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Engaging Future Engineers: Pedagogy, Policy & Practice

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***Abstract**:*

Despite being frequently misrepresented as outdated or old fashioned (IMechE, 2009, p1), engineering is increasingly called upon to deal with some of societies biggest challenges including those associated with climate, infrastructure and security. In order to meet such challenges there needs to be a supply of engineering talent able to turn its collective mind to what is required. Yet at a time when demands for engineers able to provide innovative solutions to contemporary problems is possibly at its highest, the profession is plagued by shortages and an inability to attract young people (DIUS, 2008; RAE 2008; NSF, 2009). Although the current situation appears critical, potential future shortages of engineers means that unless action is taken urgently, matters will get worse during the next 20 to 30 years.

For higher education, the challenge is how to change young peoples' perceptions of engineering in such a manner that it is seen as a worthwhile and rewarding career. This paper considers this challenge, looking in detail at why young people fail to view engineering positively. A theoretical framework outlining the various real-life barriers and drivers is proposed. A critical analysis of current policy and practice suggests that in order to promote engineering as a profession that young people ***want*** *to enter, both pedagogic and policy grounded solutions need to be found. By bringing together pedagogy and policy within an engineering framework the paper adds to current debates in engineering education whilst providing a distinctive look at what seems to be a recurring problem.*

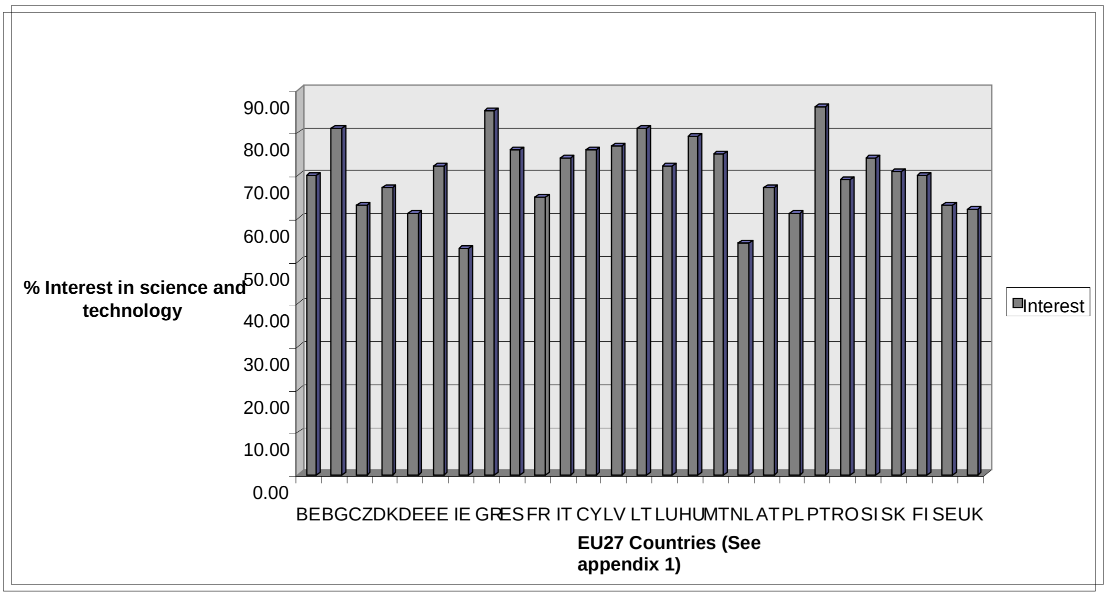
Introduction: Engineering in Contemporary Society

As a profession, engineering is increasingly called upon to solve many of societies contemporary challenges including those associated with sustainability, population growth and security (RAE, 2008). Indeed despite being frequently conceptualised as *outdated or old fashioned* (IMechE, 2009, p1), it is becoming increasingly clear that humanity is increasingly looking towards engineering to provide innovative and forward-thinking solutions in order that such problems be addressed. Conversely, whilst innovation is generally conceived to be integral to engineering, public misconceptions regarding exactly what the profession constitutes represent a real barrier – both in terms of general awareness and recruitment of young people into engineering programmes. A recent government report defined engineering as, "*where science meets society and where scientific advances impact on the health, wealth and wellbeing of individuals"* (DIUS, 2008). From this perspective, it may be argued that engineering represents a linkage between society and science, bridging theory and practice. What is not in doubt is that engineering comprises a complex and multifaceted profession which covers a wide array of different disciplines and areas (Engineering Australia, 2010). As such, it is inevitable that engineers have a major role to play in building our future society, a point highlighted in report about climate change which noted "*the engineering profession is an important stakeholder in enabling the world to adapt to climate change [ ] engineers themselves need to be provided with the opportunities to respond to the challenges*" (IMechE, 2009, p25).

