

BIG IDEAS: THE FUTURE OF ENGINEERING IN SCHOOLS.

Institution of
**MECHANICAL
ENGINEERS**

With support from



Improving the world through engineering



**LEADING
THE
CHANGE**

INSPIRING THE
NEXT GENERATION
THROUGH EDUCATION
AND POLICY

“”

**WE NEED TO PROMOTE
ENGINEERING AS A
PEOPLE-FOCUSED, PROBLEM-
SOLVING, SOCIALLY
BENEFICIAL DISCIPLINE.**

PETER FINEGOLD,
INSTITUTION OF
MECHANICAL ENGINEERS

Leading the Change

The UK has had a shortage of engineers for a very long time, and the issue is growing. Launched in 2015, Leading the Change is campaigning to broaden our approach on how we promote and teach engineering to all young people, not just those already passionate about science, technology, engineering and mathematics (STEM) subjects.

It is our belief that by working together to get children immersed in STEM subjects from an early age, we can lay the foundations for a lifelong passion for engineering, particularly with those who otherwise would not have considered pursuing this career path.

The campaign also details how the Institution is already working to enthuse young people in a number of different ways, from national and regional STEM events, scholarships and awards, industrial placements for teachers, to one-on-one support.

To find out more about our campaign, visit imeche.org/leading-the-change



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AND POLICY

This report has been produced in the context of the Institution's strategic themes of Energy, Environment, Education, Manufacturing, Healthcare and Transport, and its vision of 'Improving the world through engineering'.

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FOREWORD

**PROFESSOR JOHN PERKINS
CBE FRENG**

The Department of Business, Innovation & Skills report reviewing Engineering Skills^[1], highlighted the advantages that would result from a substantial increase in the supply of engineers in the UK. The report, which I authored, called for concerted action by the profession, industry, educators and the Government in an effort to increase the number of people choosing to pursue engineering as a profession.

Of course, this is by no means a new goal, but there is a growing awareness that more radical approaches will be needed if we are to achieve the step change in supply that all involved agree would be desirable. The aim of the Big Ideas workshop and subsequent research, organised by the Institution of Mechanical Engineers with support from the Royal Academy of Engineering and reported in this document, was to encourage stakeholders to think creatively about the nature of the challenge and to propose solutions. The result is a compelling analysis of our current situation, and a set of recommendations which, if acted upon collectively, would result in a more effective future.

For me, one of the key messages of this report is the need to orchestrate a much richer dialogue about the value of engineering to society. This is not simply about better marketing, but a change in the narrative that will attract greater interest among a wider group of prospective engineers.

Aiming to enhance technology and engineering literacy among all school students will help to create a society in which the contributions and importance of engineering are more widely recognised, engineering-like thinking and problem-solving skills more widely distributed, and the pool of young people able to pursue engineering or related technical professions is much larger.

I hope that you enjoy reading this report as much as I enjoyed participating in the process of its conception.

**STEPHEN TETLOW MBE
CEO INSTITUTION OF
MECHANICAL ENGINEERS**

The Institution of Mechanical Engineers has been active in responding to the growing engineering skills gap for many years. With the economy recovering, this persistent gap is really starting to bite. Demand for engineering skills is growing, as big projects such as High Speed 2 and new nuclear initiatives come closer to becoming a reality, alongside exciting innovation in less traditional mechanical engineering such as the expanding medical sector. Our ambition is to work with our partners in the engineering sector to find sustained solutions.

How can we develop the key infrastructure UK needs if we don't have the engineers to do the work? How can our economy thrive if key industries such as aerospace, automotive or energy fail to recruit the young women and men that will allow them to grow?

Professional institutions like the Institution of Mechanical Engineers have been involved in countless schemes and initiatives over the years to encourage young people into engineering. Projects like the Bloodhound SuperSonic Car and ambassadorial initiatives connect thousands of schoolchildren with employers every year. But are these efforts enough? We need significantly higher numbers of engineers than we are currently producing just to meet demand and estimates suggest the skills shortage could cost the UK up to £27bn a year. This means going beyond outreach and informal learning, and challenging what happens in the school system in all UK nations.

I was privileged to participate alongside leading educationalists, academics and industry representatives in the expert workshop that formed the core of this research report, and wish to commend to you its findings, and actions.

**PROFESSOR HELEN ATKINSON
CBE FRENG
CHAIR OF THE ROYAL
ACADEMY OF ENGINEERING
EDUCATION COMMITTEE**

Engineering is an activity that impacts all our lives in so many ways. Whether it is providing for our basic needs such as energy, shelter, food and the infrastructure which allows us to travel from place to place; improving our health and wellbeing or simply to entertain us through TV, computing and the internet; engineers make it happen.

For many years we in the engineering community have been concerned that young people and the public at large do not understand engineering's contribution to society. Yet results published in this report show that perhaps this concern is misplaced and public perceptions of the work of engineers is more positive than we might believe. Despite this, there is clearly a disconnect between public appreciation of engineering and young people's desire to pursue it as a career. This matters because of the impending engineering skills shortage. The question therefore must be why, despite all our best efforts over many years, are we still struggling to ignite young people's interest in this exciting, creative profession?

For me, this report that the Institution of Mechanical Engineers has produced with support from the Royal Academy of Engineering is all about that 'narrative' of the importance of engineering to humanity and our society, and also the incredibly exciting career opportunities it can offer to future generations.

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At the heart of our vision lies the need to enhance engineering and technological literacy for all.



EXECUTIVE SUMMARY

The UK is not producing enough engineers or engineering technicians, and the engineers it is producing are typically from a strikingly narrow stratum of society. Not only do we need more engineers, we require a greater diversity of people to become engineers. We also need a population confident to engage with social and political implications of living in a world dominated by technology. These facts have been well established, yet the problem in the UK remains stubbornly intractable.

Albert Einstein once said that the definition of insanity was trying the same thing repeatedly and expecting to get a different answer. Despite many well-intentioned efforts over the years, the lack of meaningful progress in narrowing the engineering skills gap has been striking. It is surely time to try something different. Rather than further one-off initiatives, it must be time to consider more structural and integrated reform.

This was the premise underlying the Big Ideas project, conceived by the Institution of Mechanical Engineers and developed with support from the Royal Academy of Engineering. Through a combination of provocative 'think pieces' from leading educators, a study of stakeholder attitudes and an international interdisciplinary workshop, the project identified a series of strategic options that, collectively, represent a compelling vision for the future of engineering education in UK schools. At the heart of this vision lies the need to enhance engineering and technological literacy for all – an essential goal as we enter a world increasingly dominated by technology and facing profound environmental and social challenges that engineering and technology must address. We need to make structural changes that will enable us to promote engineering as people focused, problem solving and socially beneficial. We also need to emphasise how the objects that define our world are developed and manufactured. Through this, both the economic and social value of engineering can be made manifest in ways that they are currently not.

The Big Ideas project offers a vision of how the UK engineering and education communities can work together to achieve a step-change. Change is called for on all sides: the engineering community needs to reflect carefully on the narrative it is presenting to young people, particularly those whose background and interests may be quite different from those traditionally associated with engineering, who may have the potential to be successful and creative engineering professionals. The education system needs to lead change and the education community needs to be supported to be able to adapt, to embed engineering thinking and practice as well as engineering careers information. Education policy-makers have the wherewithal to influence the environment in which these profound changes can be achieved, and they need to generate the momentum to ensure that they happen.

These ideas are not a short-term fix, but represent the foundation for a concerted long term effort to shift perceptions and behaviours. The aim is to ensure that engineering has the presence it deserves in the UK school education system. This will require many stakeholders to be flexible, open to fresh thinking and willing to innovate. Progress across all areas will be essential if tangible benefits are to be delivered.

It should not be assumed that the report goals made here hold the complete answer to engineering skills, but unless we challenge these structural issues, we run the risk, simultaneously of reducing our economic competitiveness and letting down the next generation. Though the future is uncertain, economists, employers and educationalists are all in agreement that having a greater highly skilled, technologically literate workforce is the best guarantee of future prosperity.

THE BIG IDEAS GOALS AND ACTIONS

The Big Ideas approach is a response to previous attempts to address skills' issues through making fundamental changes to the communication and education of engineering. The two institutions who have developed this work understand that the big changes required may take time since they involve communicating and persuading a number of key players. This work has shown that there is not one simple solution that will rapidly increase the flow of engineering talent coming through the UK education system. Instead it will take a series of measures over an extended campaign before change will occur.

Therefore, as well as presenting the ten report goals, we are also outlining the first seven actions which need to be addressed if these end-result goals are to be achieved. Further actions will clearly need to be taken as the Big Ideas approach gathers momentum.

GOALS

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- 1. Promote engineering as a people-focused, problem-solving, socially beneficial discipline.**

 - 2. Work to enhance the presence of engineering and the 'made world' at all stages from primary level upwards.**

 - 3. Ensure that apprenticeships and other technical pathways not only deliver high-quality technicians but also enable individuals to progress to the highest levels of engineering.**

 - 4. Broaden routes into engineering degree courses by promoting more flexible entry requirements.**

 - 5. Maintain a broad curriculum for all young people up to the age of 18.**

 - 6. Shift the emphasis in STEM teaching towards problem-based, contextualised learning.**

 - 7. Nurture engineering ways of thinking in all young people.**

 - 8. Create more spaces and opportunities for young people to design and make things particularly by working collaboratively in interdisciplinary groups.**

 - 9. Use Design and Technology as a platform for integrating STEM and creative design and for raising the profile of engineering in schools.**

 - 10. Change the structure of schools education to embed engineering explicitly at all levels.**

ACTIONS

1. The engineering community should commit to a common shared narrative that highlights the human and social dimensions of engineering alongside its technical achievements.

For industry, the Royal Academy of Engineering, Engineering UK and the Engineering the Future alliance of professional engineering institutions

2. The engineering community should support a single campaign to promote engineering careers, such as the 'Engineering Talent Project' which is being developed by the Royal Academy of Engineering. The programme should adopt this agreed narrative, improving the visibility of modern engineering and hence increasing its attractiveness.

For industry, the Royal Academy of Engineering and Engineering the Future alliance of professional engineering institutions

3. The profession should issue new guidance on how to communicate about engineering, to be adopted by employers, volunteers, communications professionals and educationalists, that draws on the 'Five Tribes' research.

For the Royal Academy of Engineering, Engineering UK, STEMNET and the Future alliance of professional engineering institutions

4. The Royal Academy of Engineering and the professional engineering institutions must push for a broader curriculum to age 18 implemented within the next ten years, as the main way to improve gender balance and to increase interest in technical training.

For the Royal Academy of Engineering and the professional engineering institutions

5. A new, time-limited, working group comprising each of the relevant subject associations needs to recommend how an improved focus on the 'made world' in both primary and secondary schools can practically be achieved.

For the Association for Science Education, the Design and Technology Association, the Advisory Committee on Mathematics Education and the Association of Teachers of Mathematics

6. Government should explicitly recognise the influence of teachers over the career choices of their students and promote this feature of the teacher's role. Supported by employers, it needs to deploy more resource to support teacher CPD initiatives aimed at increasing their understanding of modern engineering.

For the Departments for Education (England and Northern Ireland), Department for Education & Skills (Wales); Scottish Parliament Education Department; Department for Business, Innovation and Skills

7. Government should guarantee that high-quality technical training routes will be included in performance measures for colleges and schools.

For the Departments for Education (England and Northern Ireland), Department for Education & Skills (Wales); Scottish Parliament Education Department; Department for Business, Innovation and Skills

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The Big Ideas project sets out to challenge the view that we can bring about the necessary changes through gentle persuasion and marketing alone.



INTRODUCTION

The Warwick Institute for Employment Research calculates that for a sound UK economy, an additional 1.82 million people will be needed in engineering jobs at all levels between 2012 and 2022.^[2] Analysis by EngineeringUK suggests that over the same period there will be a shortfall of some 550,000 engineers and skilled technicians to meet demand. The Economist magazine^[3] decries this mismatch of supply and demand across the broader range of Science, Technology, Engineering and Math (STEM) subjects as "...disappointing... particularly as the lack of engineers and technicians in the country that gave birth to the industrial revolution has been well-known for more than a century."

Our successful long-term future requires that we address the major global challenges that, at their most elemental, ask how we can continue to improve our wealth, health, comfort and security, with the finite natural resources at our disposal. This will rely on sufficient numbers of young people choosing to opt for study and training, leading to jobs in this sector.

Equally there are challenges for our education system too. According to Sir David Bell, Vice-Chancellor of the University of Reading, former Permanent Secretary at the English Department for Education and Chief Inspector of Schools, we face "...a new industrial revolution – the digital revolution – with all the social and economic upheaval it brings."

His analysis^[4] focused on the dissonance between this looming revolution and an education system that is cautious of dramatic change. "The economy and society is changing out of all recognition – and yet we still have an out-of-date system, when the UK can least afford it. A broader and deeper curriculum and exam system must be our ambition."

The engineering community works hard to promote its sector to young people to avert the impending skills' gap, but shortages remain, with indications that things will get worse. Engineering is pervasive, it drives technological progress and its skills are in demand throughout the economy. But much of the activity aimed at increasing numbers resides outside of our classrooms and laboratories, is voluntary in participation and serendipitous in outcome.

The Big Ideas project sets out to challenge the view that we can bring about the necessary changes through gentle persuasion and marketing alone. The problem is too often characterised as one of scale or organisation, whereas it increasingly seems likely that it is one of a more firmly embedded cultural and attitudinal narrative – especially the explicit and tacit signalling that young people experience throughout their formal education.

The disturbingly low number of young women choosing to pursue engineering as a career is simply unacceptable, but also tells us something of the failure of a system that relies too greatly on the goodwill of enthusiasts to promote the sector. This valued approach, clearly, is not sufficient in isolation to generate the desired level of interest in this vital part of our economic and cultural experience. The 2015 Institution of Mechanical Engineers' report 'Five Tribes'^[5] showed how only 29 percent of UK teenagers are 'STEM Devotees', from which the nation will have to source all of its research scientists, clinicians, computer coders etc – and its engineers and technologists. There is a sense that all of the activity taking place in the STEM education domain, has been from one (STEM) sector attempting to poach devotees from another, while doing little to reach out to the remaining 70 percent of the population.

This is not a new or recent problem, and though we are presenting radical new ideas, in reality the problem and some of the proposed solutions have been presented before.

In 1980, Sir Monty Finniston submitted an important report to Government from the Committee of Inquiry that he chaired into the engineering profession^[6]. The references relevant to education within the report were extensive. Finniston observed how physics and mathematics at A-level or Scottish Higher Grade were standard entry requirements at universities, and having to make those subject decision choices at 13/14 was "...too early to expect most young people to be committed to any particular career".

He commented how "the problem of specialist subject choices arises from the particularly restrictive nature of English and Welsh VIth form study...".

He also made reference to a report from the then British Association for the Advancement of Science, which advocated expanding the pool of engineers through "...dropping of the strict A-level 'mathematics plus physics' arrangement in favour of more flexible arrangements".

The report's observations and recommendations echo the same challenges and proposed solutions that we observe today:

- urgent action to increase the supply of engineering technicians
- gearing examination courses to develop pupils' awareness of the modern economy and the role of technology in its development
- improved careers advice and secondment of teachers into industry

It is this familiar story from two generations ago that suggests how the problems of engineering education are cultural; deeply embedded in an education system that is simply not set up to address this sector's needs.

SABRINA'S TALE

In 2025, Sabrina starts at primary school, a carefully crafted developmental learning experience designed to cultivate the types of thinking skills that engineers employ. School inspectors would consider how well these thinking processes were catered for during their inspection regime. Following professional training, her teachers would have acquired the knowledge and confidence to weave engineering and technology seamlessly into their classroom repertoire – so that technological literacy might complement language literacy and numeracy, together with the other subjects essential for a rounded education. They would be able to offer insights into the types of jobs engineers do and career opportunities that engineering and manufacturing companies provide.

Through a reconfigured properly resourced Design and Technology curriculum, Sabrina would comprehend that engineering is a process rooted in creative thinking. This feature would continue as Sabrina moved to secondary school, where she would be encouraged to see the value in applying her creativity to real problems – to think both expansively and practically. Sabrina would be encouraged to use her mathematics and scientific knowledge in real design experiences in such a way that the connection between them was organic and obvious. Her science education would expose her to the 'natural' world, but would use content that better reflected the 'made' world too.

Along the way she would have a chance to meet and quiz working engineers (and others in related areas) during their regular school visits as well as through virtual contact. They would be able to describe their careers and talk about their day-to-day jobs, referencing the types of skills, knowledge and understanding they typically employ and drawing on what would then be more explicitly evident curriculum engineering content as touchstones. Through their involvement in shared professional development with teachers, their own narrative would be influenced by greater knowledge of their audience; what students know and understand, the diversity of values and attitudes in the class. Through training, these ambassadors would ensure that a comprehensive set of positive professional careers messages would be communicated.

These same engineers would guide Sabrina through one of a number of design challenges, that would increasingly be accepted as a powerful mechanism for developing the technical and soft skills that educationalists and industry are crying out for – problem-solving, communication and team-building. The teacher would feel confident in being able to assess learning in this context.

Pupils would start to see how form in nature and the manufactured world leads to better quality products, and teachers will frequently talk about elegance, not only in literacy and in art, but also in maths and technology.

These same broad educational principles will apply as Sabrina progresses through her secondary education, and while the content of her learning increases and becomes more complex and extensive, national and school policy would help head teachers and school governors to expand the 'skills development' component alongside knowledge acquisition that is often cited as the main focus.

Sabrina and her parents know that the big decisions about study and career choice will not take place until she has reached 16 or 17, unlike her much older brother who had to decide between science and the arts while he was still too unaware of what making these choices would entail, and too immature to understand the links between how the choices he was forced to make might affect his future. Sabrina would study a broad base of six subjects to the age of 18, including science, humanities, maths and Design and Technology, drawing on the rigour of A-levels and the breadth of Scottish Higher Grade or other countries' more expansive baccalaureate examinations. She would have the opportunity to study technical and professional subjects alongside traditional academic courses. She might see this practical experience as a direct path towards a skilled technical qualification through an apprenticeship, or simply to enhance her choice of academic route to university.

Students and parents would no longer have the same fear about making choices that did not include mandatory subjects for an engineering degree course, since universities would as a matter of course accept academically capable students who possessed a whole range of non-STEM qualifications onto their undergraduate degree courses. This shift in admissions policy would reflect increased demand for engineers, as well as greater diversity in the engineering workforce – in terms of gender, ethnicity and social background, along with skill sets.

If Sabrina does choose to study at university, she may decide to embark on a 'liberal engineering' degree. This new concept in higher education focuses on producing employment ready, culturally intelligent innovators who are both socially and ethically aware of the role engineering plays.

In simple terms, Sabrina would be significantly better equipped when the time came for her to make those life defining career choices.

To stimulate discussion among engineering education experts and other stakeholders, a range of leading thinkers were invited to put forward bold personal ideas to effect radical change in UK engineering education. The resulting personal 'think pieces' generated by each are available on the Institution of Mechanical Engineers website and are summarised below.

MAINSTREAMING ENGINEERING



Ioannis Miaoulis
President and Director
of the Museum of
Science, Boston

Over the past two decades, Dr Miaoulis has led initiatives to introduce engineering standards into all stages of the US educational system. In 2000, Massachusetts became the first state to adopt technology/engineering standards and to make them part of the state's assessment. Since then, other states in the USA have gradually followed suit.

