Challenging Frontiers:
Early Engineering Education as a Force for Change

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1. INTRODUCTION

Building on an exploratory study which explored teachers' and policy makers' perceptions of elementary level engineering education in the UK, this paper continues the discussion about the need to embed engineering into the primary school curriculum. Working closely with '*Engineering Kids First*'[2], one of the UK's leading third sector engineering education providers, this study is part of the findings of a much larger longitudinal study that seeks to explore how engineering can add context to primary school learning.

Concentrating on engineering education providers' perspectives, the study findings focused on three different areas: the geographic coverage of engineering education in primary schools by *Engineering Kids First*; the value of engineering education to primary education, and barriers to engineering education in primary schools. The paper argues that by enabling children to develop an awareness of the central role played by engineering across all areas of society, education can be brought to life.

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[2] *Engineering Kids First* is a pseudonym for a non-profit organisation that provides engineering education interventions for primary schools age children.

The paper concludes that as a foundation subject, engineering has the potential to synergise the curriculum; providing real-life exciting learning opportunities that will ignite the children's engineering imaginations and in doing so will begin to knock down the barriers to Science, Technology, Engineering and Maths (STEM) learning that are so often experienced by our children as they progress through their school careers.

1.1 Background

Society has reached a 'tipping point'. Industrial growth in the developing world, augmented by what seems to be an insatiable demand for natural resources in the 'developed' world, has resulted in what many perceive to be an unprecedented environmental crisis which some predict will negatively change the face of humanity forever[1,2,3] (for further reading in this area see Lovelock, 2013; Collins et al., 2010; Nordhaus, 2010). Irrespective of the arguments for and against the notion of 'global warming', what is not in doubt is that the challenges currently facing our world are considerable. Indeed, as natural resources inevitably diminish, so public concerns about global poverty, climate change and threats of 'terror' rise. In May 2013 alone, numerous reports of natural disasters, terrorism and war were reported across national and international boundaries including: A tornado in Oklahoma which killed 24 people and caused an estimated $2bn worth of damage[4] a cyclone in Bangladesh, which caused the evacuation of over a million people[5] ; acts of terrorism on the streets of London[6] and the war in Syria[7] . Contextualized within this fraught and often uncertain environment, the National Academy of Engineering in the USA has identified 14 'Grand Challenges for Engineering' faced by the world today[8]. Whilst laudable, in many respects the 'Grand Challenges' identified by the National Academy of Engineers are mostly practical in nature, and as such represent only the *tip of the iceberg* from an engineering perspective. A bigger and far more urgent problem is found in the question of exactly who will solve the engineering problems of the future?

Predicted future shortages of engineers in the UK in particular, but also much wider[9,10,11,12,13], suggest that there is a real need for more young people with high levels of critical thinking skills and problem solving abilities to enter the profession. Indeed, if this latter challenge is not addressed as a matter urgency, there is a strong possibility that there will be no one around to address the 'Grand Engineering Challenges' of the future.

From an educational perspective, several UK based initiatives exist which aim to promote science and engineering to school children (including the Big Bang, Tomorrow's Engineers, the National STEM Centre, National Science & Engineering Week & National HE STEM). However, whilst some attention is given to children of primary school age (under 11 years) most of the resources tend to be aimed at young people of secondary school age. Moreover, when considering the 'field' as a whole, much of the focus is on 'Science' & 'Technology' with 'Engineering' & 'Maths' receiving considerably less coverage. Such a lack of exposure has resulted in fewer young people than ever selecting engineering as a study or career choice upon leaving high school[14,15,16] . In considering this issue, this paper provides a brief analysis of one stage of a longitudinal study which seeks to investigate how engineering can be accessible to primary school children from the age of four or five years. In looking at this issue, the underlying thesis is that in order to promote a viable, sustainable and competitive future, the UK needs to increase the supply of engineering talent entering the workforce - and to do this we need to carefully consider how the subject is introduced into a child's early education.