It seems clear that if global society is going to meet such challenges, there needs to be a pool of engineering talent able to develop groundbreaking and pioneering solutions. However, at a time in history when the demand for qualified engineers able to do this is possibly at an all time high, the profession is beset with what seems for all intents and purposes to be an inability to attract young people (DIUS, 2008; RAE 2008; NSF, 2009). This results in severe skills shortages. Although superficially, the answer to such problems appears to be fairly simplistic, that is to train more young engineers, the Higher Education Sector is experiencing severe difficulties attracting adequately qualified young people onto undergraduate engineering programmes (RAE, 2007). Moreover, whilst the current situation is undoubtedly dire, unless urgent action is taken to remedy the situation, matters will deteriorate markedly over the next two decades – resulting in unprecedented shortages in the number of engineers. Furthermore, predicted shortfalls in the numbers of students expected to enrol on undergraduate engineering programmes over the next 10 to 20 years, will seriously test future governments' ability to retain and sustain local, national and global infrastructures and communities (RAE, 2008).

From an educational perspective, whilst many undergraduate engineering programmes have been transformed and updated in order to meet the changing needs of engineering students (see for example, Miller et al, 2005; Machika, 2007), it would seem that one of the factors shaping such grim predictions is that engineering is not a preferred subject of study for the current generation of young people (Gallup, 2008). Indeed, in a recent study whereby young people living in the EU were asked whether they would consider studying engineering in order to get a job, over two thirds, (71%), answered no (Gallup, 2008). This differs somewhat from interest in science and technology – both of which are areas young people are more disposed to as a viable career option. Figure 1, below, shows interest in science and technology across the 27 countries of the EU.

<u>Figure 1: Young people's interest in science and technology across the EU27 countries (Data from Gallup, 2008)</u>



Whilst interest in science and technology is relatively high, attention needs to be paid as to how to change young peoples' perceptions of engineering in such a manner that it is viewed as a worthy and relevant career. In considering why young people fail to see engineering in a positive manner, this paper suggests that in order to encourage young people to enter engineering, both educational and policy solutions need to be found. By drawing together education and policy within an engineering framework, the paper adds to contemporary debates in engineering education. In doing so it provides a critical examination of what is fast becoming a recurring problem.

Engineering Education: Placing in the 'E' in STEM.

With the global economy in a state of recession, and the engineering job market somewhat down (although still buoyant), the reasons why a young person, aged 14 to 18 years, should choose to study the prerequisite subjects of maths, science and technology necessary to enter an undergraduate engineering degree programme is of particular interest, particularly given EU Commission data indicating that engineering is viewed negatively by the younger generation (Gallup, 2008). Moreover, whilst many young people indicate an interest in science and technology (Gallup, 2008), a recent study found that two-thirds of Generation Y do not select to study STEM subjects out of a belief that to do so would restrict future career options (Science Council, 2008). In this context, Generation Y may be defined as the current generation of teenagers and young adults, aged between 11-25 years (Asthana, 2008). From the S would the Science Council report it would seem therefore, that when considering the views of young people, engineering is not alone amongst the STEM subjects in experiencing a negative public image. This negative image, which is compounded by a general belief that that STEM subjects are overly difficult or lacking in enjoyment (Science Council 2008), results in many young people being denied the chance to appreciate the breadth of opportunities <u>all</u> of the STEM subjects can offer.

A study undertaken by the Institution of Engineering and Technology [IET] (2008), further supports the findings of the Science Council (2008) study. In drawing upon the findings of an in-depth literature review critiquing just under 300 papers and articles, the IET reiterates evidence from the 1960's which suggested school pupils' perceptions of science are framed by the time they reach 12 years of age (IET, 2008). Five "switch-off" factors which negatively impact students' perceptions of studying STEM are identified: worries about limited career opportunities; concerns regarding teaching standards; beliefs regarding the degree of difficulty; the transition between primary and high school; and issues around gender (IET, 2008).