One aim of 'mainstreaming engineering' has been to enhance technological literacy in the general public. It has encouraged schools to consider the balance between teaching of the natural world and of the 'made' world – mostly, the former tends to predominate, leaving people with little understanding of how the objects they use every day have been created and how they work.

An important focus has been on the use of engineering to contextualise science and mathematics, and stress its relevance to young people's everyday lives. Learning support materials have been designed to be as inclusive as possible to appeal to all groups in society. Emphasis has also been placed on teacher development to deliver the new specifications.

A complementary objective is to encourage more young people to consider further study and careers in engineering. The structure of US college education allows greater lateral movement between courses. While a professor at Tufts University, Dr Miaoulis had great success in attracting students onto engineering courses, by situating engineering teaching within more appealing themes (such as considering fishing, or life in moving water, as a way into fluid dynamics).

In wider education, the new approach has proven successful at encouraging young people from under-represented groups (such as girls and minority ethnic groups) and there is evidence of changing attitudes (fathers are much more supportive of their daughters pursuing a career in engineering). Dr Miaoulis is involved in a range of international initiatives exploring the embedding of engineering within national education systems.

INCULCATING ENGINEERING HABITS OF MIND



Bill Lucas
University of
Winchester

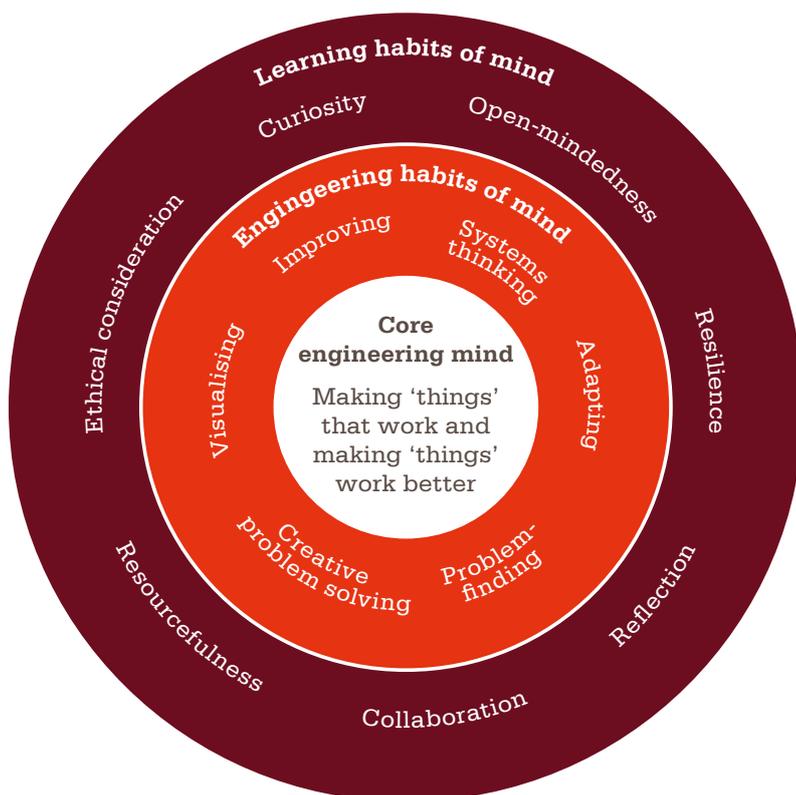
Professor Lucas and colleagues have promoted the idea that both the image of engineering and the supply of specialist engineers could be enhanced by a greater focus in schools, notably through a radical shake up of the pedagogy used in schools to promote the distinctive ways of thinking associated with engineering.

In a project sponsored by the Royal Academy of Engineering, he and his colleagues worked with the engineering community to identify a range of 'engineering habits of mind' – the thinking skills that engineers use to conceptualise and solve problems^[7]. The project also put forward a set of complementary generic 'learning habits of mind' These 'habits of mind' are shown in **Figure 1**.

The team went on to describe existing educational resources and organisations which encourage the development of key engineering habits. Typically, the teaching methods needed place emphasis on problem-based learning and on project-based active-learning approaches. Just as engineers use an engineering design process in their work, so educators need to adopt methods more likely to engage young men and women in engineering.

Follow-up work in a range of primary and secondary schools across the UK is now testing the hypothesis that use of these resources will have a positive impact on the development of engineering thinking skills, while also maintaining (and possibly improving) academic standards.

Figure 1: The 'Engineering Habits of Mind' model illustrating the characteristics and attributes of engineers



STOP THIS CRAZY EARLY SPECIALISATION



Louise Archer
King's College
London

The UK has one of the most gender-biased engineering workforces in Europe – women make up just 6 percent of the UK engineering community. The country has also had long-standing difficulties persuading girls to choose physics and mathematics at A-level and Higher/Advanced Higher Grades, currently the key routes to higher education engineering qualifications.

Professor Archer and colleagues have been involved in projects examining the career aspirations of young people, which have revealed no lack of interest in engineering as a career. However, girls are currently not attracted to courses such as physics that are the principal route of entry into such careers. Notably, those who do study A-level physics typically recognise (and relish the fact) that they are 'different' from their peers.

Professor Archer argues that the UK education system needs radical change in order to 'normalise' study of physics and mathematics. In particular, there is a need to avoid the early specialisation that tends to route young people down arts and humanities or science-based pathways early in life, which can rule out engineering careers before students have had a chance to consider them as options.

Baccalaureate-type approaches would also help to produce more rounded engineers, and develop engineering and technological literacy in those not pursuing engineering careers. Crucially, this more balanced approach might (alongside other measures) encourage more young girls to consider engineering – in part because it would potentially expose more youngsters to the subject, and partly because it would delay the decision-making process during which time the students will have matured and developed more considered insights.

MAKING SPACE FOR MAKING THINGS



Mark Miodownik FREng
University College
London

Professor Miodownik argues that the value of '*physically making things*' has been underappreciated. Our education system has long promoted academic learning as a higher goal than practical-based study. This underplays not only the intrinsic value of 'making' but also the potential of practical activities to provide a mechanism by which abstract learning can be applied in practice.

He also suggests that this neglect of 'making' has profound long-term consequences, detaching individuals from any sense of how the objects they use in everyday life were designed and made. It has encouraged the citizens of developed countries to see themselves as 'consumers' rather than 'producers', with unfortunate consequences, particularly promoting unsustainable lifestyles.

Professor Miodownik proposes that schools should develop 'making spaces', ideally at the heart of school facilities. Such spaces would provide an arena in which all students, of all academic levels, would have the opportunity to make things. They would provide spaces in which the theory taught in academic classes could be applied practically. They would also provide opportunities for cross-disciplinary project-based collaborations, for example between science and design students.

At UCL, Professor Miodownik has established a facility, the UCL Institute of Making, that supports such interdisciplinary collaboration. It is well used by UCL staff at all levels and from multiple disciplines.

SPEAKING UP FOR ENGINEERING



Peter Goodhew FEng
University of Liverpool

Professor Goodhew suggests that engineering has a crisis of identity, and has not been able to convey a sense of what engineering is – and why it is important – to the general public and young people. An ‘engineer’ is seen by many as the person who fixes the photocopier.

This issue becomes important when society is in need of more engineers. Furthermore, engineering courses in higher education suffer the highest rates of student attrition, suggesting that many students may not appreciate what engineering study actually involves or perhaps that engineering is not always taught at university as well as it might be.

The engineering community therefore needs to consider whether it is communicating effectively the value of engineering and the nature of engineering. Further, it needs to examine whether its work is sufficiently informed by social priorities, and whether engineering solutions adequately reflect individual needs and desires.

Schools are ideal places where greater awareness of engineering should be developed, and activities introduced to illustrate engineering principles and ways of thinking, from primary level upwards. By drawing on innovative learning methods teachers could help make engineering education a more engaging and rewarding experience for young people. This would include a greater focus on understanding rather than simply an accumulation of knowledge for assessment. Likewise a recognition that an extensive knowledge of mathematics is not synonymous with a career in engineering, and hence mathematics A-level or its equivalent should not be seen as essential to undergraduate engineering study.

TIME FOR SOME CREATIVE THINKING



Clive Grinyer
Barclays

Creativity is frequently associated with artistic self-expression, but creative thinking is also integral to engineering. It is fundamental both to the conceptualisation of a problem and to the development of possible solutions.

Furthermore, the design of engineered objects creates the interface between users and devices, an interaction that is fundamental to adoption and hence to the ultimate success of an engineering product. Engineering can solve technical problems but those solutions may still fail in the market if for some reason they are then not adopted by users.

Engineers therefore need to be able to extend their creativity beyond the technical to the ergonomic and aesthetic. However, it is challenging for engineers to master both the technical design components of their discipline and the user experience – even more so the look and feel. An alternative solution may be to promote collaborations with specialists who have complementary design skills as part of multidisciplinary teams.

Design is a popular area, attracting highly creative people. It would not take much for those interested in design to make the transition to engineering or to make productive contributions as part of multidisciplinary teams.

Emphasising creativity and design as an explicit component of the discipline would help to place people at the heart of engineering. Ensuring that engineering is seen as a possible destination for creatively minded individuals could significantly broaden its appeal, and also ensure that its products make a greater emotional connection with users and so be consequently more successful.

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The Big Ideas project focuses on the overarching aim of improving engineering and technological literacy of the population as a whole.



THE STAKEHOLDER SURVEY

The Institution of Mechanical Engineers was keen to gather the views of leading thinkers in engineering education, and to explore how these ideas resonated with practitioners, key audiences and other stakeholders. Working with researchers at ICM Unlimited, we drew out the main themes emerging from the pieces produced by our six 'big thinkers', and used these to shape research carried out among the following stakeholder groups:

- Teachers (n=125)
- Parents (n=1,007)
- Young people aged 17–18 (n=100)
- Young people aged 12–16 (n=1,007)
- Employers (n=178)
- Engineers (n=76)

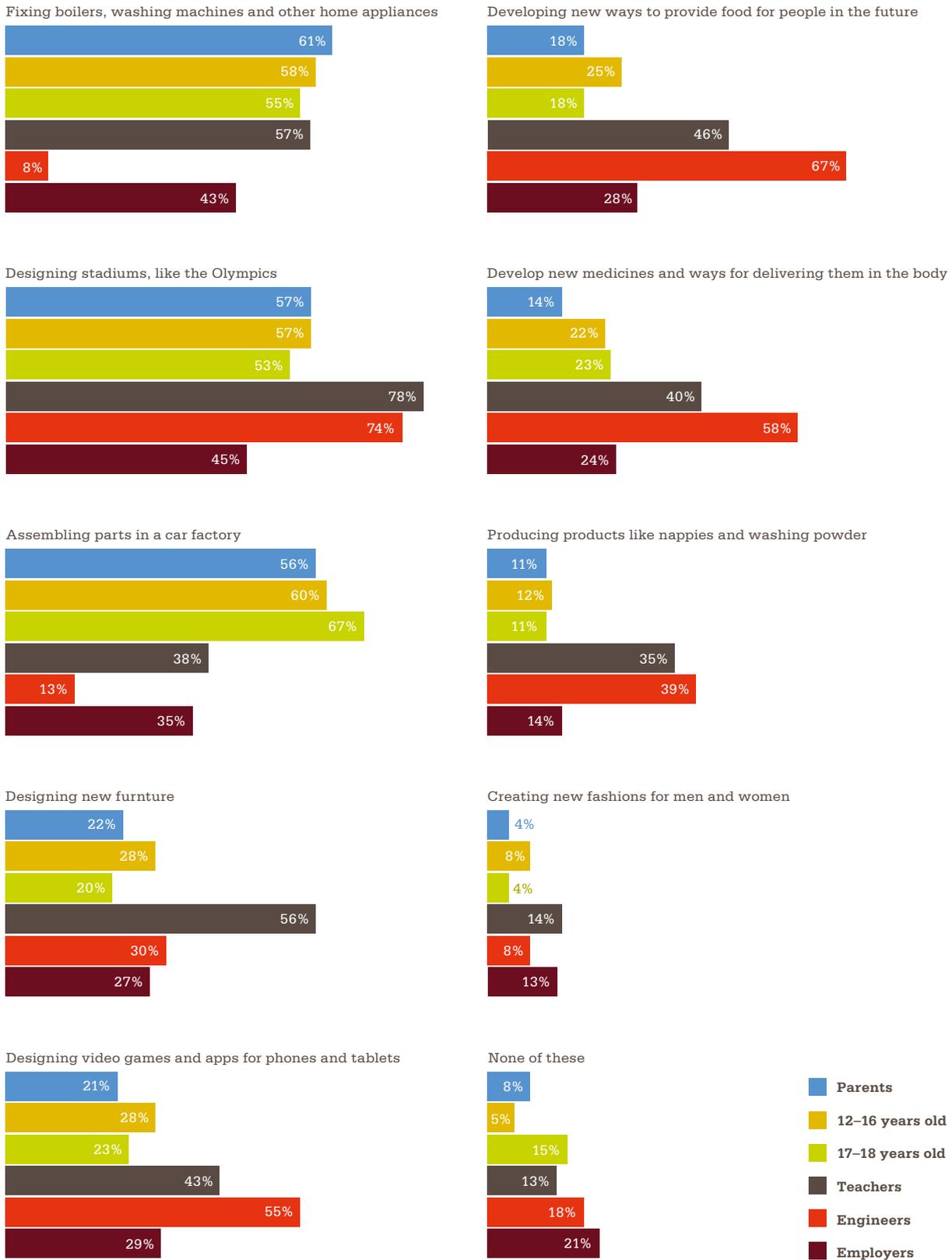
All respondents (n=2,493)

Certain questions were posed to all groups; others were tailored to specific constituencies.

UNDERSTANDING OF THE ROLE OF ENGINEERS

The survey's first question sought to test respondents' perceptions of the kind of work that engineers are involved in. It revealed that those who were not engineers typically failed to see engineering as high-level intellectual design and development, in favour of technician roles. These non-engineers had little awareness of the importance of engineering in areas such as food production or development of medicines. Encouragingly, teachers' appreciation of the breadth and diversity of engineering roles was relatively high, compared with other non-engineering groups (**Figure 2**).

Figure 2: Respondents' views on the kind of work that engineers are involved in



HOW DO ENGINEERS THINK AND HOW WELL DO OUR SCHOOLS PROMOTE SIMILAR HABITS OF MIND?

A series of questions explored the validity and desirability of the concepts underpinning the 'engineering habits of mind' model.

Across all groups, there was relatively good agreement that the six habits do capture the way that engineers think (Figure 3). 'Defining the question' scored lowest among teachers, parents and young people (but not engineers), suggesting it may be an underappreciated aspect of engineering.

Scores from teachers and young people were similar, whereas they were somewhat lower from parents, possibly a reflection of the relative lack of understanding of the role of engineers in this group.

Overall, the UK school system was thought to be doing reasonably well at developing these engineering thinking skills (Figure 4), although the scores suggest there would be room for improvement. Interestingly, engineers were the group most impressed with the current system; employers were slightly less positive than other groups. Teachers felt that 'Defining the question' and 'Moving from abstract to concrete' were the areas that were addressed least well, the latter perhaps an indication of the neglect of practical work – specifically the more open-ended investigative work, seen as valued but resource intensive.

Notably, there was very strong support across all groups for schools to encourage developing engineering habits of mind. Young people and employers were marginally less positive than the other groups. Hence, while the current education system is thought to be developing these thinking skills to a degree, it is likely that moves to nurture them more widely would be positively received.

Figure 3: Respondents' views on engineering habits of mind exhibited by engineers

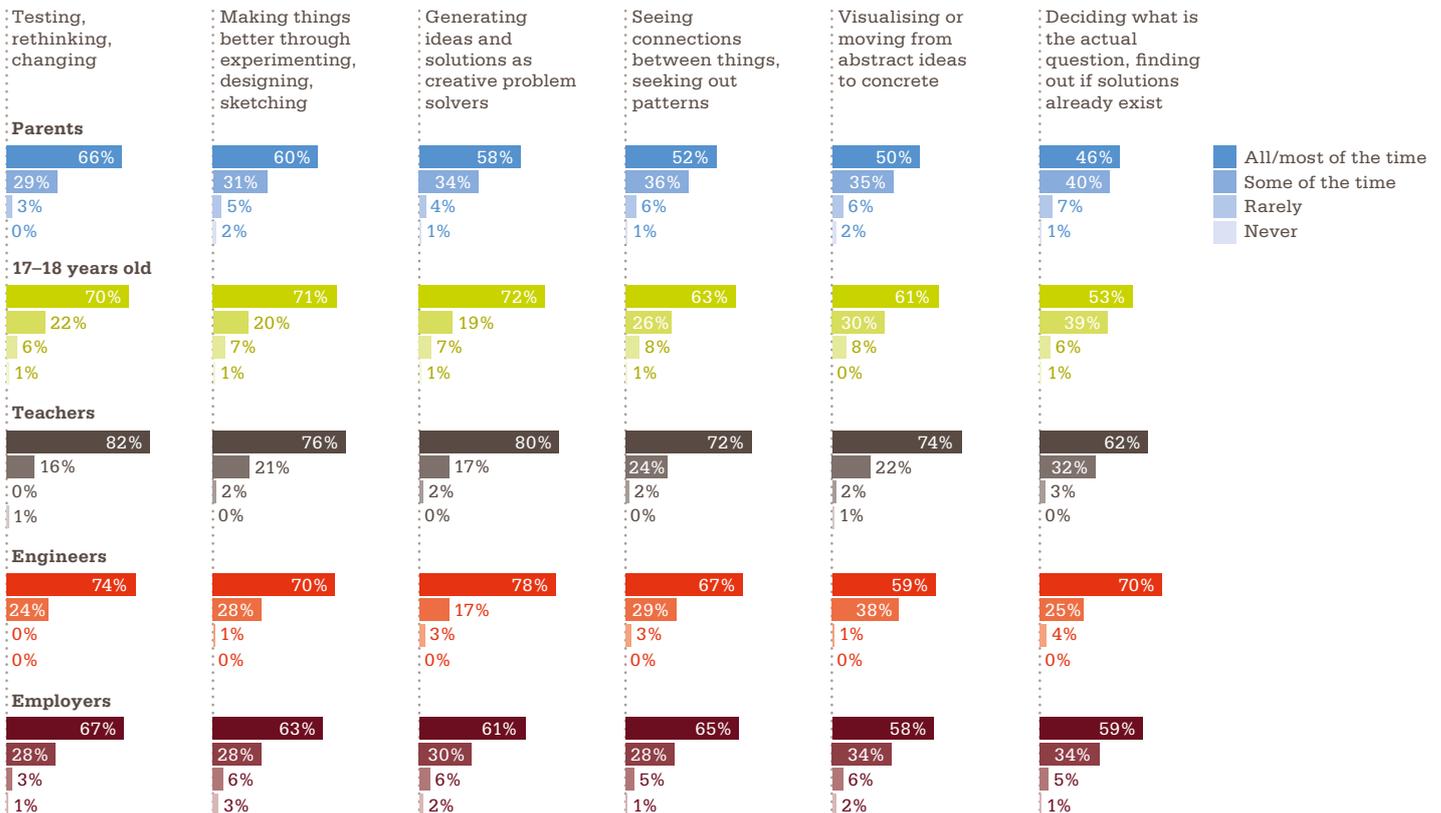
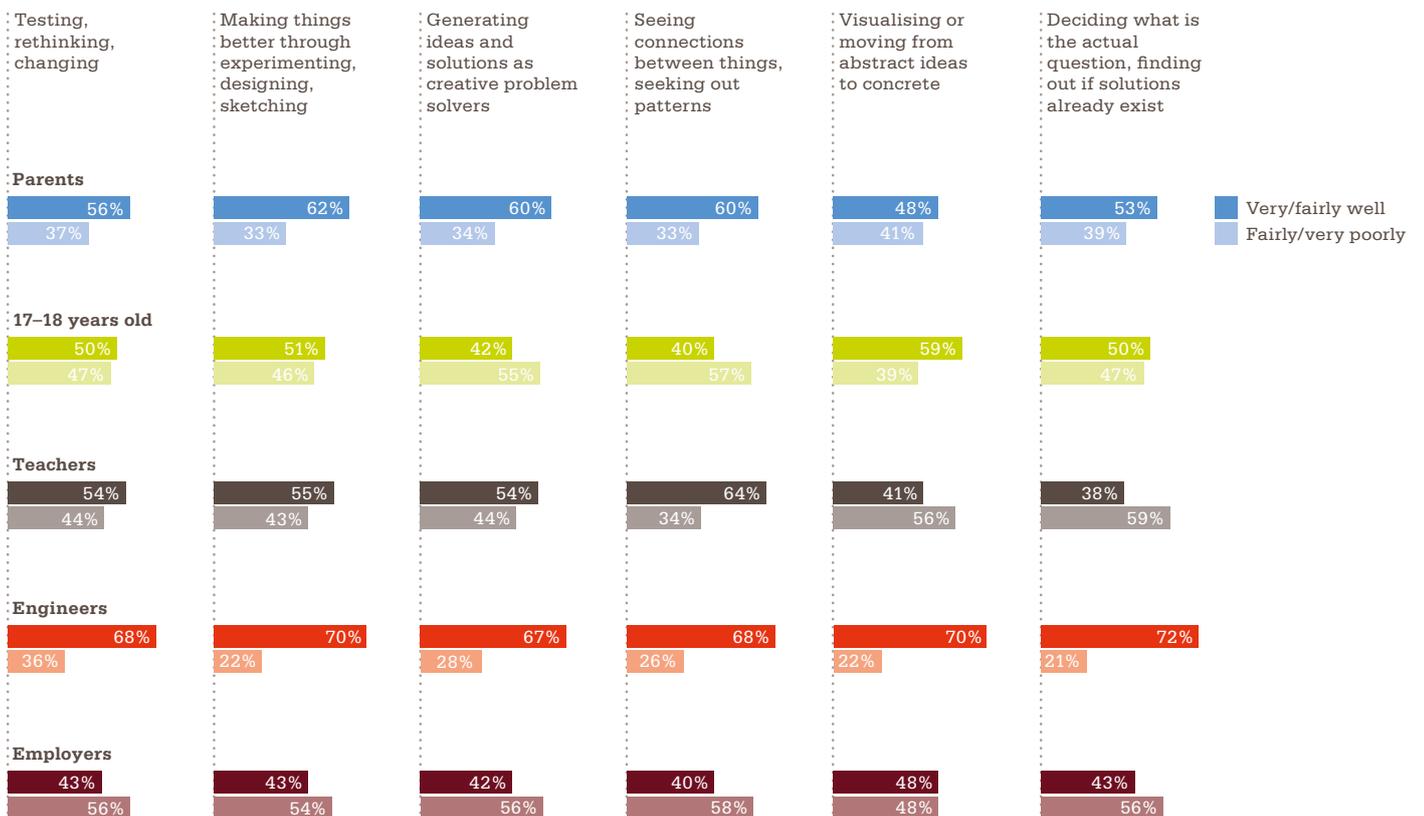