2. METHODOLOGY

Building on an exploratory study conducted in 2009 which began with the research question 'What barriers exist in the provision of primary level engineering education in the UK?'[17], the aim of the longitudinal study is to monitor, evaluate and enhance elementary level engineering education at primary school level. Adopting an Action Research approach, the part of the study discussed in this paper relates to fieldwork conducted in April 2013. A two-day fieldtrip was undertaken in one of the UK's leading providers of primary level engineering education. During this period, in-depth semi-structured interviews were conducted with six members of staff responsible for delivering and facilitating training activities to teachers who then facilitate engineering education in schools. The interviews were recorded and later transcribed. The data was thematically analysed. In addition to this, organisational data in relation to the nature of the interventions provided by *Engineering Kids First* and the geographic coverage of the organisation was examined and analysed.

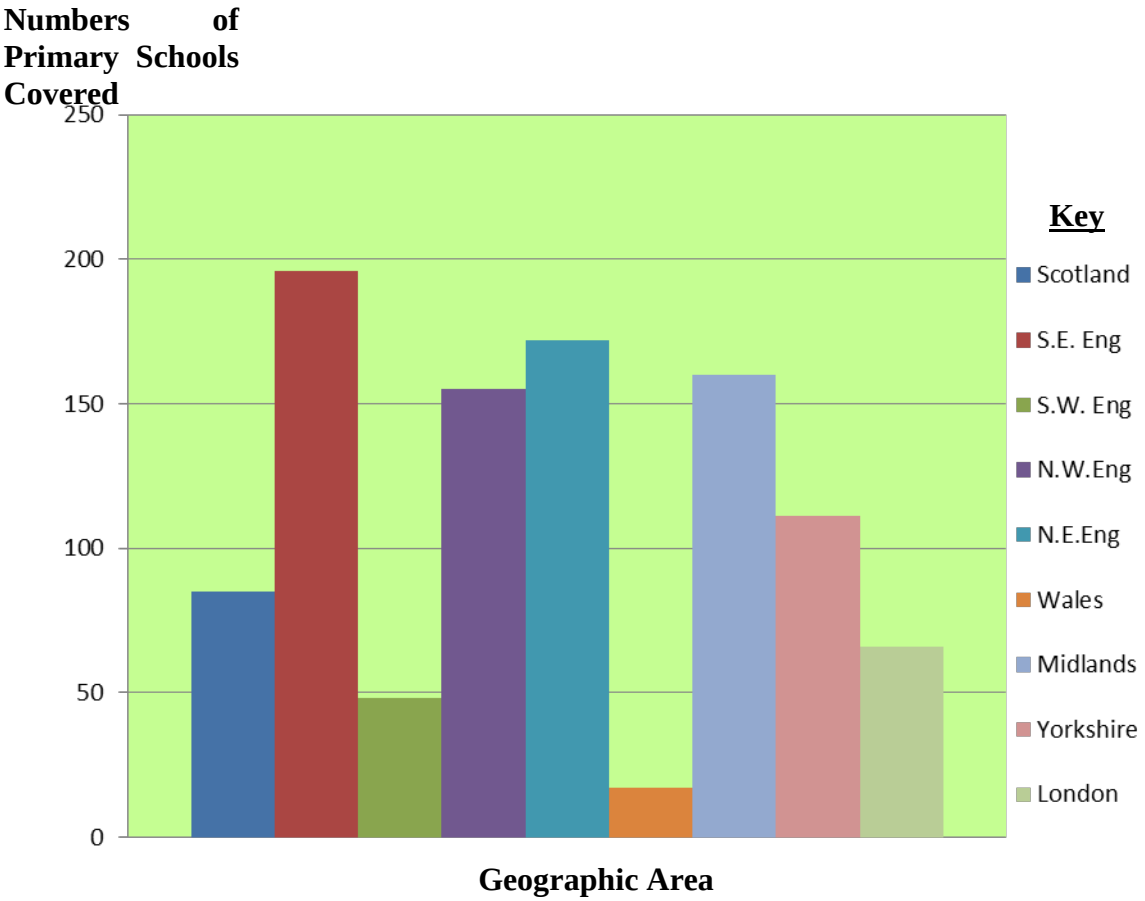
Whilst the data uncovered in relation to the exact nature of the intervention provided is not the subject of this paper, it is important to note that a large number of organisational documents, papers, websites and other resources were accessed and analysed. The findings of this document analysis, together with the qualitative data discussed below, will be used to guide and inform the next stage of the project. In this way, each stage of the longitudinal study is used to inform and guide the next. Data analysis is on-going and a flexible approach has been adopted which enables the research team to make strategic and empirical decisions regarding the suitability of each research tool on a contemporaneous basis.