Pedagogical issues encapsulating teaching and learning approaches, lecture content, quality and standards are discussed in some depth in the literature and represent a notable challenge to those responsible for undergraduate level engineering education in particular (Booth, 2004; Maillardet, 2004), and across the Higher Education Sector more generally (Mc Kimm, 2009, Hounsell, 2009). Whilst student perceptions of the level of difficulty associated with studying Maths and Science at a higher level have long been the subject of debate (for further discussion see LMS, 1995; Jones et al, 2000), little attention has been paid in this area with regards to engineering education. Possibly the main reason for this is the fact that Generation Y have no little or no knowledge regarding what engineering comprises and therefore have no perceptions or expectations whatsoever.

Issues around transition for pupils moving from junior to high school are also widely researched with the period being identified as one of the most critical in a pupil's education (Huggins & Knight, 1997; Zeedyk et al, 2003). Factors determining the success of the transition period include, social class, culture and gender, with social class being particularly relevant in terms of those from a lower social class experiencing more difficulties and gender being relevant with considering the success of girls from middle class background (for further discussion see Lucy and Raey, 2002; Breen et al, 2009). Similarly, previous studies into the transition into higher education have found that this is also a crucial period in students' educational journey. Research suggests that many students are ill-prepared for university and that the transition is not helped by inadequate or misdirected support mechanisms in many Institutions across the Sector (Pitkethly and Prosser, 2001; Harvey et al, 2006). It may therefore be argued that both periods of transition are important within the context of engineering education particularly as engineering tends to be omitted from the school curriculum altogether. This means that university is generally the first time students are exposed to engineering as a discipline – consequently their support needs with regards studying are likely to be high.

Disparities reflective of gender issues are evident in both engineering, and engineering education. Such gender disparities are manifest in skills shortages as institutions experience increasing difficulties in recruiting sufficient numbers of undergraduate. The resultant negative impact to the wider economy is analyzed and discussed at length in the UK policy literature (Langlands, 2005; NSF, 2009; RAE, 2009). Although universities have a responsibility to address such inequities, the need to deal with gender disparities in engineering education extends far beyond the remit of higher education. Whilst the government has taken steps to raise the profile of engineering for women, with the introduction of organisations such as WISE (for further details see WISE, 2010), there can be little argument that schools need to promote the subject to girls and in doing so encourage them to consider engineering as a viable and exiting career option.

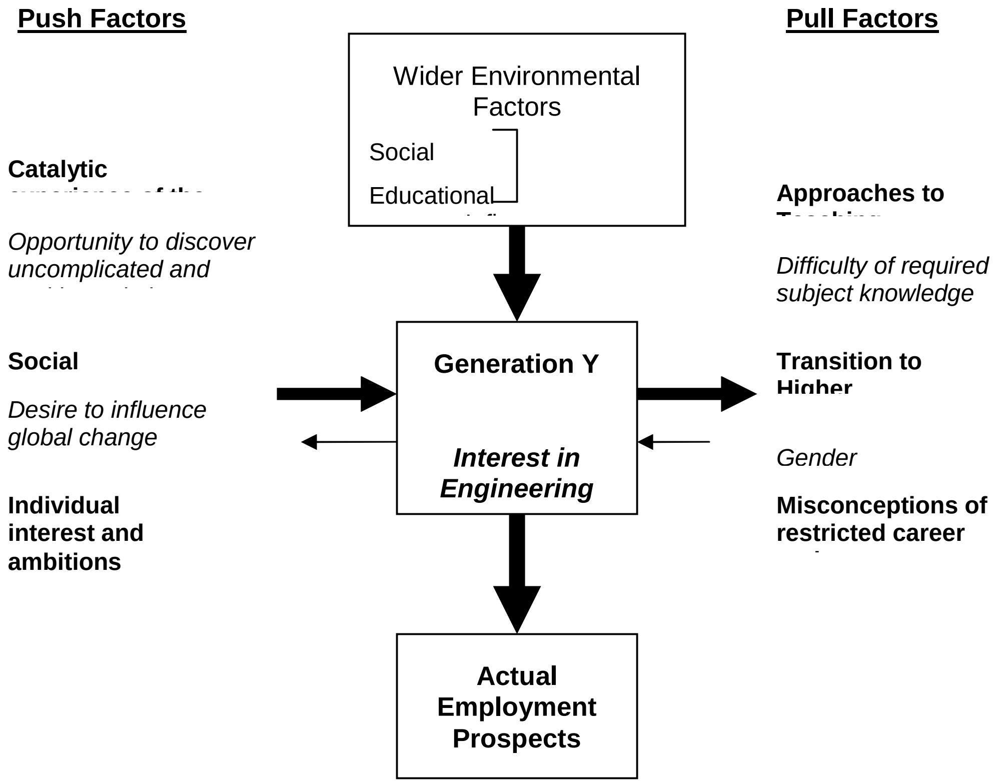
It would therefore seem that the five “switch off factors” articulated by IET (2008) represent a substantial challenge to engineering education; a challenge heightened by widely held views of engineering education as a difficult and somewhat elitist discipline (Science Council, 2008). Moreover, whilst across society there is much talk about science, a focus on engineering is rare – resulting in general misperceptions amongst young people (and others) with regards to what engineering is about and what an engineer does (RAE, 2007). Indeed, when considering the public standing of the profession, the situation is often made worse by the fact that many people confuse engineering and science – and fail to fully understand the differences between the two disciplines (NAE, 1998; RAE, 2007).