Figure 4: Respondents' views on how well the education system currently develops these characteristics in young people



WHAT INFLUENCES YOUNG PEOPLE'S DECISIONS?

A lack of students choosing to study physics and mathematics post-16, particularly girls, is an important factor currently limiting the numbers going on to study engineering at university and pursue a career in engineering or other technical areas.

Research participants identified a range of factors as significant in discouraging girls from studying mathematics and physics (**Figure 5**), including a lack of female role models, a belief that they are boys' subjects, a perception that they are too hard and the influence of peers (engineers, uniquely, placed heavy emphasis on the influence of teachers).

Similarly, respondents identified a number of perceptual and structural features that they felt influenced boys' reluctance to continue studying these subjects (**Figure 6**). Some were shared with girls (including the belief that the subjects are too hard), while others seemed to have a greater impact on boys than girls – for example, a lack of interest in the subjects. Engineers and teachers believed that perceptions about the difficulty of subjects are more off-putting to boys than girls.

Figure 5: Perceived influences on girls' decisions

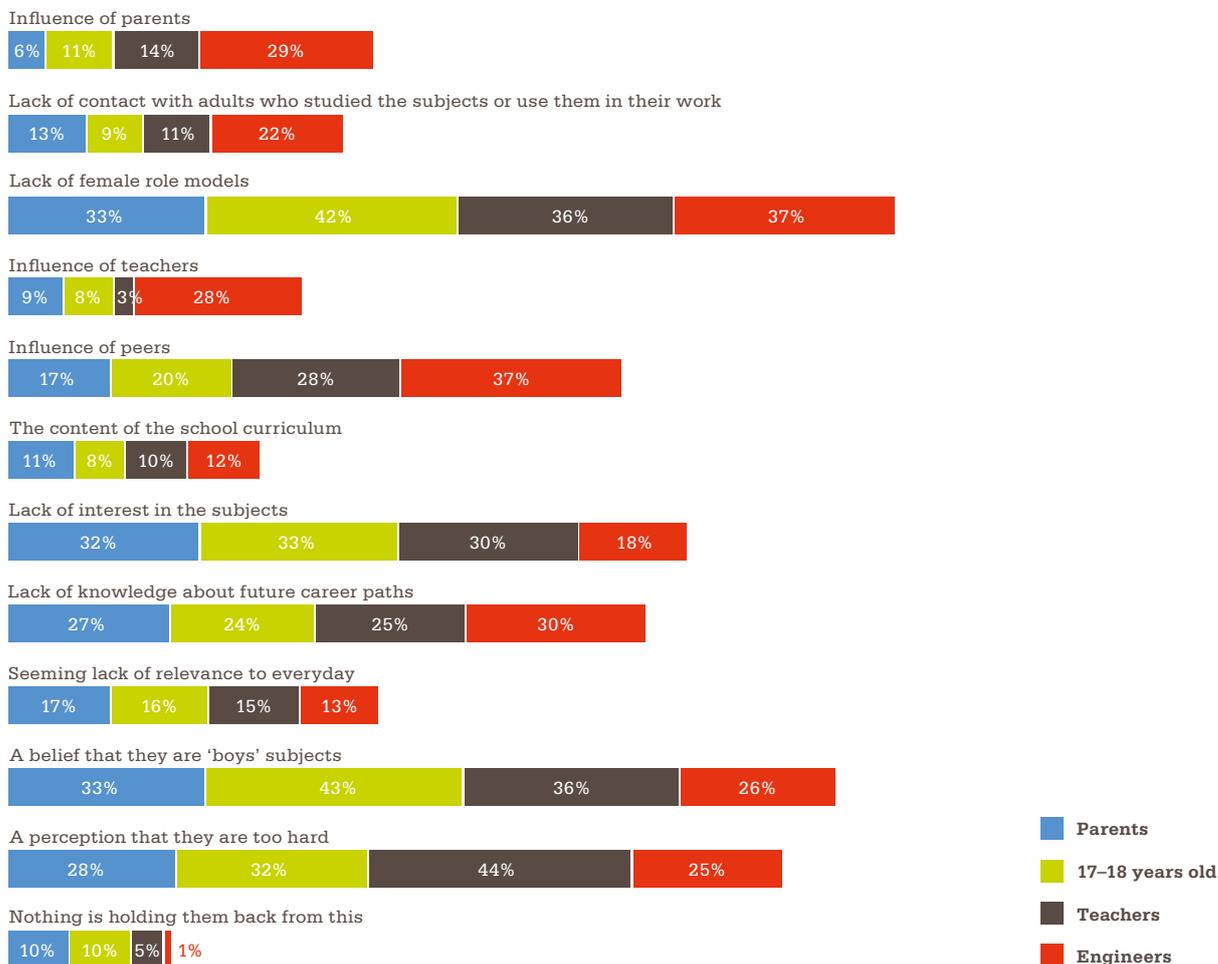
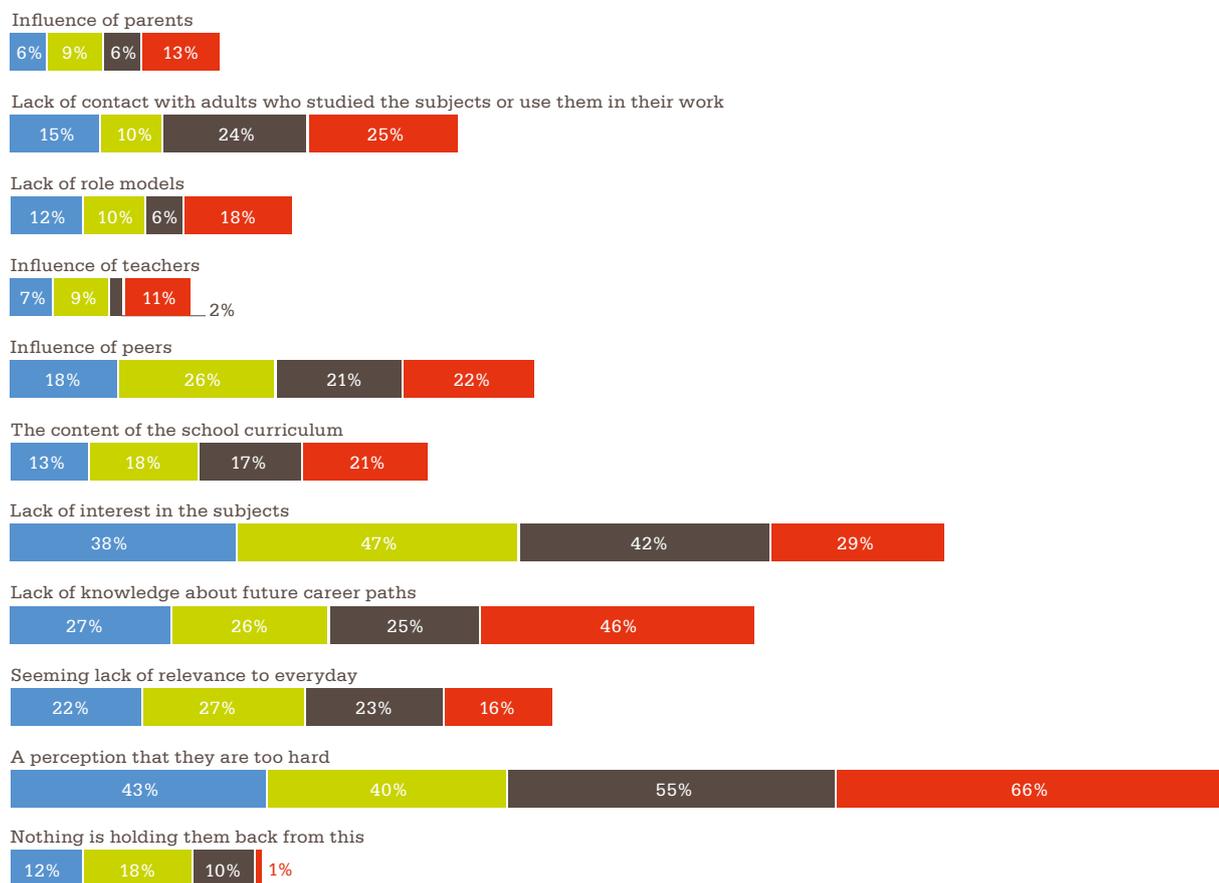


Figure 6: Perceived influences on boys' decisions



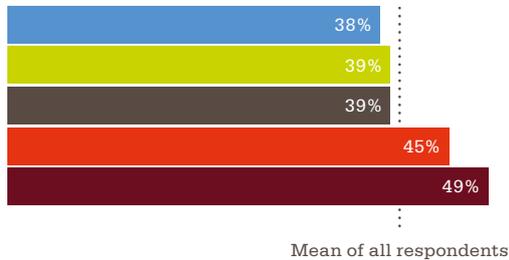
BACKING FOR A BACCALAUREATE

It has been suggested that putting in place a broader education, and thereby minimising early specialisation, would increase the numbers of young people, especially girls, pursuing engineering careers. Survey respondents agreed with this idea to a degree (**Figure 7**), with significantly greater numbers thinking it would increase rather than decrease the numbers ultimately choosing to study engineering. There were, however, significant numbers who felt it would make no difference, while overall the impact was thought likely to be stronger on boys than girls.

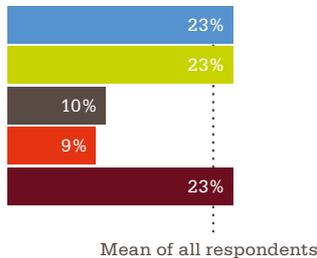
Figure 7: Respondents' views on whether a broader education system to age 18 would increase the number of boys and girls studying engineering

Girls

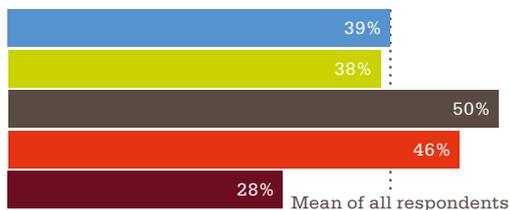
I think they would be more likely to study engineering



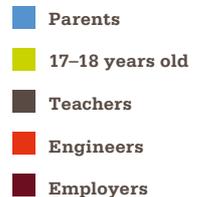
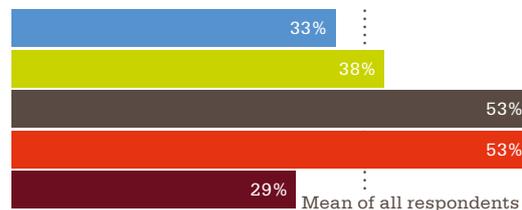
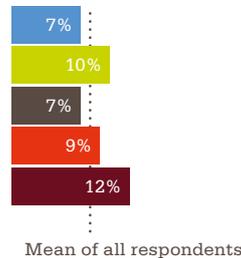
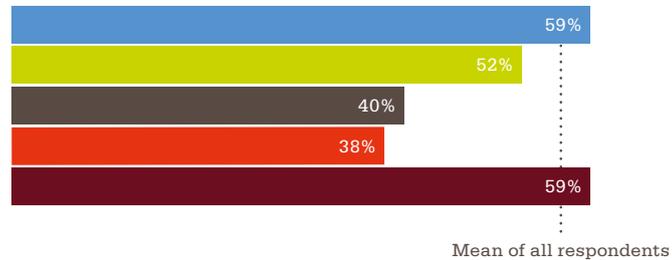
I think they would be less likely to study engineering



I think it would make no difference



Boys



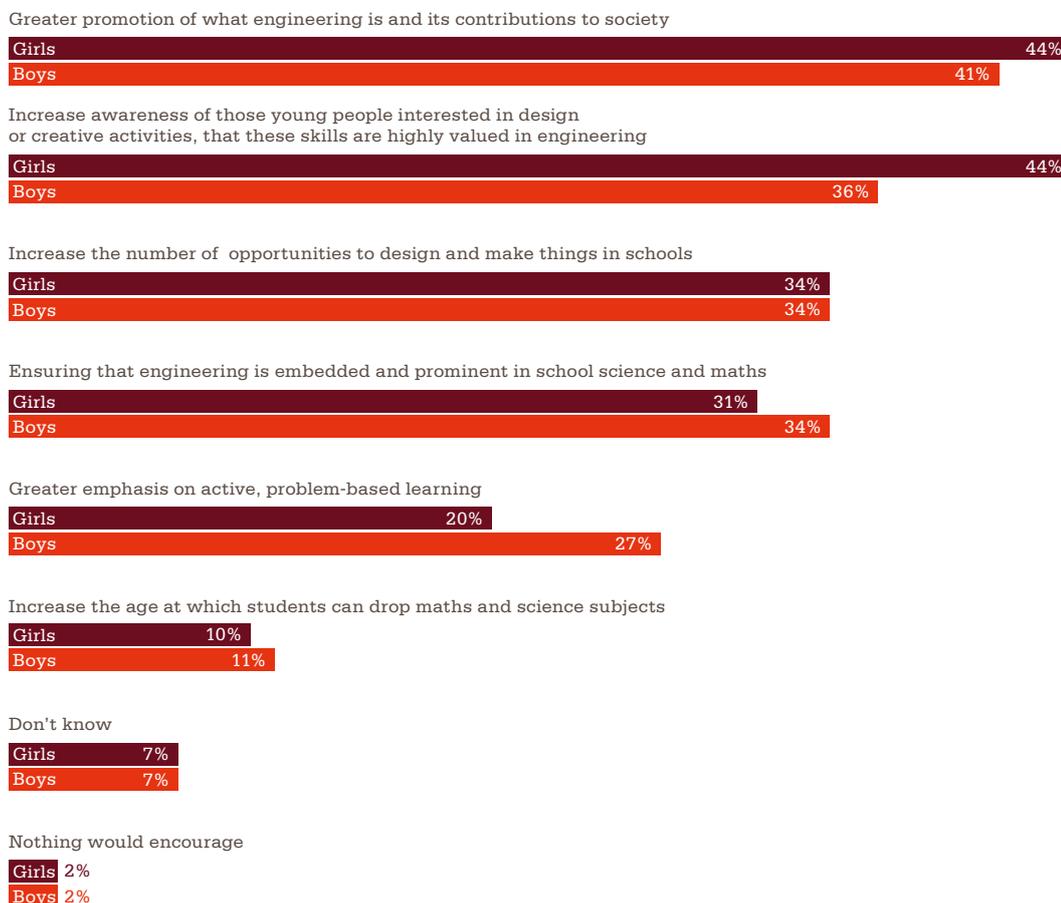
PROMOTING THE SOCIAL VALUE OF ENGINEERING

In previous Institution of Mechanical Engineers research^[8], there was clear evidence of a disparity in the motivating interests expressed by girls and boys. *Five Tribes: Personalising Engineering Education* revealed that, even among youngsters with a passion for STEM subjects, there is a stark difference along gender lines in the types of technology that appeal. Girls appear more inclined than boys to be drawn to engineering that has clear social value – typically environmental or medical.

In the *Big Ideas* study, we invited survey respondents to select from a range of possible factors that might encourage girls or boys to consider engineering careers. Once more a focus on societal value was seen as highly important, particularly for girls. (**Figure 8**) Equally important was raising the profile of creativity and design within learning linked to engineering. Presenting more opportunity for design and making in schools was perceived as having a good chance of generating further interest in boys, especially by teachers and engineers, though significantly fewer teachers advocated this approach for girls.

Of particular interest, one-third of all stakeholders agreed that more explicit embedding of engineering in science and mathematics lessons would lead to an increase in those considering engineering. Teachers particularly supported this measure for encouraging girls into technical training and engineering.