3. FINDINGS

3.1 Organisational Portfolio

The exploratory study conducted in 2009-2010 identified *Engineering Kids First* as the main provider of elementary level engineering education in the UK[17]. The organisation is unique in that it does not provide the engineering intervention itself, but rather trains teachers to do so. In this way, engineering becomes part of the teacher's professional portfolio and hence the activity is sustained year-on-year. In seeking to gain an understanding of the organisation's reach in terms of the number of schools that have teachers that have participated in the training, the researchers mapped the organisations' outreach. The results of this are shown below in Figure 1

FIGURE 1: *Engineering Kids First*: Coverage 2006-2013



Since its foundation in 2005, *Engineering Kids First* has trained teachers from 1010 schools. The potential outreach in terms of the number of children who have, as a consequence of the training, had the opportunity to participate in engineering activities is impossible to gauge. Although a conservative estimate of 50 children per teacher would put the figure at 50,500 over an 8 year period. Whilst this figure is undoubtedly impressive, in context it is simply a 'drop in the ocean'. In considering the wider environment, according to government records there are currently 21,398 publically funded schools in the UK[3]. There are 4,855,677 primary age pupils registered within the state school system, the vast majority being in England (4,093,710), whilst Scotland had 365,321 pupils, Wales, 232,863, and Northern Ireland, 163,771.

Having looked at the geographic coverage of the organisation, in-depth interviews were conducted with six of its staff responsible for running the training activities and facilitating engineering education competitions amongst primary schools. The findings of these interviews were thematically analysed and two main themes identified: The value of engineering education activities in primary schools; and, barriers to engineering education at primary level.

[3] 16,971 – England: 866 - North Wales: 2,099 – Scotland: 1,462 – Wales (CILT, 2013: http://www.cilt.org.uk/home/research_and_statistics/statistics/primary_statistics/how_many_schools_and_pupils.aspx Accessed 25/6/13)

3.2 The Value of Engineering Education in Schools

Possibly the most important pedagogic outcome from the training and subsequent activities offered by *Engineering Kids First* relates to the teaching of Design and Technology, Maths & Physics. One of the trainers explained:

> *Teachers are frightened of design and technology. Engineering Kids First is about helping them do it. They'd rather do anything else.*
>
> Scott

Another discussed how placing engineers into the learning environment is of benefit not only to the children, but perhaps more importantly to the teachers themselves:

> *Once the engineers go into the classroom the teachers start to realise* ***they*** *can do maths, science technology and engineering.*
>
> Mandy

Whilst the organisation's founder and managing director explained the extraneous benefits of engineering as a subject:

> *Engineering in primary schools allows for the practical application of maths and science. It engages more children than you would normally with those subjects.*
>
> Sam

The question of engagement was taken up by other interviewees one of whom summed up the additional value of the intervention:

> *You get some kids who aren't academic but they can do the modelling. The practical stuff. Some of the kids we get engaged are totally switched off to other subjects.*
>
> Mel

Whilst two of the others explained how engineering can 'fit' into the wider curriculum:

> *The engineering lesson involves taking a wide look at the process of making the model and the product itself. The kids will not only build the model, they will look at how it works and why it works in a certain way. They will look at the vehicles. The history of transport. And they write a portfolio, showing what they've done.*
>
> Jo

> *The engineering lesson takes a wide look at various aspects of education within an engineering context. From maths, looking at the circumference of wheels, to science and movement. ICT in the Powerpoints and literacy with the wordwall, reading and writing. There's some history in there with Henry Ford. Engineering brings it all together.*
>
> Kate

The potential role that engineering education could play within the curriculum was evident when looking at the teaching materials used by *Engineering Kids First*. Encapsulating Maths, Science, Literacy, History, Design & Technology as well as Art, the intervention brings together different areas of learning to provide children with an exciting and interesting learning opportunity.