Conversely, in contrast to the IET (2008) report, earlier research by the Royal Academy of Engineers (2007) identified the key “drivers” encouraging people to engage with engineering. Five drivers were identified: the “wow” factor; simplicity; social responsibility; potential for large scale change; relevance to own interests and concerns.

The “wow factor” may be conceptualised as a formative experience or occurrence whereby an individual is suddenly struck by a new idea or way of thinking about engineering solutions, resulting in a quest for greater understanding. It captures the distinctiveness and excitement of engineering as a factor shaping positive change. Indeed, the larger the “wow factor”, the larger the publics’ engagement and interest. A second “driver” was the apparent lack of complexity of some engineering breakthroughs, which, when discovered, act to spark interest and promote the profile of engineering to a wide range of people. Social responsibility within engineering was also seen positively, particularly where the social and other benefits could be easily identified. Taking all these factors together, and building upon the contemporary interests and concerns held by the younger generation in respect of sustainability and the green agenda, is the idea that as a profession, engineering has the potential to bring about significant positive change to the world (RAE, 2007, pp 30-35). It is this idea that the profession needs to build upon in order to attract more young people.

Taking all the literature together it can be argued that Generation Y are influenced by a number of “push” and “pull” factors, which both encourage or discourage them from considering engineering as a career choice. Figure 2, below, provides a diagrammatic representation of these factors.

Figure 2: Attracting Generation Y into Engineering: Push & Pull Factors



Bringing together the "push" and "pull" factors on Generation Y with regards to interest in engineering, it would appear that at the moment the negative "pull" factors far outweigh the positive "push" factors in terms of general awareness and public perceptions. Thus, the need for the profession to balance the above factors is vital. Moreover, that there seems to be more barriers than incentives influencing Generation Y, makes the need for engineering to promote itself as a relevant and worthy forward-thinking profession of paramount importance.

Higher level engineering education provides students with the basics of engineering science. Within this context there is a clear need to provide students with sufficient awareness of how to apply the theories and principles learned in the classroom to real life engineering problems. One method of addressing this issue is for engineering education to align itself with industry – with courses arranged in such a manner so as to enable students to explore real-life industrial and social challenges. Pedagogical approaches utilised in contemporary engineering education, including problem-based learning (UNESCO, 2008) and CDIO (2009) act in part to address this issue. Although it should be noted that one difficulty with applied learning is that it requires time and commitment to develop and may prove costly in nature.

Pedagogy & Practice: A Matter of Practice

In many respects Generation Y are perceived to have significantly different attitudes and values in respect of work than did previous generations (Dessler, 2009). Indeed, it has been suggested that newly qualified graduates are the most high maintenance workforce in history, bringing with them not only a set of unique strengths and abilities, but also a number of challenges and issues (for further discussion see Hira, 2007; Zaslow, 2007). Furthermore, as the recession continues to impact the economy and job market, the apparent negative characteristics of Generation Y graduates (as being fickle, demanding, inexperienced and lacking loyalty) mean that across all sectors of society, 18-25 year olds that are experiencing the highest levels of unemployment (Tahmincioglu, 2009). It is the responsibility of Higher Education to help young people combat such negative stereotypical views and in doing so promote their employability and talents. From an engineering education perspective this may be achieved by promoting students' transferable skills and competencies, or by the introduction of a capabilities driven programme bringing together both generic and engineering skills and abilities (Bowden, 2004).

