member providing school-wide leadership and, ideally, a dedicated industry-linked school governor. The work of these leaders should be supported by bodies such as the professional engineering institutions, industry and employer organisations. A respected national engineering champion could act as a representative of these school engineering leads, and provide a focal point for engineering in schools and a channel of communication with central government.

There is also a need for schools' strategies to adopt a people-centred approach to engineering, emphasising its social benefits and personal relevance. It should also be inclusive, focusing on general engineering and technological literacy and a wide cross-section of students, not just those with established interests in the discipline. The aim would be to broaden the appeal of engineering, challenge negative perceptions, and encourage greater participation by girls.

Although there was widespread support from parents for engineering to be taught as a separate subject, schools engineering qualifications have not been widely taken up. On the other hand, engineering offers a context in which concepts from science and mathematics can be explored, reinforced and made more tangible, and has obvious relevance to design and technology. It may therefore be more productive to consider how engineering can be integrated into and made more explicit within existing curricula – at all stages of school education and building on activities that are already taking place but are rarely 'badged' as engineering. One solution under discussion is for school examination bodies to make opportunities for engineering activity explicit in science syllabuses. This would include practical applications of science, employing authentic engineering concepts and setting out project challenges.

Design and technology offers another potential opportunity to enhance the presence of engineering in the classroom. Engineering could be more explicitly referenced in D&T teaching, with concepts such as 'design for good' to run alongside 'good design' and stronger links emphasised to engineering roles and careers. The renaming of 'design and technology' as 'design, engineering and technology' has also been suggested, again raising the visibility of engineering. Design and technology illustrate how mathematics and science can be applied in real-world situations, and the newly introduced design and technology includes expanded mathematics content. The subject is also a natural home for problem-based learned, for teaching of engineering thinking skills, and for stressing the social context of technology and engineering. On the other hand, design and technology still faces a significant struggle to establish itself in UK schools as a valuable, rigorous and aspirational subject. Perhaps more explicit incorporation of engineering could support efforts to bolster the subject's educational credibility and perceptions of its societal value.

Complementing curricular revisions, there is also the potential to promote engineering by developing engineering thinking skills. Increased use of problem-based approaches, as used in engineering habits of mind projects, may be a fruitful direction to pursue. It may also be helpful to consider ways in which students' development of these skills and competences could be formally assessed and recognised.

In the absence of a formal place within compulsory education, the engineering community currently relies heavily on curriculum enrichment and enhancement activities to reach school students. However, recent research has challenged the impact this has had on the numbers of students taking STEM A-levels or in widening participation[7], raising questions about its effectiveness as an approach for encouraging students to consider technical and engineering career paths. Potentially, enrichment and enhancement activities could have greater impact if they were aligned more specifically with a revised and engineering-oriented curriculum and skills development programme. In addition, new learning activities could be piloted in the enrichment and enhancement context and, if successful, then introduced into mainstream lessons.

Furthermore, there are opportunities to integrate imaginative non-traditional forms of student engagement, such as debating or other deliberative exercises, into enrichment and enhancement programmes. These kinds of activity encourage research and reflection and emphasise social context, thereby engaging wider groups of students and emphasising engineering's personal and societal connections.

Although individual schools can make a difference by developing engineering strategies as described above, this should be seen as part of a wider suite of changes in the education system. For example, there are still strong arguments in favour of a broader-based curriculum, with more students continuing to study science and mathematics beyond age 16. The value of apprenticeship routes into technical careers needs to be more widely stressed and presented as an alternative of equivalent status to the university route. In addition, there is still a need to ensure that workplace cultures do not discourage participation of women and other under-represented groups.

Indeed, a recurrent theme in this programme of work has been the idea that attitudes to engineering are deeply embedded in society, particularly around gender stereotyping and the nature of engineering roles. While this is undoubtedly a challenge, schools offer a unique environment in which misperceptions can be addressed and aspirations kindled. Currently, the opportunities offered by engineering are being disproportionately exploited by those with a family background of engineering (or high levels of 'science capital'[8]) and by male students. Schools could be the vehicle through which these iniquities are addressed.