Figure 8: Respondents' views on factors they felt would encourage: a) girls and b) boys to consider engineering career paths

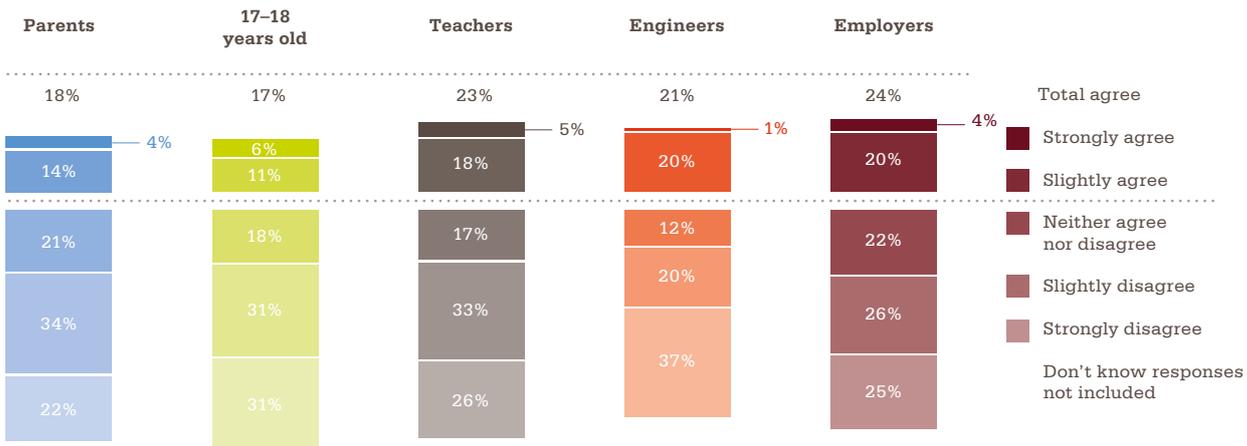


THE KNOWLEDGE-SKILLS DEBATE

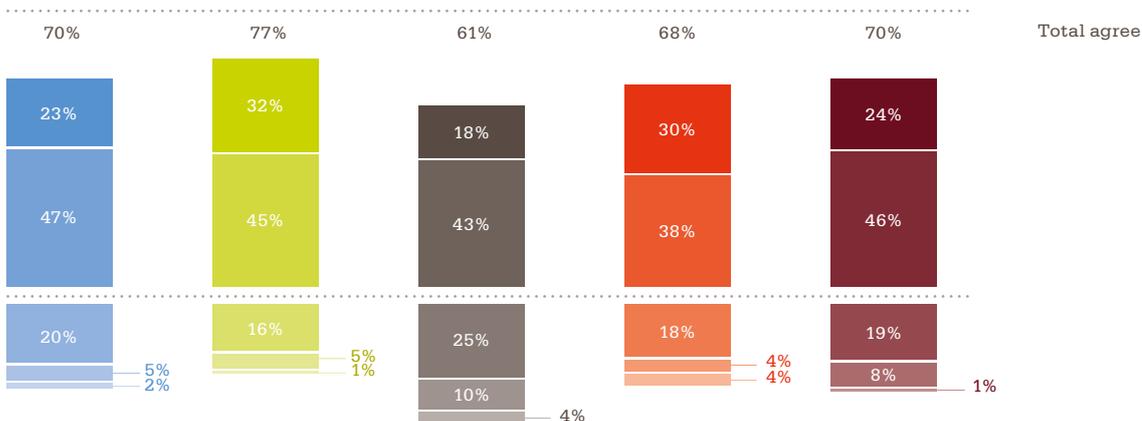
Over recent years the UK education system has often been criticised for focusing on acquiring facts and less on developing skills. Open-ended exploratory (science) investigations are seen by some as part of the answer since they echo the way in which science is done in real life. And, of course, problem-based learning is synonymous with engineering. Although there was support for a shift in this direction, its likely effect on increasing interest in engineering was felt to be greater on boys.

Figure 9: Respondents' views on aspects of the current curriculum in schools

The current curriculum content does not need to be changed since it has been tried and tested over time



Schools are happier teaching the known and proven rather than the contemporary and exploratory

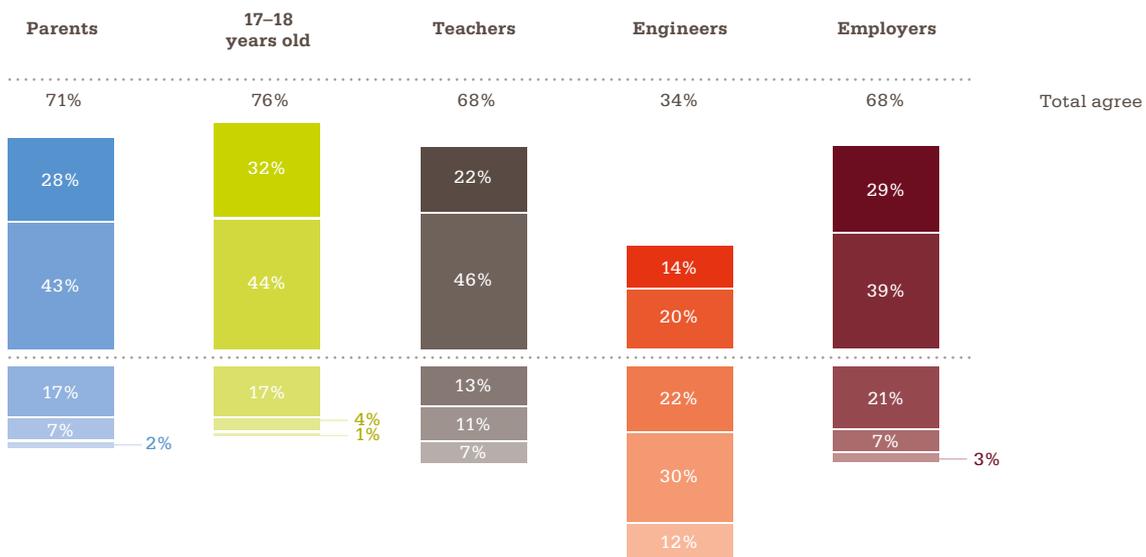


EDUCATION SYSTEM: CURRICULUM

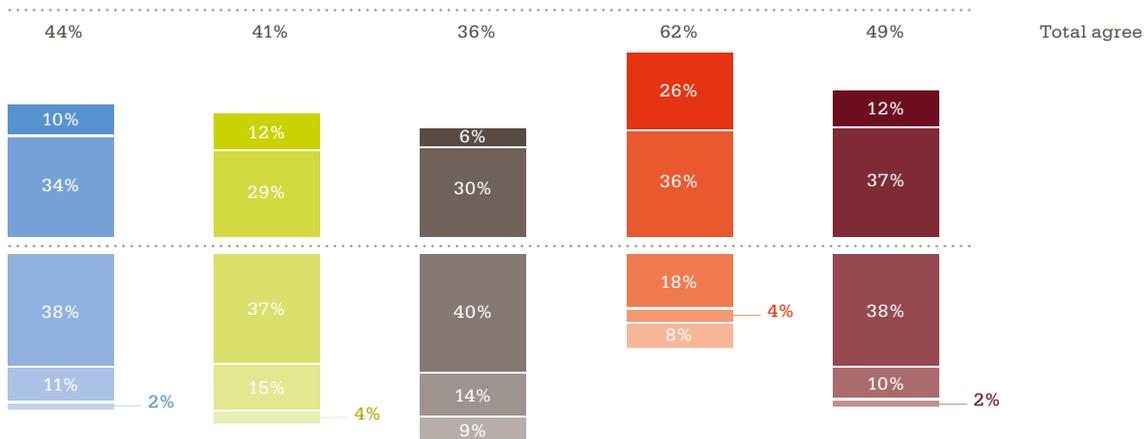
The stakeholder survey further set out to uncover the extent to which what is taught in schools reflects the nature of the world we inhabit, and indeed, whether this was desirable (Figure 9). Schools were thought to favour teaching about the natural world over the 'made' world (engineers were most likely to believe this yet at the same time least supportive of a curriculum that draws on the wider dynamic technological landscape).

There was general support for a more dynamic and up-to-date curriculum, yet widespread agreement that schools were currently set up to teach the known and proven rather than the contemporary and exploratory.

We live in a fast-changing world and what is taught should reflect this rather than focusing too much on what has gone on before



Our schools are set up to teach about the natural world rather than the manufactured world



“”

Design and Technology should be used as the platform for integrating STEM and creative design, and for raising the profile of engineering in schools.

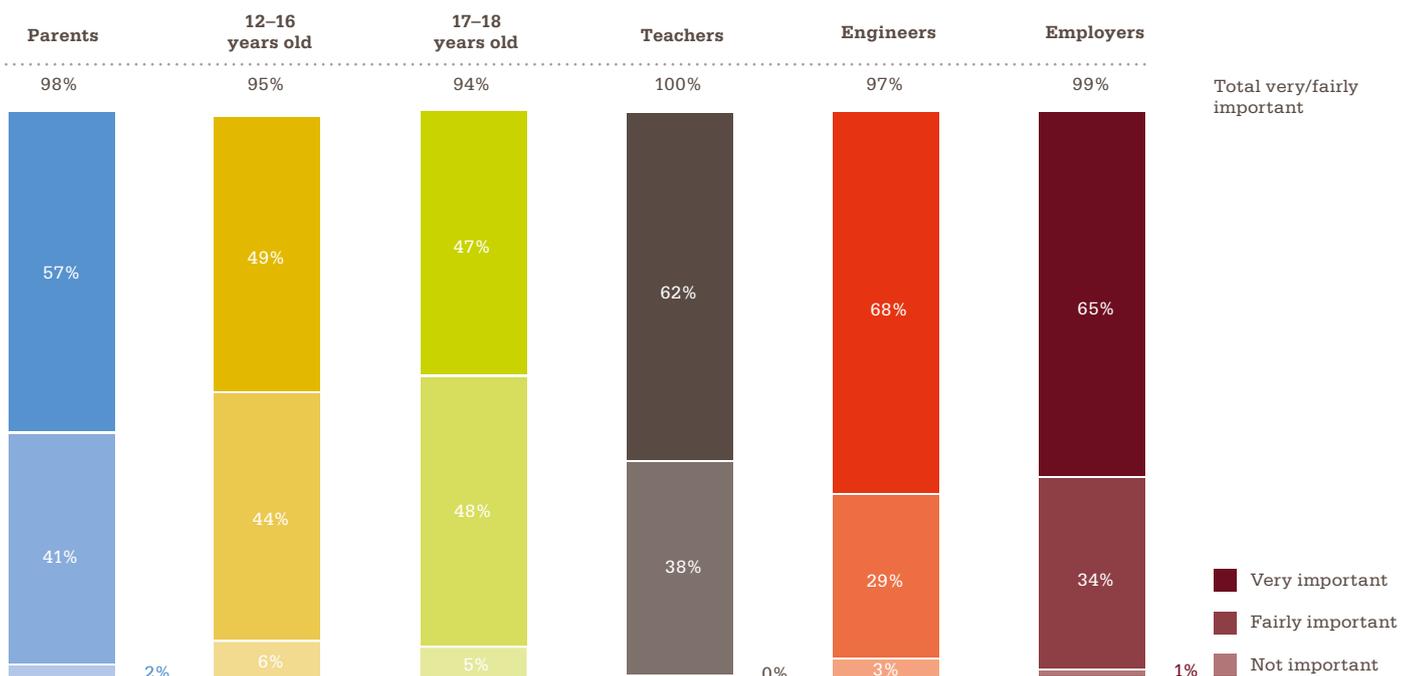


EDUCATION SYSTEM: DESIGNING AND MAKING THINGS

There was overwhelming support from all groups for the idea that schools should be encouraging young people to design and make things. (Figure 10)

'Making things' was thought to be beneficial for a range of reasons, with the idea that it helps young people understand how the world works, seen as marginally the most important. There was also a sense, especially among teachers and engineers, that designing and making offers a real experience of learning. Of the responses on offer, young people were most likely to point out that 'making things' was more enjoyable than 'thinking about things'.

Figure 10: Respondents' views on the importance of designing and making in the curriculum



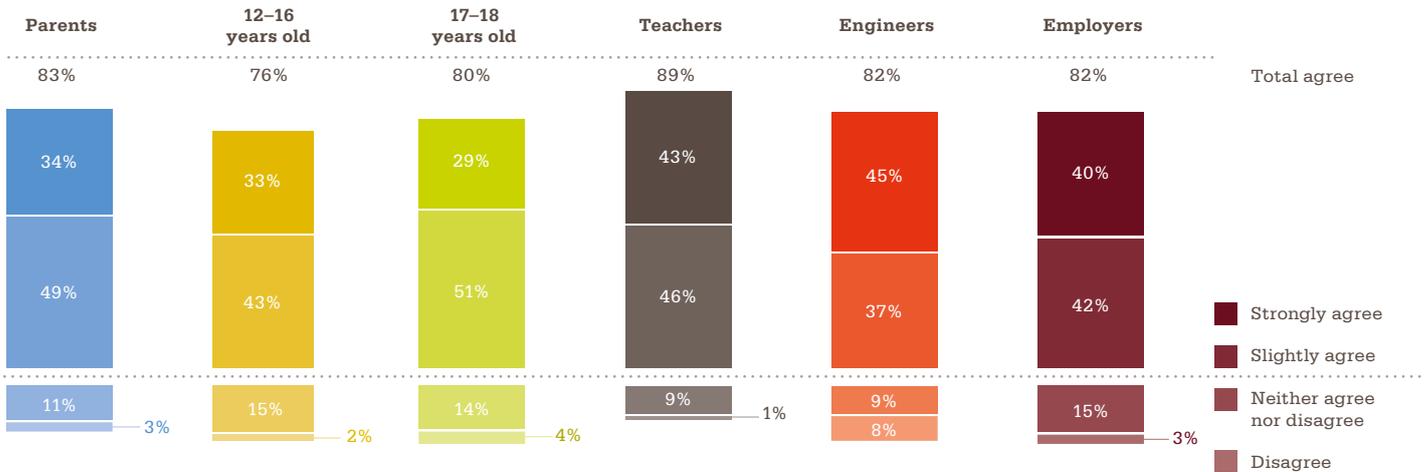
EDUCATION SYSTEM: CREATIVITY IN STEM TEACHING

There was widespread agreement that STEM teaching encourages creativity. Although sizeable minorities thought that creativity was important in arts/humanities and not STEM subjects, a majority in all groups recognised the importance of creativity in STEM. This view was held most strongly among engineers and teachers, slightly less so by young people. (Figure 11)

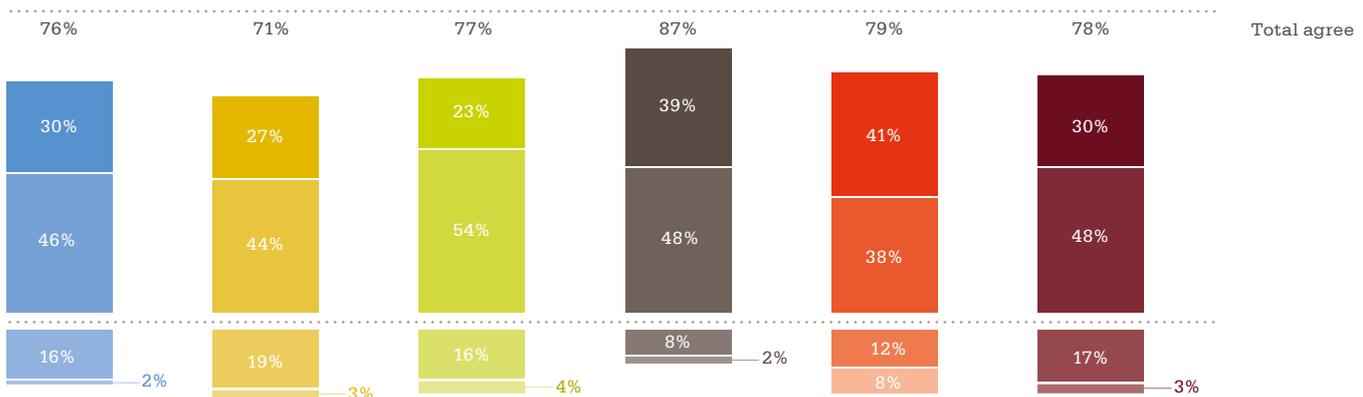
Recognising and communicating the importance of creativity in engineering could be a way to encourage more young people to consider engineering career paths. When it comes to engineering, there are different types of design careers that will appeal to different students. The idea that engineering could do more to attract young people with an interest in 'design' was strongly supported by all groups. There was equally strong support for the suggestion that STEM students and design students should work together collaboratively – teachers being the most supportive of this idea, with young people slightly less in favour. On reflection, it might be worth attempting to understand more about the conception of 'design' among the various stakeholders since it is more likely to be construed more towards aesthetic and ergonomic, rather than technical design.

Figure 11: Respondents' views on creativity, design and STEM subjects in schools

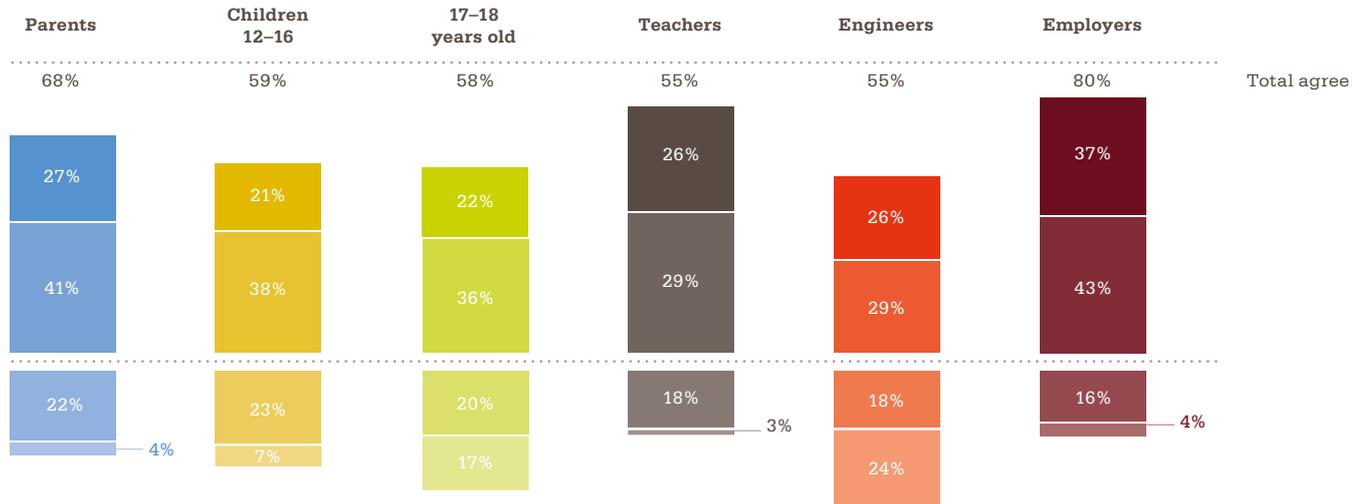
Engineering could do more to attract young people with an interest in design