Within British society opportunities for young people to experience engineering tend to be limited within what often appears to be a "resource heavy **initiative** culture". Engineering education initiatives often depend upon an individual figure within a school and, more often than not, are based around a competition model. A written record of this initiative culture is evident in the UK Government's response to public concerns about the study of STEM subjects at a secondary level. Most notably the publication of the "Shape the Future Directory" (STEM Directories, 2008). This Directory lists around 80 engineering-focused initiatives for school children from primary through to secondary school and further education. Although it gives detailed information about the various engineering initiatives, the document itself does nothing to boost young people's knowledge-base of, or enthusiasm for, engineering. Moreover, whilst the initiatives are aimed at school children, the Directory itself is directed at teachers.

One particularly high profile UK initiative is the London Engineering Project (LEP, 2009). The country's largest engineering initiative, LEP is funded by the government. Currently operating as a 'Pilot' project, the programme aims to develop engineering talent in 5 of the poorer London Boroughs. Ultimately, its purpose is to increase future participation in engineering education at university level (RAE, 2008). Although the long term outcomes and success of the LEP (which is operating in 50 primary and secondary schools) has yet to be established, emergent evidence indicates that in the short term the children are being enthused by the engineering challenges integral to the Project (HEFCE, 2009). This suggests that exposure to engineering at an early age can engage children's interest and spark an enthusiasm for engineering. Whilst projects such as the LEP seem to be making some initial steps towards raising the profile of engineering within primary and secondary schools, the issue of how to build on children's initial experiences and enthusiasm and carry it through to university level has yet to be addressed. Moreover, currently there is not a clear engineering education 'pipeline[1]'. This makes it almost impossible for the interest developed during any early interventions to be nurtured in such a way to encourage the next generation of engineering talent.

The interactive approach utilised by the few engineering-focused initiatives differs greatly from the less direct, but widely available, hard-copy publications and 'electronic' materials about science and engineering. Materials, including the "Engineering-Go for It!" publication and website (ASEE, 2009) and "Flipside" (IET, 2009) aim to bring engineering to life in a way that which appeals directly to young people. However, whilst such publications are creative, concerns remain regarding the sheer volume of electronic material available to young people with regards to engineering. Lacking in coherency, the danger with such unmonitored information is that it may actually at to turn young people 'off' (Pinnell et al, 2008), or even worse, be damaging to the profession as a whole.

A further barrier impacting Generation Y in respect of engineering relates to perceptions of the career options an engineering qualification may lead. Many young people fail to see engineering as a 'good' or viable career choice. This is despite the fact that, at a time of recession, the prospects for engineering graduates are generally better than those of other disciplines. The 2009 Graduate Recruitment Survey suggests that when compared to other professions engineering has the brightest prospects for the coming year, with a predicted 8.3% rise in jobs. Data for 2007 reveals good prospects for graduating engineers with 72% entering employment and 14% going on to some form of further study. Although the demand for engineering graduates is high, concerns persist regarding the numbers of suitably qualified graduates available to fill such (AGR, 2009). Engineering education in

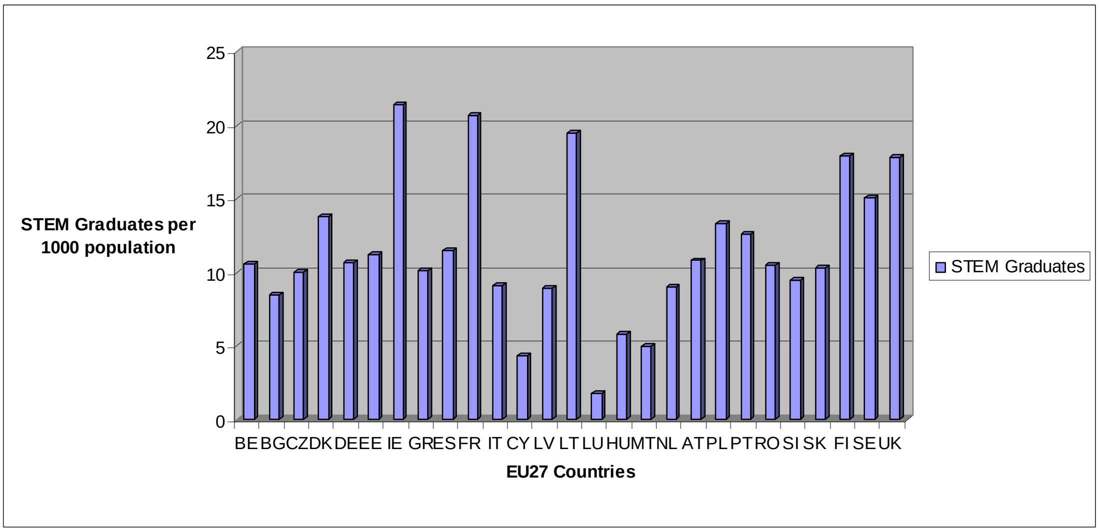
[1] [1] Engineering Education *Pipeline*: In this context the word 'pipeline' refers to a child's total educational experience – from first starting school at age 4 or 5 years to graduation from University.