"We Think It's Important But Don't Quite Know What It Is" The Culture of Engineering in Schools
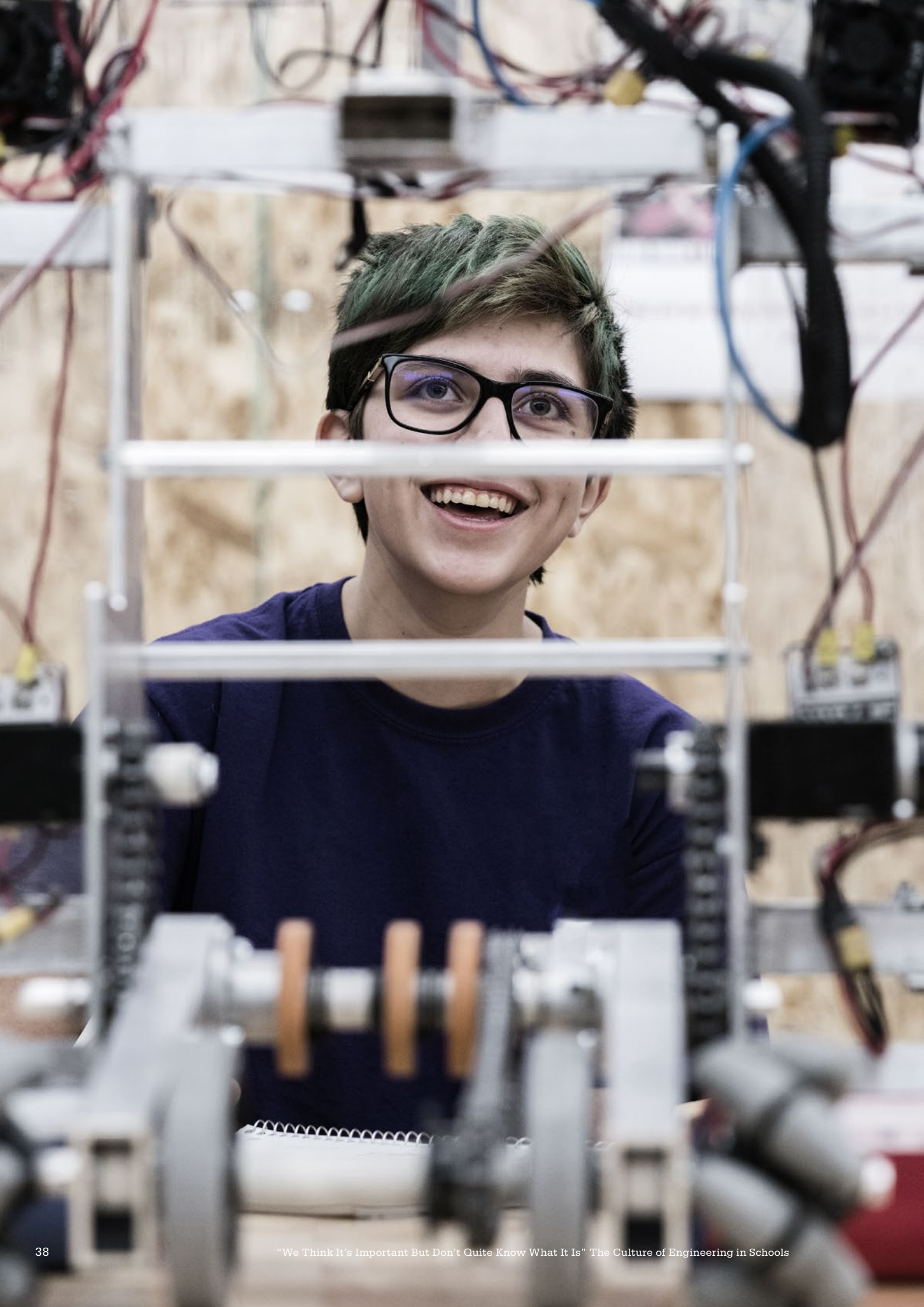
RECOMMENDATIONS

1. As part of its industrial strategy, Government should situate engineering at the heart of schools education by:

   - Setting up a working group of leading educationalists and other stakeholders to review and report on innovative ways to integrate engineering into young people's education

   - Appointing a nationally respected Schools Engineering Champion to provide a channel of communication between schools, Government and industry, and to advocate the wider cultural value of greater technological literacy alongside the economic rationale for investing in skills to prepare for the Fourth Industrial Revolution

2. National Education Departments should begin this process by ensuring that engineering is integral to classroom learning by:

   - Advocating curricula that better reflect the importance of the made world to modern society, and make explicit reference to the engineering applications of science, mathematics, and design and technology

   - Promoting approaches to teaching that emphasise and value engineering 'thinking skills' and problem-based learning

3. Individual schools should adopt an engineering vision and strategy, with support from local employers and national governors' associations, which would include:

   - Appointing a member of the school senior leadership team as an Engineering & Industry Leader to establish and communicate a vision for the school and to drive change

   - Appointing a dedicated Industry School Governor to work alongside and advise the Engineering & Industry Leader, and to embed employer relationships in school governance

   - Implementing a robust careers strategy such as the benchmarks set out in The Gatsby Foundation's Good Career Guidance report, with special emphasis on embedding careers awareness in the curriculum

4. The engineering community should present a unified narrative around engineering that will be attractive and relevant to a wider range of students by:

   - Stressing the creative problem-solving nature of engineering, its social benefits and relevance to individuals

   - Providing opportunities for students to take part in activities that explore the political, societal and ethical aspects of technology.

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Further information, including all research instruments and Debating Matters stimulus materials, are available in the Supplementary Materials Report PDF.

http://www.imeche.org/eis-supplementary

APPENDIX: SCHOOLS SURVEYED

School	Region	School type	Gender	Age Range	Sixth Form	Number of Pupils	Boys	Girls	% FSM	Progress 8 Score
A	London	Community school	Mixed	11–18	Yes	1125	585	540	16.2	0.14
B	London	Academy sponsor-led	Mixed	11–19	Yes	1202	610	595	40.3	0.33
C	London	Academy convertor	Mixed	11–18	Yes	920	550	370	14.1	0.05
D	Greater Manchester	Other independent school	Girls	3–18	Yes	640	0	640	n/a	n/a
E	Greater Manchester	Voluntary aided school	Mixed	11–19	Yes	1035	610	525	12.1	-0.07
F	Sheffield City Region	Community school	Mixed	11–18	Yes	1171	560	610	10.1	-0.36
G	Sheffield City Region	Academy sponsor-led	Mixed	11–16	No	986	495	495	35.1	0.02
H	Sheffield City Region	Community school	Mixed	11–18	Yes	1549	755	795	7.3	-0.02
I	Sheffield City Region	Academy sponsor-led	Mixed	11–19	Yes	1065	550	515	16.3	0.09
J	Sheffield City Region	Academy sponsor-led	Mixed	11–16	No	856	425	430	19.6	0.24
K	Sheffield City Region	Academy convertor	Mixed	11–18	Yes	1563	755	810	11.6	0.01