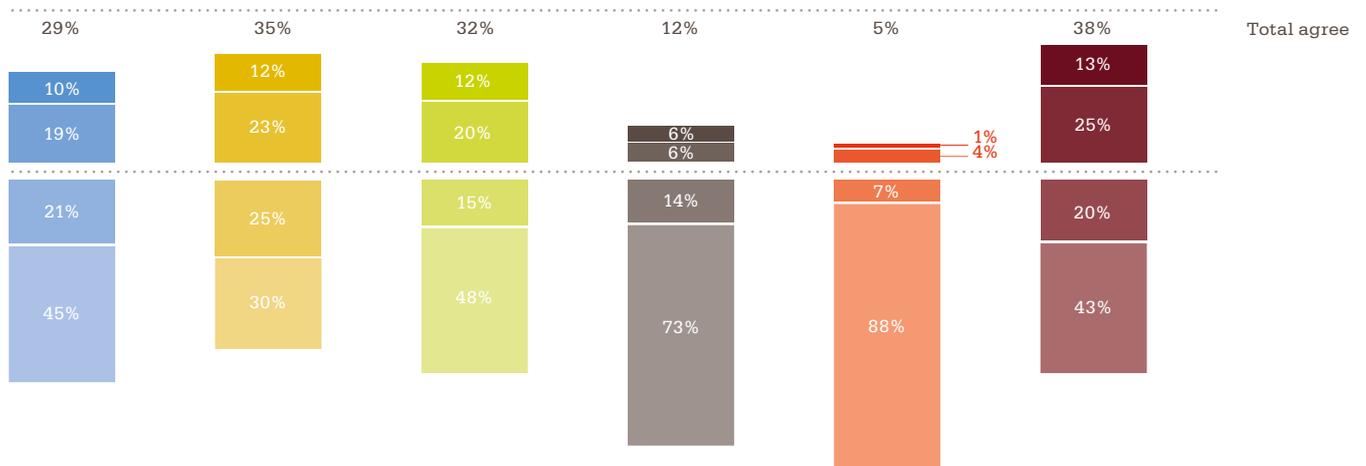
It would be beneficial to provide more opportunities for young people specialising in STEM subjects to work with those interested in design



STEM teaching encourages creative thinking



Creativity is important in arts and humanities but is not important in STEM subjects



It is important to promote creativity in STEM subjects

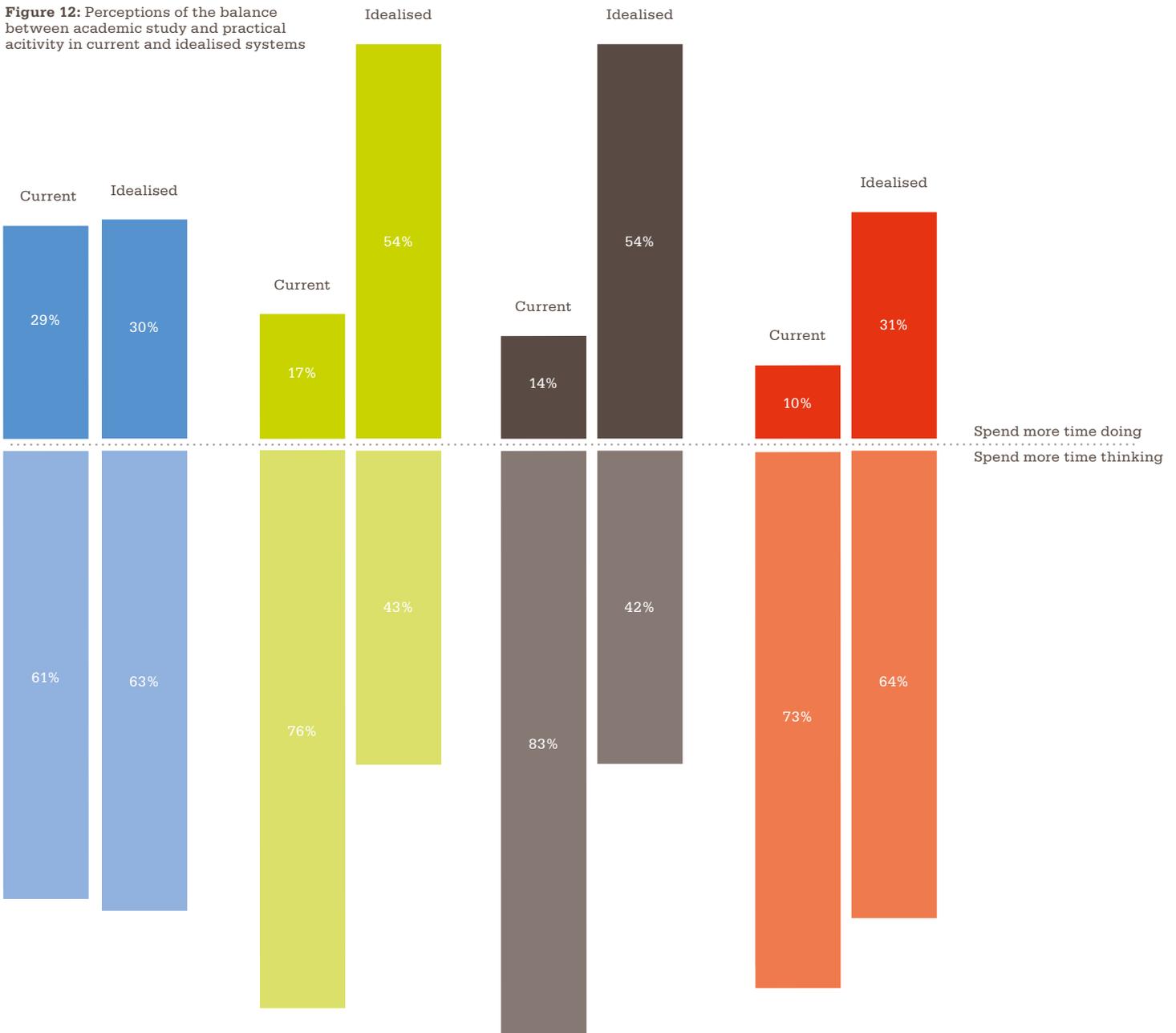


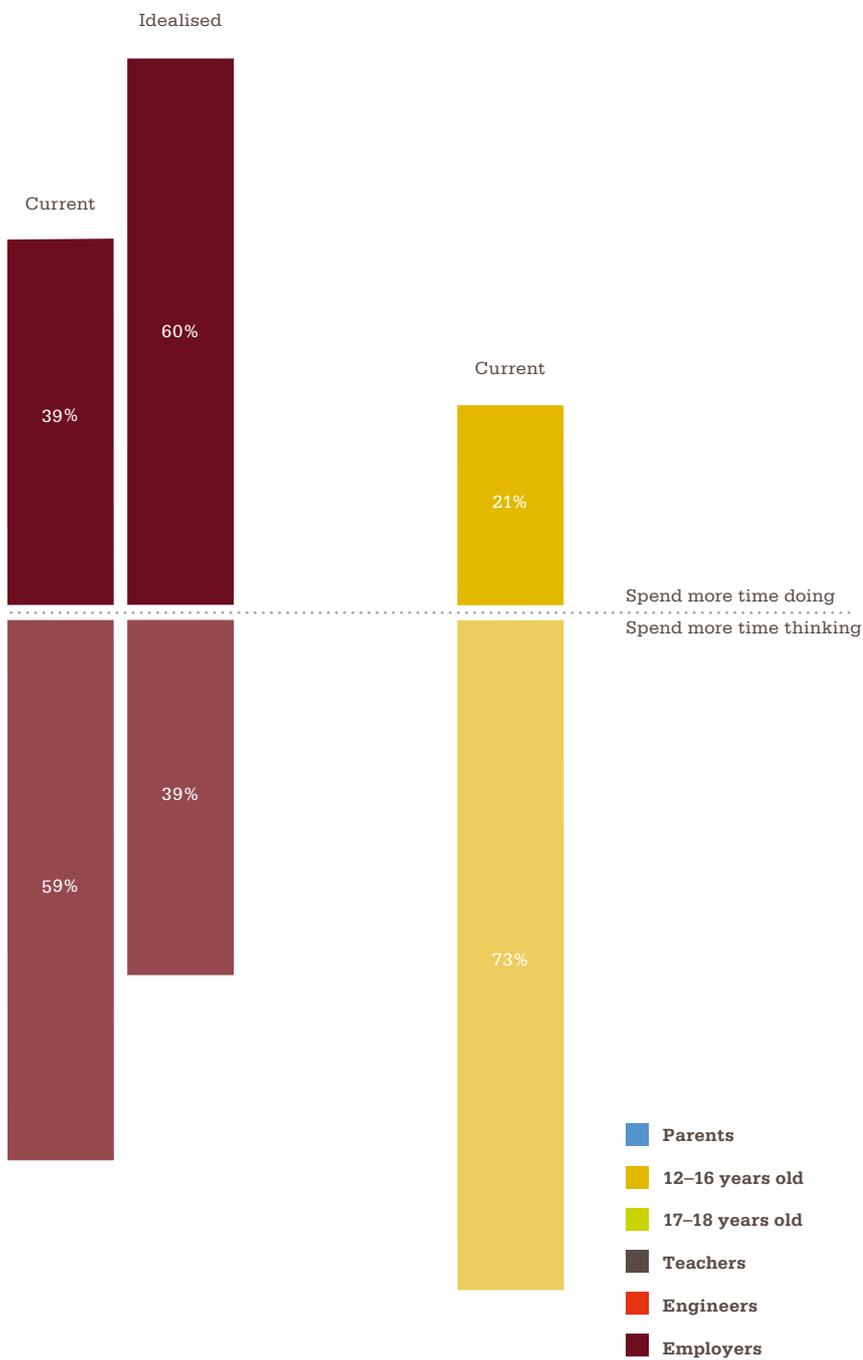
EDUCATION SYSTEM: THE BALANCE BETWEEN 'THINKING' AND 'DOING'

A factor that places engineering at a disadvantage in the school system is felt to be the emphasis on theoretical learning or academic study over practical work. Young people, teachers and engineers all felt that the balance in the current system is strongly skewed towards 'thinking' over 'doing'. This perceived bias was seen, even in the responses of younger children (aged 12–16). Interestingly, the bias was perceived to be smaller by parents (and employers) (**Figure 12**).

When asked where they thought the balance ought to lie, young people, teachers and employers all thought the balance should be shifted significantly towards practical work. Engineers, by contrast, saw the ideal balance as still favouring academic study. Moreover, parents also felt the ideal balance should strongly favour academic study.

Figure 12: Perceptions of the balance between academic study and practical activity in current and idealised systems





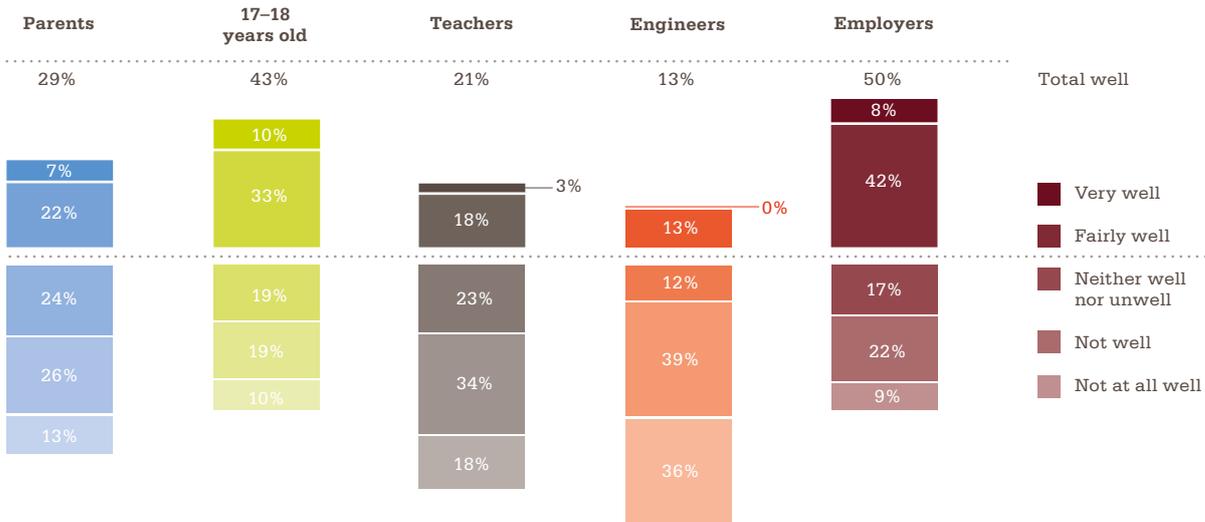
COMMUNICATING ABOUT ENGINEERING

Some argue that the engineering community has not been effective at communicating either its contributions to society or what engineering actually involves. The stakeholder survey results suggest that engineers are actually getting the message out about their contributions to society reasonably well, although there is room for improvement (**Figure 13**). Engineers are notably less positive about their communication than are other groups. In terms of communicating what engineering is and what engineers do, the picture is more mixed – although engineers are again the most pessimistic group.

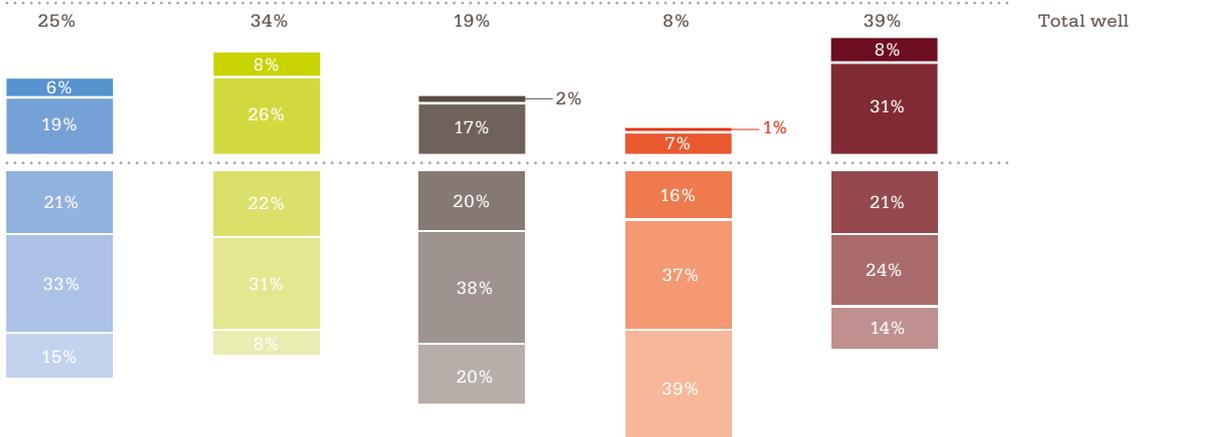
Encouragingly, engineering is generally thought to be responding to society’s needs (although not perhaps to the extent that engineers would wish). In terms of listening to users/consumers, respondents’ scores were less favourable but overall attitudes remained positive. All groups recognised that engineering is not appealing to under-represented groups – indeed, engineers were most acutely aware of this issue.

Figure 13: Perceptions of how well engineering communicates with public audiences

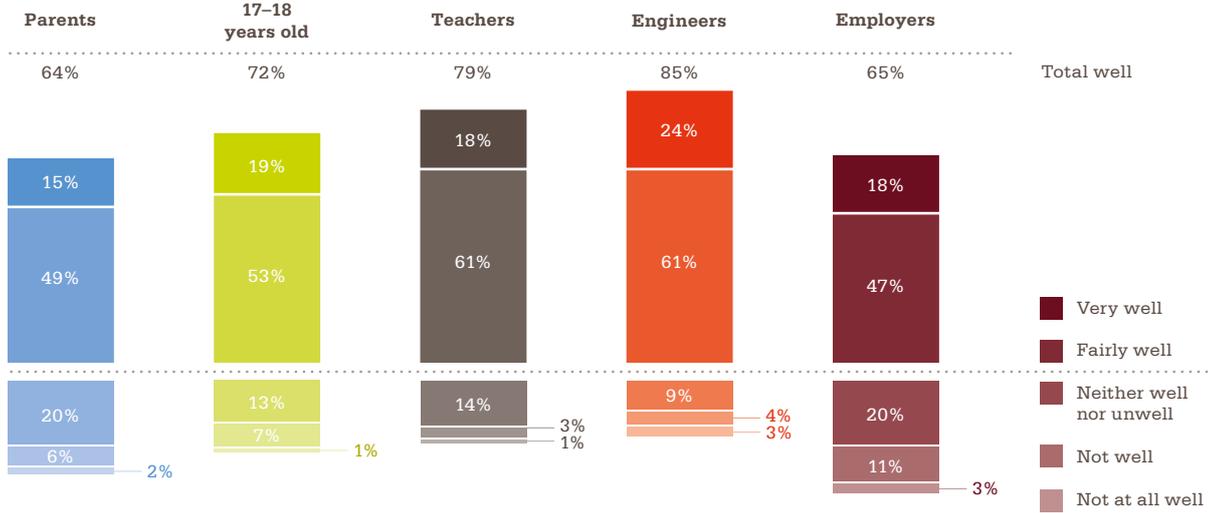
Communicating its contribution to society



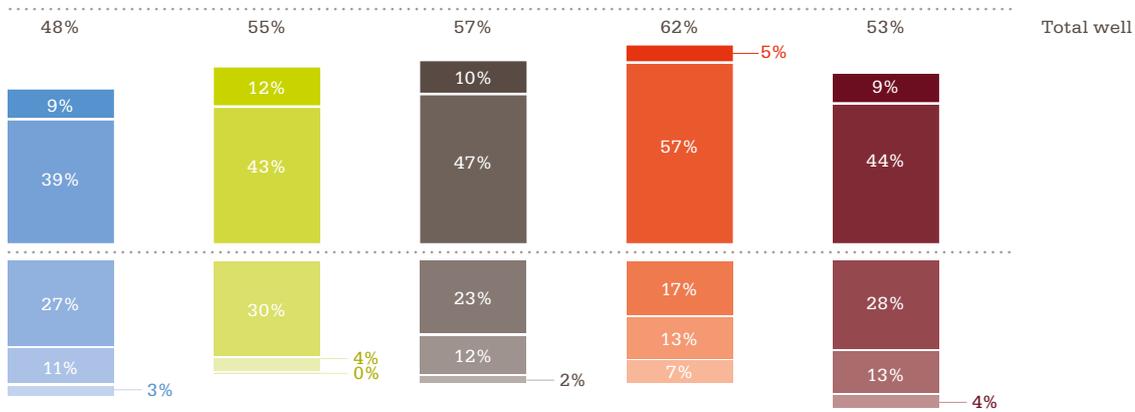
Communicating what engineering is and what engineers do