the 21st Century needs to address such concerns by providing graduate who are not only qualified to take up vacancies – but are also enthusiastic about engineering and looking positively towards a future career in the profession.

Interest in engineering is often higher in the developing world than it is in developed countries (Wu, 2009). This is reflected in higher public perceptions of the status of engineering as a profession throughout the developing world. Indeed, in countries such as China, where engineering is viewed as a positive and socially responsible career choice the number of engineering graduates has grown markedly over the past few years (Wu, 2009).

Figure 3, below, shows considerably variability in respect of the number of STEM graduates for each of the EU27 member States.

Figure 3: STEM graduates per 1000 population for EU27 countries in 2006. Data source European Commission – Eurostat (http://epp.eurostat.ec.europa.eu/



A simple correlation analysis of this data with GDP and interest in science and technology, shows there is no correlation between GDP and the number of graduates. Furthermore, there is a low negative correlation of 0.35 between GDP, the number of graduates and interest in STEM. Whilst this data needs further investigation, it appears that although the relationship between interest in engineering in particular, and STEM subjects in general, is complex and multidimensional, perceptions of the status of engineering as a worthwhile and fulfilling career may be a major factor shaping public opinion.

Discussion & Concluding Remarks

From a pedagogical perspective, the idea of aligning the engineering curriculum and teaching and learning with the needs of industry and society needs to be investigated further. Particularly in relation to the expectation that university education should equip students with a particular set of skills and competencies. In a field as wide as engineering it is difficult to find agreement in respect of what such skills and competencies may comprise. Furthermore, focusing the curriculum directly on the needs of the current economic and industrial climate, in terms of addressing current short-term skill shortages, may prove to be an expensive mistake in the longer term. Whilst educators need to remain aware of short-term market needs and provide an education which addresses current "windows of opportunity" (Katila and Mang, 2003; Huang and Ritter, 2004), such an approach may be criticised for being strategically unsound. Indeed, whilst consultation with industry needs to become an integral part of future curriculum development, it is important that engineering educators capture the views and requirements of a wide range of stakeholders including senior professionals, policy makers and alumni groups. It should also be noted that whilst higher education is in the business of building human capability through ethical and sustainable development, there is no room for trial and error. Indeed, in holding a duty of care towards the next generation, engineering educators are obliged to provide a high quality educational experience that provides with the relevant skills and competencies necessary for a life long career in engineering.

In trying to identify and clarify some of the challenges faced by the engineering community in trying to attract Generation Y into engineering, this paper has only begun to scratch the surface. Children today find it difficult to distinguish between science and engineering, often failing completely to understand what engineering is all about. The lucky few exposed to engineering tend to have a limited experience within a single initiative or competition in their school. Indeed, even those choosing to study engineering at undergraduate level often do so in despite failing to fully understand what engineering is about.

The urgent need to raise the profile of engineering as a profession is self-evident. Such raised awareness should be achieved in a coherent and targeted manner, and supported by adequate resources and realistic policies. Engineering education needs to be placed at the heart of public debate by raising awareness and addressing commonly held misconceptions. Government should consider making engineering a core subject within the curriculum making it clearly distinguishable from science. With children's perceptions framed by age 12, the focus must be on primary level education – although the effort needs to continue through to university entrance. By embedding engineering into the school curriculum, children will be provided with a range of creative learning and teaching resources and interventions which will bring all STEM and other subjects alive. Such creativity does not negate the need for quality, but instead reinforces it. Therefore, whilst developing resources, engineering educators must ensure that the curriculum is delivered in a professional and aligned manner.

In conclusion, this is a substantial challenge - but one that must be met if society is to have a rewarding and sustainable future. In short, perhaps the message the engineering profession needs to get across to today's teenagers is best be summarised by Von Karmen who stated "scientists discover the world that exists; engineers create the world that never was" (2009)

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