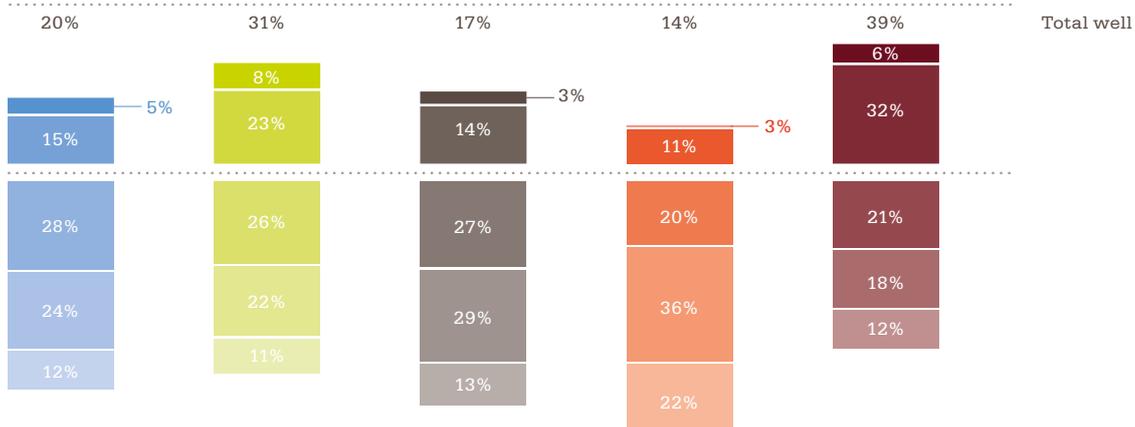
Responding to society's needs



Listening to users/consumers



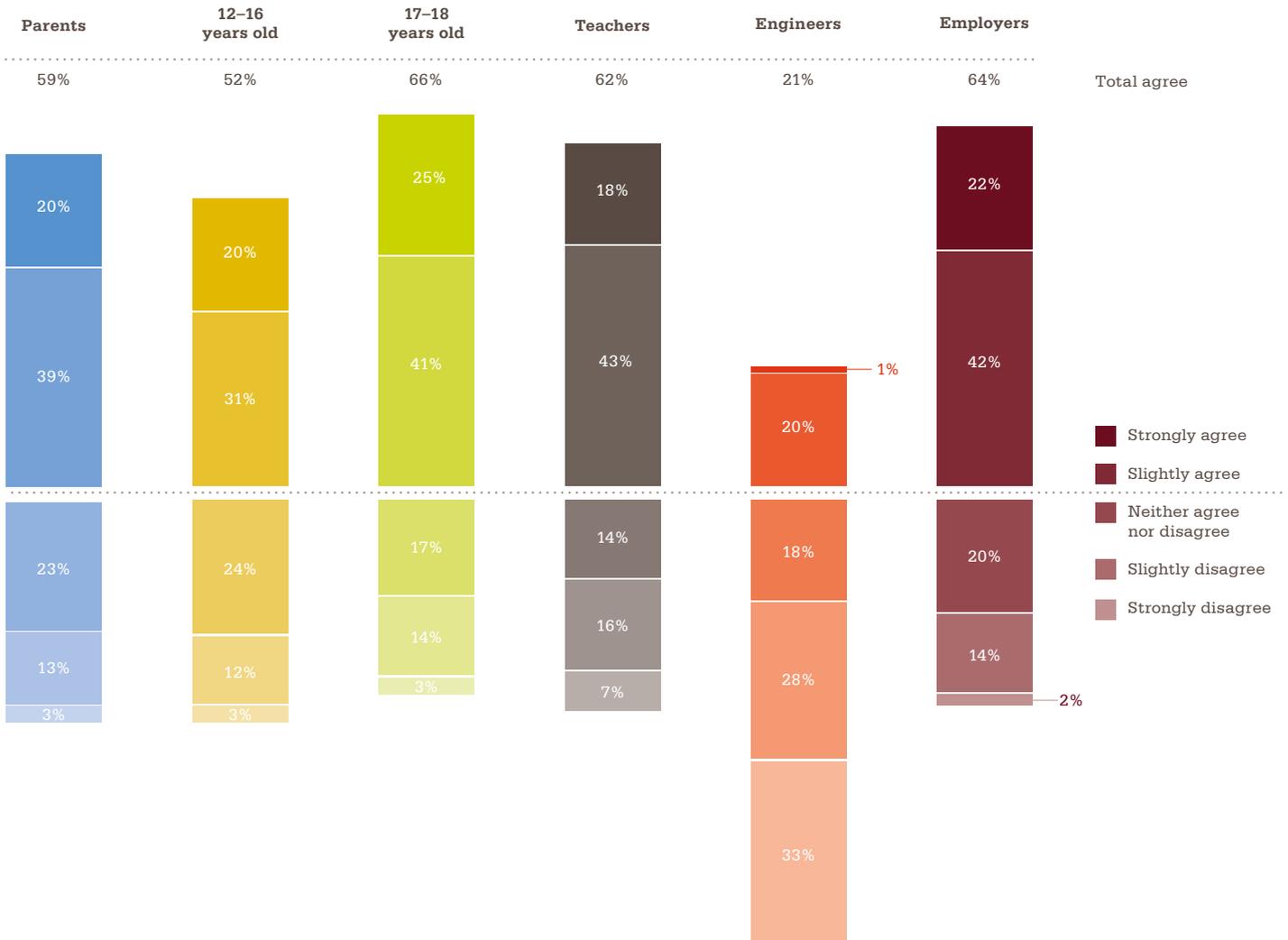
Appealing to currently under-represented groups



ENGINEERING IN CONTEXT

A belief that the specialist and highly skilled role of engineers is not widely appreciated has led some to question whether engineering has the social status it deserves. In fact, the survey showed that respondents in most groups thought that engineering was generally perceived to be of relatively high status. (**Figure 14**) The views of engineers were markedly discordant – much smaller numbers believed that engineering was seen as a high-status profession.

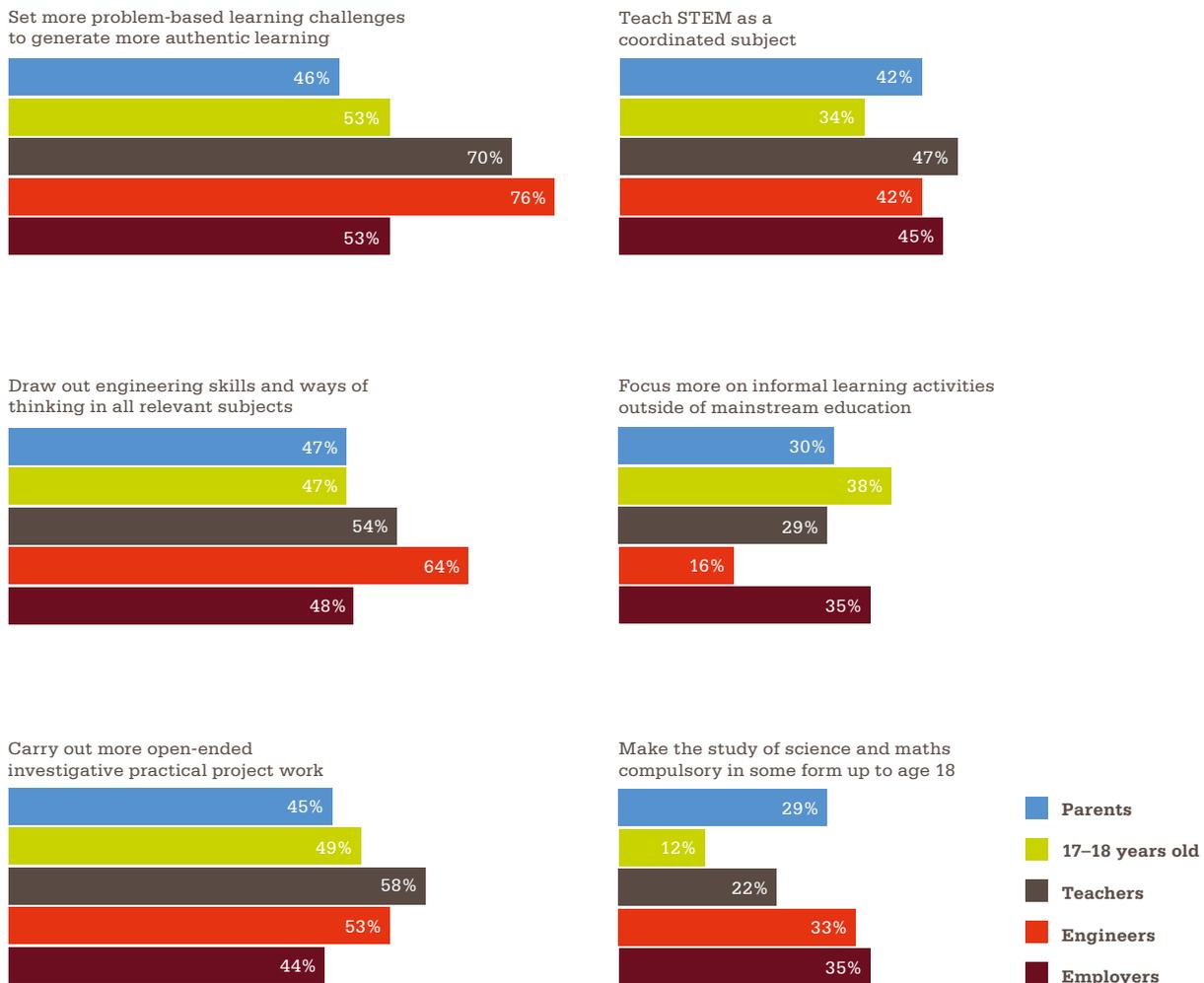
Figure 14: The extent to which engineering is seen as a high status profession



In terms of possible actions to position engineering better in UK schools, a range of options received support, although groups differed in those they thought would be most effective. Engineers and teachers were particularly keen on problem-based learning and on integrating engineering across a range of subjects. Most groups, especially teachers, saw advantages in promoting investigative practical work. Parents were less enthusiastic about problem-based learning, possibly as it is a relatively new and therefore less well understood than 'traditional' academic forms of study. (Figure 15)

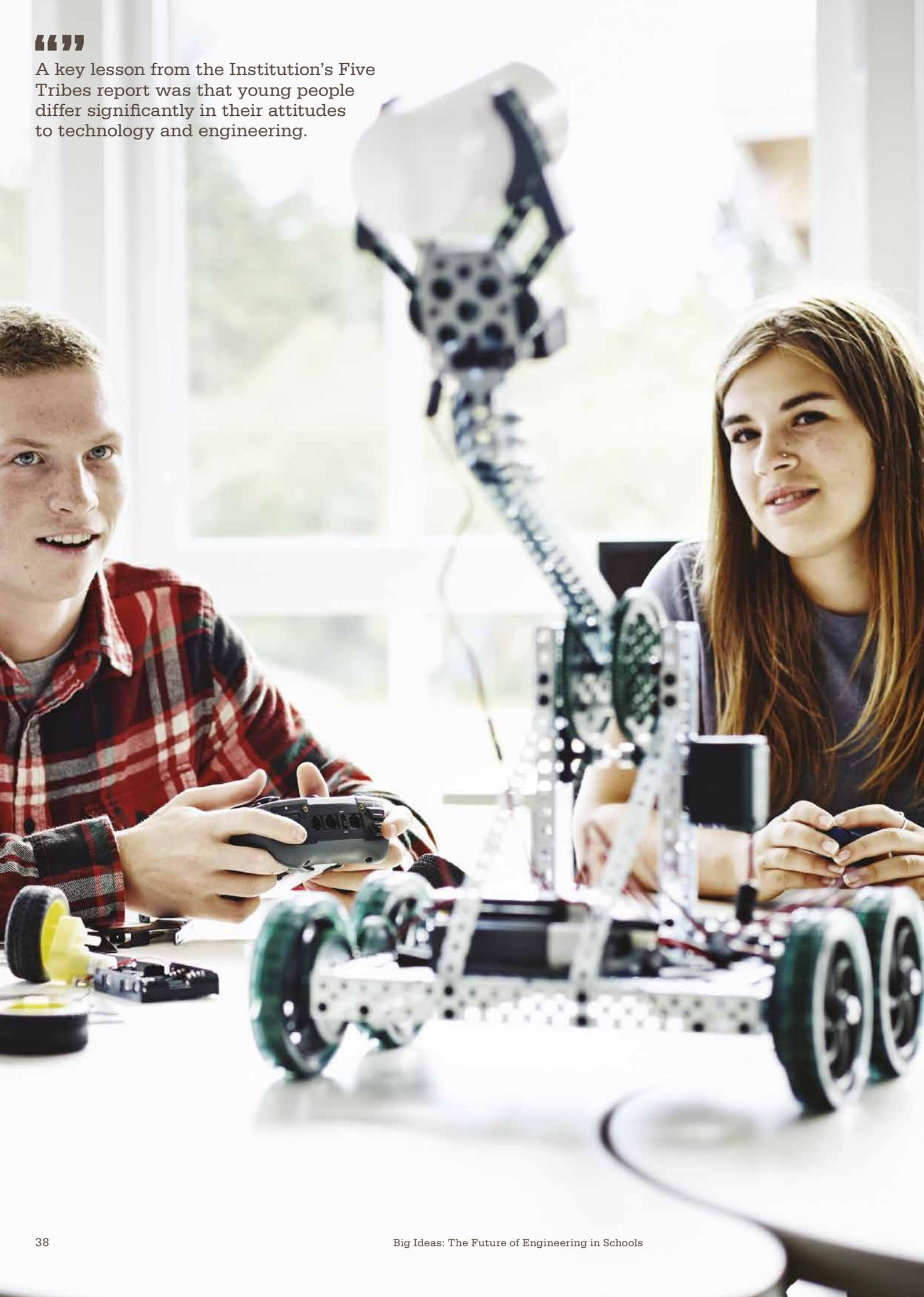
Notably, greater use of the informal sector and extracurricular activities received only lukewarm support. Compulsory study of science and maths up to age 18 was seen as just as valuable (except by young people).

Figure 15: How to position better engineering in young people's school experience



“““

A key lesson from the Institution's Five Tribes report was that young people differ significantly in their attitudes to technology and engineering.



REPORT GOALS

By bringing together the workshop stimulus materials, discussions at the workshop, feedback from participants and data from the Big Ideas stakeholder survey, we have identified a series of goals.

A key theme emerging from the workshop was the need to develop technology and engineering literacy across the entire population*. If engineering has a problem in not being properly understood outside its own community, the school environment is the logical place in which to start building such literacy. Enhancing technology and engineering literacy among all school students will help to create a society in which the contributions and importance of engineering are more widely recognised. Developing engineering habits of mind and nurturing problem-solving skills would result in a much larger pool of young people able to pursue engineering or related technical professions.

This ambitious overall goal defines a set of aspirations for UK engineering education, establishing a longer-term direction of travel.

The ten Big Idea Goals:

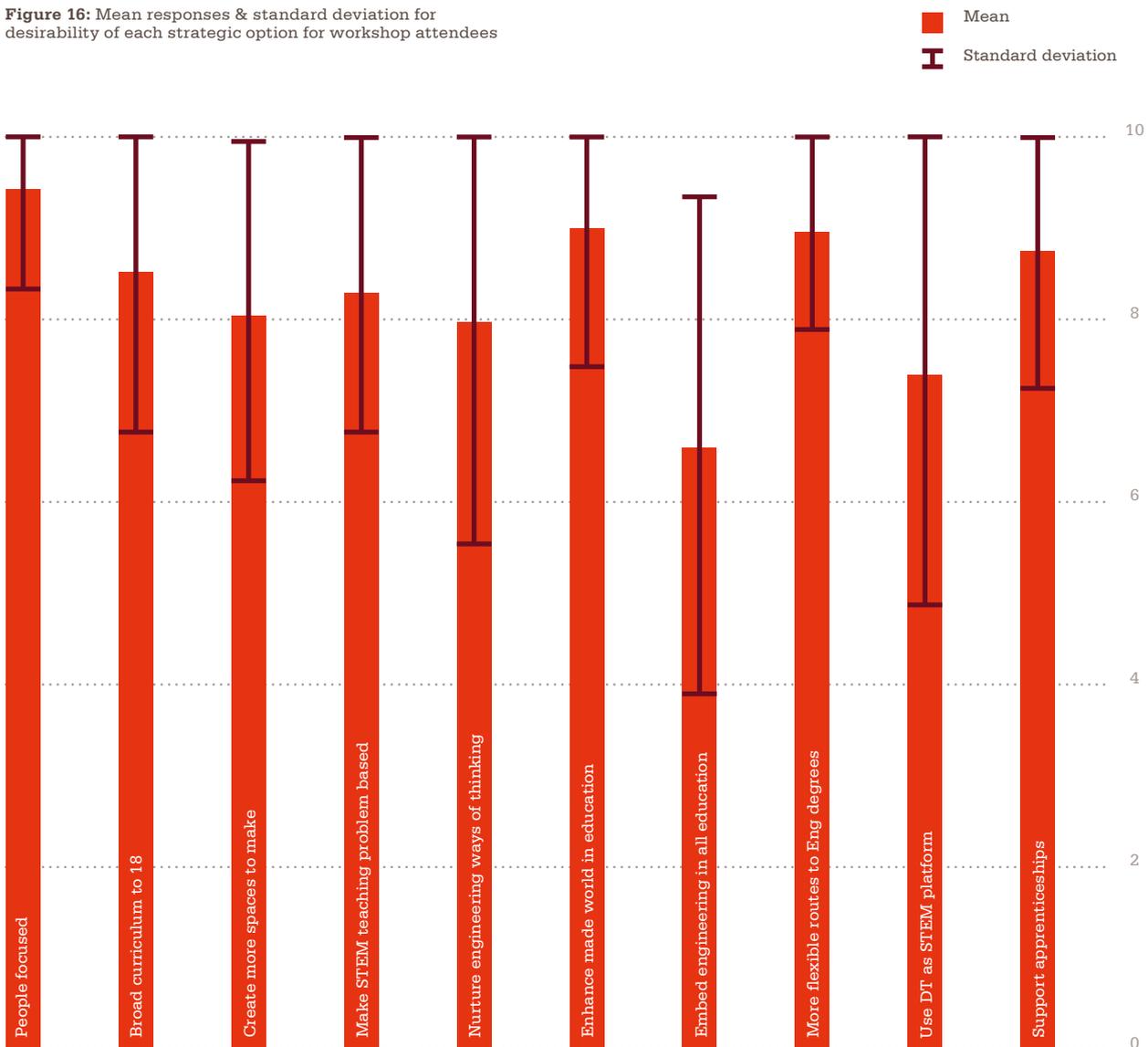
- Promote engineering as a people-focused, problem-solving, socially beneficial discipline
- Work to enhance the presence of engineering and the 'made world' at all stages from primary level upwards
- Ensure that apprenticeships and other technical pathways not only deliver high-quality technicians but also enable individuals to progress to the highest levels of engineering
- Broaden routes into engineering degree courses by promoting more flexible entry requirements
- Maintain a broad curriculum for all young people up to the age of 18
- Shift the emphasis in STEM teaching towards problem-based, contextualised learning
- Nurture engineering ways of thinking in all young people
- Create more spaces and opportunities for young people to design and make things particularly by working collaboratively in interdisciplinary groups
- Use Design and Technology as a platform for integrating STEM and creative design and for raising the profile of engineering in schools
- Change the structure of schools education to embed engineering explicitly at all levels

*No attempt was made to define 'engineering and technological literacy'. A broad definition is adopted here that would encompass an appreciation of the nature and importance of engineering and technology, and the development of problem-solving thinking skills and some degree of practical expertise. Engineering and technological literacy can thus be seen as an enabler, providing life skills that provide individuals with personal and professional benefits and also enable them to contribute to society as informed citizens.

These goals have been tested by a further online survey of the workshop participants to establish levels of support and consensus among them. Responses showed both the desirability and the feasibility of each goal and offered the chance for further comment.

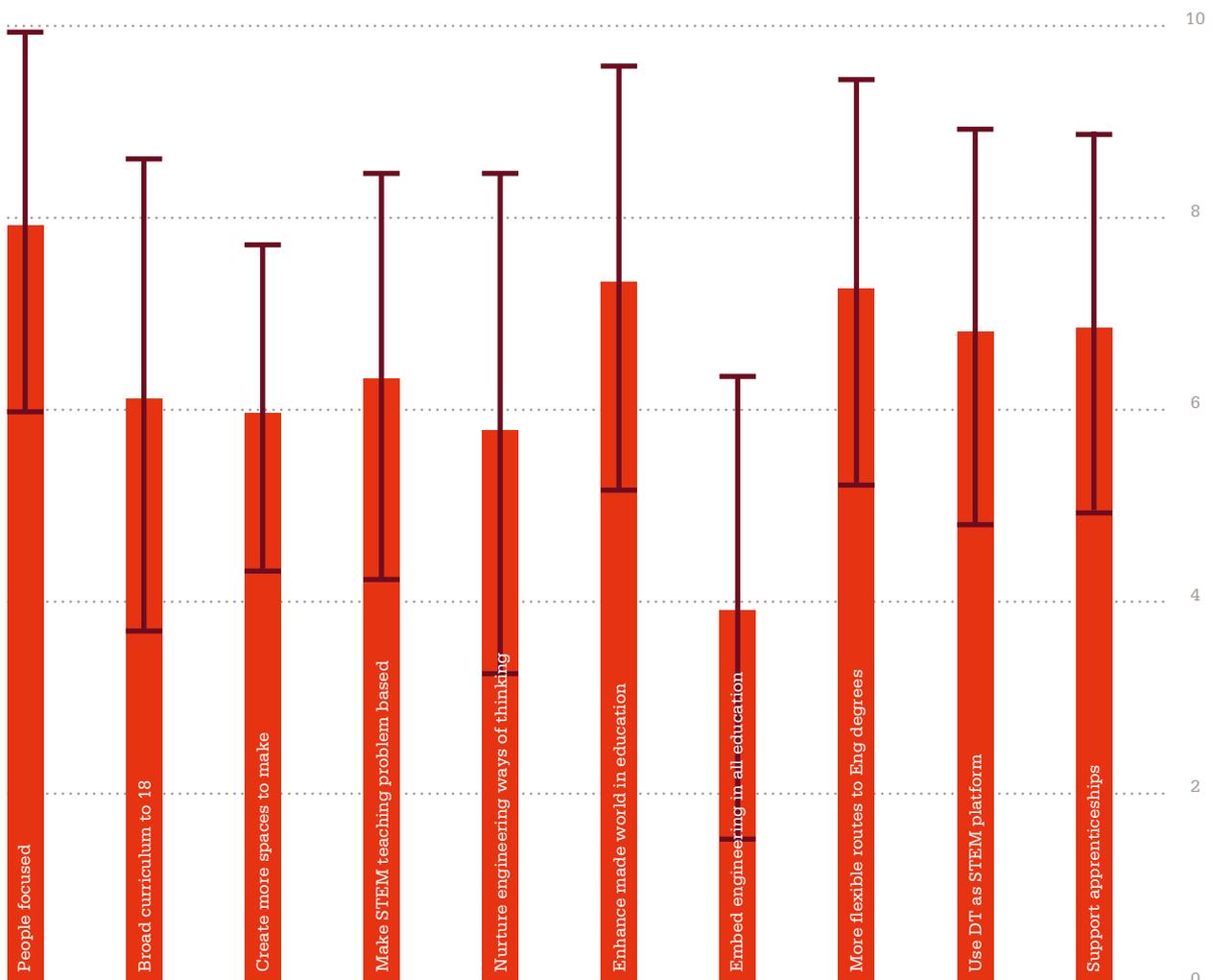
Across the board, most goals were well received. All but two achieved a mean score of 8 or greater out of 10 for desirability (**Figure 16**).

Figure 16: Mean responses & standard deviation for desirability of each strategic option for workshop attendees



Reflecting this difference between aspiration and the challenge in achieving them in practice, scores for feasibility were markedly lower than for desirability (Figure 17). In particular, fundamental change to incorporate engineering specifically in the curriculum was seen as particularly difficult to achieve. Developing a broader curriculum was also seen as highly challenging, whereas widening entry criteria to university study was seen as relatively feasible.

Figure 17: Mean response & standard deviation for feasibility of each strategic option for workshop attendees



These results are summarised in **Figure 18** showing the top two options for both desirability and feasibility being the same. The recommendations for action therefore clearly fall in these two areas:

- Promoting engineering as a people focused, problem solving, socially beneficial discipline
- Working to enhance the presence of engineering and the “made world” at all stages from primary level upwards

Figure 18: Ranking of desirability and feasibility for draft strategic options

	Desirability	Mean score	Consensus	Feasibility	Mean score	Consensus
1	Promote engineering as a people-focused, problem-solving, socially beneficial discipline	9.42	high	Promote engineering as a people-focused, problem-solving, socially beneficial discipline	8.03	medium
2	Work to enhance the presence of engineering and the 'made world' at all stages from primary level upwards	9.08	high	Work to enhance the presence of engineering and the 'made world' at all stages from primary level upwards	7.00	medium
3	Ensure that apprenticeships and other technical pathways not only deliver high-quality technicians but also enable individuals to progress to the highest levels of engineering	8.95	high	Broaden routes into engineering degree courses by having more flexible entry requirements	7.22	medium
4	Broaden routes into engineering degree courses by having more flexible entry requirements	8.50	high	Ensure that apprenticeships and other technical pathways not only deliver high-quality technicians but also enable individuals to progress to the highest levels of engineering	6.89	medium
5	Maintain a broad curriculum for all young people up to the age of 18	8.46	high	Use Design & Technology as a platform for integrating STEM and creative design and for raising the profile of engineering in schools	6.50	medium
6	Shift the emphasis in STEM teaching towards problem-based, contextualised learning and the development of engineering thinking skills	8.32	medium	Shift the emphasis in STEM teaching towards problem-based, contextualised learning and the development of engineering thinking skills	6.50	medium
7	Nurture engineering ways of thinking in all young people to enhance general life skills	8.21	medium	Maintain a broad curriculum for all young people up to the age of 18	6.08	medium
8	Create more spaces and opportunities for young people to make things by working collaboratively in interdisciplinary groups	8.13	medium	Create more spaces and opportunities for young people to make things by working collaboratively in interdisciplinary groups	6.00	high
9	Use Design & Technology as a platform for integrating STEM and creative design and for raising the profile of engineering in schools	7.3	low	Nurture engineering ways of thinking in all young people to enhance general life skills	5.87	low
10	Change the structure of school education to embed engineering explicitly at all levels	6.79	low	Change the structure of school education to embed engineering explicitly at all levels	3.97	medium

“”

As a society we have become passive recipients and consumers of amazing engineering creativity.



BIG IDEAS: THE BIG ISSUES

Though the focus of this work was to identify ways to encourage more young people into engineering, a number of broader themes emerged from the Big Ideas workshop presentations and discussions, feedback after the meeting, survey and the responses to the early versions of the goals. These themes raise meaningful questions, beyond simply how we address a shortage of expertise and skills.



There HAS to be a shift away from the planes, trains and automobiles being seen as 'this is engineering' ...girls especially are more likely to become engaged.

— *Workshop participant*

IMPORTANCE OF ENGINEERING AND TECHNOLOGICAL LITERACY FOR ALL

Outside of the sector, there is a limited understanding of what engineering actually is. In part, this may reflect the perception that, technologically, anything is possible. As a society, we have become passive recipients and consumers of amazing engineering creativity. Yet at the same time, we exhibit a diminishing wonder about how a new solution might come into being or how an idea may have been formed.

There was a good deal of consensus at the workshop on the fundamental need to promote wider engineering literacy. The main reason given was to foster a greater appreciation of engineering in society as a whole rather than targeting just those most likely to consider a career in engineering. This was felt to have two benefits. On the one hand, it would create a more engineering-literate population with a greater appreciation of engineering and also equipped with valuable problem-solving skills potentially applicable in many walks of life, professional and personal. On the other hand, the enhanced visibility of engineering would increase the size of the pool from which future engineers could be drawn.

In a technologically dependent world, it was felt that improving engineering and technological literacy would be greatly beneficial both to individuals and to society as a whole, particularly if national leaders and influencers had a more rounded understanding of the principles and values of engineering.

HOW ENGINEERING IS PORTRAYED: PUTTING PEOPLE CENTRAL

Engineering is still predominantly defined by its products. In recent years, several organisations have attempted to shift this perspective, focusing more on engineering as an ‘enabling’ discipline and a social one too – providing the capacity to improve the world. Such moves were heartily endorsed at the stakeholder meeting. In particular, there was a recognition that more could be done to position engineering as a humanitarian vocation, creating opportunities to make peoples lives better. This was widely felt to be a crucial way to increase the appeal of engineering to young people, particularly those who are less obviously drawn to the conventional archetype of an engineer but who may otherwise have a real interest in the discipline or associated areas.

In particular, it was felt that aligning engineering with human values and stressing its potential to improve wellbeing could be an effective way to appeal to girls.

As well as providing an alternative and more engaging perspective for young people, this shift in emphasis might also have a beneficial effect on practising engineers.

A few notes of caution were sounded. Some queried the extent to which this view of engineering actually reflected the day-to-day life of engineers.

And it would also be important not to lose sight of the fact that the aspirations were achieved through specific ways of thinking and acting.

SOCIAL JUSTICE AND MOBILITY

A further important aspect of engineering was also identified – its ability to promote social mobility and social justice. Engineering is essentially meritocratic – the quality of engineering can generally be assessed objectively. Moreover, as a field it should be open to all with the appropriate aptitudes, and provides a route to a rewarding and high-status career, irrespective of social origins.

In practice, however, the lack of visibility of engineering means that entry into engineering careers is dominated by those with an existing connection, such as having an engineer in the family or those benefiting from effective careers guidance at school. Enhancing the attractiveness of engineering careers, and broadening the range of individuals pursuing them, could make a significant contribution to social mobility.

This will require engineering to focus on its inclusivity – especially on its poor representation of women. Conversely, there is an opportunity to consider how the power of engineering can be exploited to create a fairer society.



This is really important to promote engineering to a more diverse cohort.
— *Workshop participant*

IMPROVING COMMUNICATION

The stakeholder survey revealed that engineers believe they are doing a poor job in communicating the value of engineering and what engineers actually do. Placing 'people' centrally when talking about what engineering is for, was widely felt to be crucial. However, this will be dependent on the engineering sector becoming more effective in how it communicates.

Consistent with the general theme of enhanced engineering literacy, there was a strong emphasis on the need to enhance the public profile of engineering.

A lack of engineering role models and the desirability of having engineers represented in popular dramas such as soap operas was one popular theme, though there was also a degree of scepticism surrounding how effective this would be. Doubts were also raised about the ability of, and over-reliance on, high-profile events such as the Big Bang Fair to convey the right messages about engineering.

There was widespread support for embedding a deeper appreciation of the value and opportunities offered by engineering. As well as broadening appeal to a wider constituency of young people, this greater visibility would also better enable engineering to compete with other high-status professions.

IS ENGINEERING A BROAD CHURCH OR A NARROW PRIESTHOOD?

A key challenge to communicating engineering seems to be the lack of consensus of what engineering actually is. The popular perception is that almost anyone engaged in a practical trade or profession is an engineer. Many professional engineers however adhere to the principle that 'true' engineers are only those who have achieved chartered status, and that maintaining the high status of engineering is essential to attract the brightest and the best.

There was significant disagreement about whether the conflicting views of engineering as a broad church or a priesthood were a problem or not. Some saw the broad church model as an advantage.

An elitist approach could also be seen as off-putting to many young people, important when the profession needs to attract more people (and more diverse people). The broad church concept also provides opportunities to embrace engineering technician roles, for which there is also strong demand among employers. Valuing a diversity of roles, and not coming across as only interested in the academic elite, is not incompatible with professional engineering institutions maintaining high standards for chartered status.

However, engineering institutions have traditionally been strongly focused on promoting the status of their professions, with the existence of an elite, seen as synonymous with quality and rigour in the sector. Equally, a 'priesthood' model is attractive to some young people. The stakeholder survey uncovered concerns among engineers that the profession was not viewed as high status. There may therefore be resistance to ideas where the status of engineers may in some way be watered down. Reference is often made to countries such as Germany, where the status of engineers is felt to be higher.

There were some calls for an internal debate among the engineering profession about what the true definition of an engineer should be. Some felt this should be the starting point for any wider communication, to ensure that the community was committed to a consistent set of messages.

ENGINEERING IN THE CURRICULUM: YES OR NO?

The idea that engineering should be explicitly introduced into the curriculum polarised opinion. Some felt this was the ideal solution. Others were supportive in principle but were not convinced it was a practical option. However, it was pointed out that significant change is possible, with computing being highlighted as one example. Others were less convinced that it was necessary. An alternative model would be to consider how an engineering perspective could be embedded into other subjects rather than being seen as a standalone subject.

Whatever the pros and cons, there was near-universal agreement that it would be extremely difficult to implement. Nevertheless, that was also the position in the USA, where substantial progress has been made, and is the most common response in other countries, irrespective of its perceived benefits.

Engineering is not universally taught in schools in the UK and, as our research shows, is poorly understood among the general public. Should such a fundamental part of our economic and cultural life be left to informal learning, family ties or chance encounters? Or should it form part of compulsory education? If the latter, how might it appear in the curriculum?

Without necessarily introducing engineering specifically into the curriculum, opportunities were already thought to exist to raise the profile of engineering in the education system. The number of students taking engineering qualifications is vanishingly small (in England in 2012, 1,816 pupils sat the GCSE in engineering, 1,046 took electronics and 105 took manufacturing; 225 pupils studied engineering at A level). Although efforts could be made to promote these specific qualifications, the mood of the workshop was that the natural home for engineering is within the science, mathematics and/or D&T curricula.

Some suggested that explicit engineering content, taught and assessed, was the best way to address the visibility problem, following the lead set by the USA. Others argued that, even if it were desirable, the practical obstacles were simply too great.

As Dr Miaoulis was at pains to point out, “it can't be done” was also the most common initial response in the USA. Certain groups responded with outright hostility, particularly those who felt threatened that their area of the curriculum was likely to lose out. The USA is perhaps living proof that, actually, it can be done, and may also provide a model illustrating how it can be done.



In 2012, only 225 pupils studied engineering at A-level in England.

EMPHASISING THE 'MADE' WORLD

The Big Ideas survey found support for the assertion that the natural world receives greater attention in schools than the 'made' world. Addressing this imbalance would have the potential to raise the profile of engineering and enhance engineering literacy. Some felt that, while it may not have the visibility it deserves, the 'made' world does feature in education, providing a platform on which to develop engineering concepts.

HELPING YOUNG PEOPLE TO THINK LIKE ENGINEERS

It is widely recognised that there are specific ways of thinking associated with science, integral to the scientific method. Education in secondary schools has not traditionally placed great emphasis on these ways of thinking, generally focusing instead on the body of knowledge that is the 'product' of science. Engineering has much lower visibility than science in schools, but again the conventional focus has been on products and less so on the methodologies of engineering or the thought processes of engineers.

The visibility of engineering could also be enhanced within existing educational structures by the greater use of approaches that develop the ways of thinking characteristic of engineers. This was the rationale for the Royal Academy of Engineering sponsored report: *Thinking like an engineer – Implications for the education system*. The Big Ideas survey confirmed that these thought processes well reflect perceptions about the habits of mind exhibited by engineers, and that they are good skills to teach young people. Their potential application outside engineering was seen as particularly beneficial.

The Big Ideas survey found significant agreement that these six ways of thinking effectively capture engineering thought processes, and would be valuable skills to teach in schools. Again, promoting this approach would provide a way to boost the visibility of engineering in schools without necessarily changing the curriculum.

Some respondents, however, commented that the engineering habits of mind as defined were somewhat generic, although this would not affect their application in non-engineering domains. Questions were raised about the extent to which these 'habits' were derived from the distinctive thought processes of female engineers or how they engage with values or students' intrinsic interests.

WHAT IS THE POTENTIAL FOR MAKING; AND MAKING SPACES FOR MAKING?

The concept of 'making spaces' in schools was very positively received. Currently 'academic' studies were felt to be more highly prized than practical work, a legacy of a long history in which academically less able young people were channelled towards practical subjects. The general move away from practical work in schools was lamented. Ironically given the current focus on the three Rs (reading, writing and arithmetic), it was pointed out that the second 'R' was originally 'wrighting' – creation by a skilled craftsman.

Existing science labs or workshop spaces were seen as potential locations for making spaces. The possibility of developing more community-oriented making spaces was also raised, perhaps in collaboration with 'maker movement' organisations, although the logistical challenges would be great.

On the other hand, it was also suggested that 'making' needed to be seen in context if it were to be a more authentic representation of engineering. Making should therefore not be seen in isolation but in the context of problem-solving.

'Making spaces' were seen as offering the potential for joint project work for students studying different subjects, enabling collaboration between STEM and design. Practical work could be just as much a part of chemistry, art, geography or history as physics and D&T. Furthermore, such spaces would create more opportunities for collaboration between groups – such as physics students and those with an interest in design. The stakeholder survey showed how parents were least in favour of this approach, suggesting that any attempt to adopt this approach would need to be persuasively communicated.

More broadly, adoption of the 'making spaces' idea should be seen as part of wider moves to rehabilitate and value practical work of all kinds, particularly more open-ended practical investigative work.

CONTEXT FOR DISCUSSING CAREERS

Better careers education would almost certainly increase uptake of engineering. Young people obtain much of their careers information from their teachers, but teachers often have limited experience of available opportunities. Enhancing the visibility of engineering within schools, through curriculum change or by embedding of engineering into existing practices, could provide opportunities to discuss the range of engineering-related careers available, and also justify enhanced professional development support in this area.

There is considerable interest in engineering careers at a young age, among students of varying levels of ability. Clearly, this early interest is not being exploited effectively. As well as a poor awareness of what engineering actually entails, perceptions of narrowly defined entry routes may be major disincentives, excluding those unable or unwilling to consider maths and physics A levels and equivalent qualifications. Though some courses do offer some flexibility, this is not widely signalled to school students and their parents. A better understanding of the broad range of engineering-related careers – including chartered engineer but also engineering technician and design-oriented roles – could help a wider range of students make more informed choices and identify appropriate professional and technical routes into careers.

Government and employers use a 'pipeline' analogy to model the process of producing an engineer. The pipe is said to be 'leaky' at the transitional phases such as the move from school to training or study – so there is 'wastage' along the way. It's a powerful metaphor and works well when attempting to describe the problem from the perspective of an employer or an engineer, but less likely so in defining how a teacher might see the educational process. For them, 'wastage' is simply about students making different choices. The leaky pipeline is also unforgiving – failure at any point is irrevocable.

Adopting some of the Big Ideas would amend this model so that loss from the system might be rerouted elsewhere. It would also address perceptions that engineering was a lifelong vocation opted into at 14. In essence:

- There's more than one destination
- There's more than one way there
- Have we made the destination seem attractive so people want to go there?
- Have we given them adequate directions?
- Have we made the journey possible?

THE BENEFITS OF PROBLEM-BASED LEARNING

Problem-based learning is well suited to engineering education, and was strongly supported both in workshop discussions and feedback and in the Big Ideas survey. Problem-based learning provides an opportunity to embed engineering into schools without necessarily changing the current curriculum.

If as stated by Mark Miodownik (**page 14**), 'making and creating things generates understanding, and makes theory relevant', so does exposing students to solving problems where the outcome and the precise strategy for doing so, are unknown. How does our current school education currently draw on this? A multitude of more innovative teaching (and assessment practices) can be envisaged, but problem-based learning is particularly suitable for conveying the essence of engineering practice and teaching engineering habits of mind.

Problem-based learning is increasingly popular in universities and was widely seen as being a potentially important way to enhance the learning experience. The concept is not new in UK schools, but the introduction of a national curriculum, widespread testing and competition between schools may have diminished the appetite for discovery-based learning. The Big Ideas survey found considerable support for the approach. Nonetheless, the need to equip teachers with the appropriate skills was also recognised.

Indeed, the degree of required change was seen by some as a major obstacle and some argued forcefully for more conventional approaches.

The inference here is that the science and other STEM subjects as construed in our current education system are at odds with open-ended investigative methods.

The main advantage of problem-based learning is that it provides context to theoretical knowledge gained in subjects such as physics and mathematics – often criticised for delivering an education too remote from students' everyday lives. Further, 'making spaces' could provide a location in which practical problem-based learning could be applied.

STARTING EARLY: THE IMPORTANCE OF PRIMARY

A repeated theme in the workshop was the importance of embedding engineering early in life. It was suggested that young children's natural curiosity and keenness to play and experiment made them 'proto-engineers'.

It was strongly argued that formal secondary schooling does much to dissipate these natural tendencies. Nevertheless, primary school provides fertile territory in which to begin developing engineering literacy, building on the innate natural tendencies of young children. The sparks lit at this age could last a lifetime.



I think problem-based [learning] tickles curiosity and engineering thinking is often there from childhood, but it is killed too early on in education.

— *Workshop participant*

CREATIVITY, CROSS-DISCIPLINARY COLLABORATION

“The difference between science and the arts is not that they are different sides of the same coin... or even different parts of the same continuum. Rather, they are manifestations of the same thing... They spring from the same source. The arts and sciences are avatars of human creativity.”
Dr Mae Jemison, first female African-American astronaut to travel in space.

The engineering habits of mind model emphasises the importance of ‘creative problem-solving’. Engineering is at heart a systematic, rigorous discipline. It also requires creative thinking to formulate a problem and to conceive of possible ways of solving it. Design is increasingly recognised not as an optional extra but as fundamental to the success of an engineered product.

The Big Ideas survey revealed that creativity was seen as central to the teaching of STEM subjects, and nurturing creative thinking a key goal of STEM teaching. Problem-based learning may provide a better context in which creativity can be developed. An important aspect of creative thinking is the ability to conceive of possible alternatives, yet the compartmentalisation of subjects inevitably limits capacity for divergent thinking. Cross-disciplinary collaboration, for example in making spaces, could again provide a context in which to develop creative skills in joint projects.

THE PLACE OF DESIGN AND TECHNOLOGY

One of the themes generating most discussion was the potential role that design and technology (D&T) could play. One big advantage is that it already has a presence within schools, potentially providing a foundation on which to build engineering visibility.

Furthermore, the subject has the potential to provide the link between science and arts/humanities. On the other hand, it was also recognised that D&T is currently suffering in many schools. Despite still being one of the most popular non-compulsory subjects at GCSE, it faces considerable pressures, including from the English baccalaureate, which some at the workshop felt was squeezing subjects not included in the accountability measure.

Another important issue is D&T's historical legacy and other obstacles were identified to the greater focus on D&T. The name of the subject also raised considerable debate. Some suggested that the word ‘engineering’ should be included specifically in it, or that the importance of ‘creativity’ should be recognised in its name.

Sir James Dyson describes D&T as “...a phenomenally important subject. Logical, creative and practical, it's the only opportunity students have to apply what they learn in maths and science – directly preparing them for a career in engineering.” He then challenges policy-makers not simply to protect the subject but to make sure it appeals to the “brightest of young minds”.

The debate surrounding D&T education draws on three interlinked themes: status, rigour and history. For many politicians, parents and teachers, D&T is synonymous with limited aspiration and the old image of woodwork, metalwork and domestic science. Despite half a century having passed, the historic bipartite education continues to cast a long cultural shadow – reflecting a system that limited aspiration for most. Typically, pupils went to a secondary modern if they had failed to make it to the (academic) grammar school.

DELAYING DECISION-MAKING

Creativity, design and manufacturing are now recognised to be of huge economic, cultural and entrepreneurial significance, yet the accountability system for schools remains uncomfortable with D&T. As reflected at the Big Ideas workshop, despite the subject being seen as a potential focal point for STEM activity, doubts were raised about the desirability (rather than feasibility) of D&T playing a more meaningful role in school outcomes. This may reflect wider concerns about the subject's perceived status or the thoughts on the proportion of the current cohort of D&T teachers who were felt to be conversant with new technology.

There is undoubted potential to introduce engineering concepts more specifically into D&T courses of study. It may, for example, be a subject in which engineering thinking habits could be nurtured. But it can only be effective if changes are made to raise its profile and to stress to pupils, parents, employers and politicians the subject's rigour and relevance to work. Head teachers and school governors must put their weight behind the subject, despite its lack of core status. Meanwhile, D&T teachers must incorporate better use of contemporary digital technologies into their courses. The changing nature of the subject demands professional updating so that teachers have the confidence to make use of new and emerging technologies in their lessons. There is a particular need for greater D&T expertise in primary schools – and in all education sectors, an acknowledgement that resourcing D&T is more costly than most other subjects, but well worth the investment.

There was strong support for delaying decision-making in subject choice, seen as an important way to boost general engineering literacy and to develop more rounded engineers – as well as delivering a more rewarding education.

It was recognised that, although there is widespread support for broadening young people's educational experience, change would be difficult to achieve. Obstacles include the current focus on mathematics and literacy in the English system – using results in a narrow range of examinations as a measure of individual school success shapes what is taught and how. Recent changes to accountability measures such as 'Progress 8' and 'Attainment 8' have been introduced to mitigate against a narrowing of subjects, but schools are still under pressure for their pupils to achieve good results in a small suite of 'academic' subjects included in the English Baccalaureate measure.

While there was good support for the idea that pupils should not be forced to specialise at relatively young ages, there was less certainty about whether increasing the age before subject choices are made would increase the numbers of young people pursuing engineering careers. In the Big Ideas survey, the balance of opinion was that it probably would be beneficial in this way.

Several bodies and notable individuals have called for a broadening of the UK education system and introduction of baccalaureate-type approaches. In June 2015, for example, the Royal Society argued that all students should study science and mathematics until age 18. The Institution of Mechanical Engineers has also argued for a baccalaureate system. In July 2015, Neil Carmichael, chair of the Commons Education Select Committee, suggested there was 'a strong case for a baccalaureate beyond 16' to boost maths education.

It has also been suggested that less early specialisation would lead more young people to choose engineering, not least because fewer would have lost opportunities due to dropping science or mathematics at an early age, and more would have been able to combine STEM study with other subjects in which they excelled. Nevertheless, the Big Ideas survey (and respondent feedback) raised some doubts about the extent to which a broader education would increase the numbers of young people (particularly girls) studying engineering. It is also debatable whether young people would be in favour, reinforcing the need for a more engaging teaching of science and mathematics. On balance, however, the benefits would seem to significantly outweigh any disadvantages, for engineering and society more generally.

BROADENING ENTRY: THE NEED FOR MATHEMATICS

Entrance onto many engineering degree courses has typically required a good pass in mathematics at A-level or Scottish Higher Grade – particularly for Russell Group universities. The Big Ideas workshop presented an opportunity for participants to ask whether this entry requirement was essential – could university courses, for example, offer fast-track mathematics in the first year for academically high achieving students who did not take mathematics at A-level or equivalent? This idea gained traction over the workshop's duration.

In essence, how might we widen the access to engineering degree programmes, particularly to those who might arrive at engineering through routes other than academic STEM subjects, such as through design?

Eliminating the need for mathematics at A-level or equivalent for university entrance could potentially make the profession accessible to larger numbers of young people, including young women who are currently under-represented in mathematics classes in post-16 education. However, it was recognised that there would be potential concerns about the quality of graduates following this pathway.

Although an interesting approach, it is acknowledged that students would find their first year challenging and require significant support to develop their maths skills and 'maths confidence'. There are, of course, many universities that do not require mathematics A level (or Scottish equivalent) as an entry qualification to engineering degrees. However, recent Royal Academy of Engineering research highlighted that students with no mathematics A-level were significantly more likely to discontinue studies after their first year of an engineering degree compared with those who had attained well in the subject at A level. Introduction of a baccalaureate-type system might prove beneficial in this area, providing more opportunities for young people to maintain a wide set of academic interests and still be able to pursue higher engineering study.

Entry criteria into higher education institutions are, of course, not within the gift of the school education system. Nevertheless, if universities were to adopt this approach more widely, this could have a significant impact on the careers and study advice given by teachers to young people.

The course entry demands of universities are the cornerstone of educational change, since they determine what happens in school. It is likely that greater flexibility here would make the other Big Ideas more feasible. The challenges this poses include:

- Would the removal of the mandatory mathematics qualification affect the quality of engineering in the UK?
- Would higher education institutions be prepared to adapt their course content and teaching?
- How well set up are higher education institutions to do this?
- Would professional engineering institutions require the same output standard of mathematics for graduates on accredited engineering degree programmes or would they be prepared to reduce requirements?

BROADENING ENTRY: THE ROLE OF APPRENTICESHIPS

Many of today's senior engineers followed the apprenticeship career route. In the UK, following a period of decline in which the graduate pathway became the principal route to chartered status, there is now growing interest in apprenticeships, both as a way of delivering more skilled engineering technicians and as a possible route to chartered status.

Engineering is almost uniquely placed in having technical routes to registration that run alongside academic qualification. Historically, the sector has done much to enable talented individuals from all sectors of society achieve a fulfilling and rewarding career. Many of today's industry leaders started out in technical apprenticeships, working their way to the top, in some cases with skilled technical qualifications, and others with degrees.

The apprenticeship approach was widely supported by attendees of the workshop. Young people should be made aware of a spectrum of engineering-related careers, graduate-level and pre-graduate-level, the latter potentially leading to chartered status. It is, however, important not to convey a sense of a two-tier workforce, composed of an elite of chartered engineers and 'lower-status' technicians.

On the other hand, potential obstacles were highlighted, including the limited ambition and support offered by engineering institutions and the practical challenges of ensuring consistent high-quality apprenticeship provision and vocational training away from the workplace.

Government, employers and educationalists need to ensure that engineering apprenticeships are presented as rigorous valued training options, equal in stature to academic paths. Flexible movement between technical and academic pathways would accommodate differences in preferred learning styles and maturation. They would also offer some level of reassurance to many that they can change direction if they feel they have made the wrong choice. Industry and policy-makers should ensure that technical training is seen as valued, fulfilling and well-paid, as both a final destination and a stepping stone for further career progression.

Since gender bias in engineering apprenticeships is even greater than that seen in undergraduate degree courses, more needs to be done to make them appealing to young women and people of under-represented social and cultural groups. Many of the proposals made in this report would help to address this question, including a better understanding of the experience of working in the modern workplace – and ensuring that the modern workplace is a welcoming environment for all.

AN AGENDA FOR CHANGE

The rationale for the Big Ideas project was the fact that decades of schemes to promote engineering to young people have not led to notable expansion in recruitment. The UK is not producing enough engineers or sufficiently diverse engineers – most obviously, precious few female engineers but there is also significant under-representation from black and minority ethnic groups. This is not a new issue, suggesting that past approaches have had minimal impact and more radical solutions are needed.

The different strands of the Big Ideas project generated many views and much debate about how to increase the numbers and diversity of young people studying engineering post-18 and pursuing engineering-related careers. Although science and STEM learning in UK schools has received plenty of attention, engineering in the schools system has been examined much less thoroughly. In recognition that this is less well-trodden ground, Big Ideas deliberately aimed to be agenda setting and broad in scope.

AN EDUCATION FOR TECHNOLOGICAL LITERACY

Although the Big Ideas workshop focused on schools education for engineering careers, a general understanding of engineering and technological literacy emerged as a key theme. While promoting engineering as a career is applicable to a large minority of young people, and a priority for those working in the sector, engineering and technology literacy is essential **for all** young people. Some of society's biggest challenges – sustainable energy generation, population growth, the outcomes of the communications revolution and an ageing population – are making us increasingly reliant on engineering and technology. Access to technology can be profoundly empowering. The fruits of engineering ingenuity present exciting opportunities, as well as major challenges, and young people will need to be equipped to make informed choices about how they wish to live their lives and how engineering is used to benefit society.

Big Ideas discussions suggested new ways of looking at engineering education. In particular, attention focused more broadly on the overarching aim of improving engineering and technological literacy of the population as a whole. One goal of this approach would be to create a population with a greater appreciation of the importance of engineering and technology and the contributions they make to modern society. It would be a population equipped with problem-conceiving and problem-solving skills applicable in both personal and professional walks of life.

This means changing narrative rather than removing content. Crucially, this approach would also increase the reservoir of individuals available to undertake further study of engineering and pursue engineering-related careers. It would create more fertile ground in which engineering could flourish – a society in which engineering was more highly valued as a discipline, career opportunities more widely appreciated, and engineering seen as a more attractive career choice.

Adopting this wider perspective on engineering and technological literacy also encourages a more pluralist view of how young people can pursue technical and professional routes to engineering and of the range of engineering-related roles that are available to them. Rather than thinking solely of a linear route – like a conveyor belt or pipeline – how might we establish a range of pathways by which young people can reach a variety of professional destinations?

A key lesson from the Five Tribes report was that young people differ significantly in their attitudes to technology and engineering. Hence a focus on engineering and technological literacy should not overlook the fact that the approaches adopted to build such literacy will need to be tailored to the needs and interests of specific groups of young people.

GOALS

Within this broad framework, a series of goals have been developed to map out how the UK schools education system could (i) enhance technological literacy; and (ii) enhance professional and technical routes into engineering.

Feedback from workshop participants and other leading thinkers, as well as the results from the Big Ideas stakeholder survey, led to the final list of goals summarised below.

1. Promote engineering as a people-focused, problem-solving, socially beneficial discipline
2. Work to enhance the presence of engineering and the 'made world' at all stages from primary level upwards
3. Ensure that apprenticeships and other technical pathways not only deliver high-quality technicians but also enable individuals to progress to the highest levels of engineering
4. Broaden routes into engineering degree courses by promoting more flexible entry requirements
5. Maintain a broad curriculum for all young people up to the age of 18
6. Shift the emphasis in STEM teaching towards problem-based, contextualised learning
7. Nurture engineering ways of thinking in all young people
8. Create more spaces and opportunities for young people to design and make things particularly by working collaboratively in interdisciplinary groups
9. Use Design and Technology as a platform for integrating STEM and creative design and for raising the profile of engineering in schools
10. Change the structure of schools education to embed engineering explicitly at all levels

PROMOTE ENGINEERING AS A PEOPLE-FOCUSED, PROBLEM-SOLVING, SOCIALLY BENEFICIAL DISCIPLINE

There was near-universal support for the idea that engineering should stress its capacity to enhance quality of life and focus more on people. Engineering has tended to be pictured through the lens of its outputs – the ‘planes, trains and automobiles’ view of engineering. This may appeal to many STEM devotees identified in the Five Tribes report, but will not engage other groups who also need to be drawn into engineering.

There is much greater scope to stress how the products and processes of engineering – and engineering thinking skills – can be used to achieve humanitarian, socially beneficial or other desirable goals. A car can be seen as a marvel of modern engineering or, alternatively, as a way in which a wheelchair user could be helped to enjoy the countryside. Learning engineering skills, and understanding how to apply those skills, is fundamentally empowering. The scope to apply these skills is almost limitless. An inspiring message for young people is how engineering provides the intellectual and practical tools to change the world for the better.

Several organisations have already recognised the value of this approach – evidenced in the straplines of bodies such as the UCL Faculty of Engineering Sciences (‘change the world’), the Institution of Mechanical Engineers (‘Improving the world through engineering’) and Royal Academy of Engineering promotional materials (‘Engineers save lives’). To be effective, these ambitions should be conspicuously evident in the activity of these organisations – and in their wider narrative.

Incorporated into this approach is a deliberate emphasis on people. The engineers of the future need to place people at the heart of everything they do – from responding to social priorities and the major challenges that societies face to developing solutions that reflect users’ needs and desires, rather than expecting users to adapt. These principles are, of course, second nature to many already, but need to be further embedded into the engineering psyche.

This priority also touches upon the important issue of how engineering communicates with wider society and particular audiences within it. It is clear that the engineering profession could do more to communicate both its contribution to society and what engineering involves. There is a need for a clear framework to support more effective communication that engages better with the interests and values of groups other than just those with an existing interest in the physical sciences and their application.

Indeed, Professor Averil Macdonald has argued that STEM careers are perceived by under-represented groups such as girls as ‘not for people like me’^[8]. A major challenge for engineering is to understand the values and aspirations of different groups of younger people and to align messages so that engineering is seen as a discipline and a career that resonates with more young people, and hence comes to be seen as a profession ‘for people like me’.

Engineering has traditionally focused on nouns – the products of engineering. Communicating what engineers do however needs a focus on verbs. A greater emphasis on adjectives could also help engineering appeal to girls, as could stressing aspects of engineering – team work, creativity, what goals can be achieved through engineering – that are likely to resonate more with them.

This conceptualisation of engineering will also call for further debate on the priority given to protection of chartered engineer status. There is a strong argument to be made that, in an era when there is a need to attract more young people, focusing on elite aspects of engineering can be off-putting to many. Maintaining a loose definition of engineering, and stressing the diversity of engineering roles (including technician-level careers), may be more helpful. The specifics of chartered status can form part of more sophisticated discussions, highlighting one career trajectory and engineering niche after the conversation with young people has begun.

Actions for goal 1:

- **The engineering community including engineering institutions and the Royal Academy of Engineering should commit to a common shared narrative that highlights the human and social dimensions of engineering alongside its technical achievements.**
- **The profession should issue new guidance on how to communicate about engineering to be adopted by employers, volunteer engineers, communications professionals and educationalists that draws on the “Five Tribes” research.**
- **The Royal Academy of Engineering and the professional engineering institutions must push for a broader curriculum to age 18, implemented within the next ten years, as the main way to improve gender balance and to increase interest in technical training.**

WORK TO ENHANCE THE PRESENCE OF ENGINEERING AND THE 'MADE WORLD' AT ALL STAGES FROM PRIMARY LEVEL UPWARDS

One of the greatest challenges facing engineering is its lack of visibility in the UK education system. The rarity of engineering as a specific subject is one obvious aspect of this low profile, but more generally there is a perceived bias towards the natural rather than made world in school science teaching (a perception supported by the Big Ideas survey).

Introducing engineering explicitly into the UK school system would be a major challenge (discussed further below). An alternative and perhaps more tractable approach would be to work within existing educational frameworks, to identify ways in which teaching could focus more on the 'made' world and on engineering.

A key advantage of this approach is that it would require less fundamental change in the educational system. Indeed, the foundations may already exist in current teaching that focuses on made products. An important goal would be to grow these areas and to reinforce their connections to engineering when they are covered in schools.

Enhancing (STEM) teachers' confidence and ability to embed frequent references to engineering and engineering careers within their teaching would not only support their pupils in making choices but also emphasise that, although science and mathematics are the prevalent STEM subjects in schools, in the external world it is engineering and technology that predominate. Clearly, more needs to be done to raise awareness of the diversity and nature of career opportunities in engineering (and, as discussed above, more thought needs to be given to how these opportunities are portrayed, if they are to strike a chord with currently under-represented groups).

Actions for goal 2:

- **A new, time-limited, working group comprising each of the relevant subject associations needs to recommend how an improved focus on the 'made world' in both primary and secondary schools can practically be achieved.**
- **Employers of engineers must support a major programme of work such as the Engineering Talent Programme, that adopts the narratives here and improves the visibility of modern engineering and hence increases its attractiveness.**
- **Government should explicitly recognise the influence of teachers over the career choices of their students and promote this feature of the teacher's role. Supported by employers, it needs to deploy more resources to support teachers CPD initiatives aimed at increasing their understanding of modern engineering.**
- **Government should guarantee that high quality technical training routes will be included in performance measures for colleges and schools.**

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