3.3 Barriers to Engineering Education in Schools

Whilst the value that engineering could potentially add to the curriculum was given much credence by the employees of *Engineering Kids First*, the difficulties created by the time-constraints placed on teachers in working within the framework demanded by the curriculum was also noted:

> *The biggest constraint to introducing any sort of engineering in schools is the curriculum. Well, not so much the curriculum but the teachers. They're under so many time constraints they just say "we can't do this" without considering it properly. We tell them that they could fit it in if they ran an after school club.*
>
> Selena

> *Some of the teachers say "This is great, but how are we going to implement it when we only have one hour of DT a week?" They make it work by collapsing the curriculum down into a single day, doing a technology day. Or fitting the activities in over a week.*
>
> Scott

Whilst the 'tight' nature of the curriculum was one issue, another significant barrier to the organisation was actually accessing schools:

> *Trying to get into schools is horrendous. Keeping in touch with the teachers after the training is tough, but important.*
>
> Mandy

Conversely, whilst 'getting into schools' proved difficult for *Engineering Kids First* as an organisation, one comment made by one of the trainers seemed to sum up why schools are not engaging with the numerous organisations offering engineering and science initiatives, there are simply too many of them:

> *In Scotland there are something like 300+ initiatives supporting DT in schools. How are teachers supposed to know which one to pick? Which one fits with the curriculum? It's confusing.*
>
> Kate

Considering the remit of *Engineering Kids First* it is perhaps not surprising that the organisation's employees identified more positive points than negative. The staff were extremely committed to enhancing education through engineering.

4. DISCUSSION

This small study, whilst part of a much wider longitudinal study has begun to discuss the issues around offering engineering education in primary schools from the perspective of one of the country's largest providers to schoolchildren of age 4-11 years. From a wider perspective[18] , the need to attract young people into engineering has never been greater hence initiatives, such as that offered by *Engineering Kids First*, are vital. Although current debates acknowledge that programmes which offer children the chance to participate in real-life engineering-focused learning activities are vital pedagogical tools in the fight to attract more young people[19,20] (see for example: IMechE, 2010, Mac Bride et al, 2010), the fact remains that in the UK only a small minority of primary school children are ever introduced to engineering as a concept. Indeed, engineering education within the UK primary school system is at the best sporadic, generally being offered by individual teachers willing to act as 'engineering champions'. Additionally those interventions that are offered are inevitably time-limited and usually extra-curricular in nature.

It should be noted that whilst engineering is not on the curriculum, Design & Technology is[21,22] . An important facet of engineering, DT aims to facilitate pupils' ability to participate in future technological advances. However, as a subject, DT is very different from engineering as a discipline in that it has a much wider remit.

From a policy perspective, the need to inspire more children to take an interest in engineering in particular, and science and maths in general, has recently been discussed at a high level with several Members of Parliament raising the issue. In a speech to the Policy Exchange, Stephen Twigg MP discussed the benefits of vocational education in schools arguing that "*Strengthening the skills of young people in Britain is a great patriotic cause. It should be seen as part of our economic mission – at the heart of our drive to maintain our competitive edge in the world"* (Policy Exchange, 23/1/13[23]). Within Parliament itself, on 13th February 2013 a '10 Minute Bill' put forward by Peter Luff MP[24] warned of future shortages of engineers and argued that there is a need to get engineering and science expertise into schools. This was followed on the same day by lively debate under the chairmanship of Hugh Bayley MP which discussed the need to promote engineering at primary level and to encourage more young people to consider engineering as a career[23] (Houses of Parliament, 13/2/13).

A few weeks later, Peter Luff MP continued the discussion pointing to the complexity surrounding current extra-curricular provision of engineering and science based learning in schools whilst arguing that there is a real need to capture children's interest at an early age… "*At its simplest, we need to inspire boys and girls at a much younger age to want to do well in the two key subjects of maths and physics. Perhaps the single greatest need is to make more girls want to do physics. We do not need more schemes in order to do so. Indeed, there are probably already too many*" [25] . There can be little argument that engineering provides the ideal means by which children can develop critical thinking and problem solving skills. It brings design, technology, science, maths, the humanities and literacy together in such a way so as to enable children to develop an understanding of a range of problems.

5. CONCLUSION

The nature of current engineering education provision at primary school level represents a real pedagogical dilemma, one that must be challenged and addressed. Engineering has always been a 'frontier' discipline, challenging the norms of society by providing real-life solutions to a range of different problems. By introducing children to engineering as a foundation subject numerous barriers to education can be overcome, in this way a new "Educational Frontier" can be forged.

In conclusion, there can be little argument that engineering has the potential to synergise the curriculum. Well thought out engineering activities can provide real-life exciting learning opportunities that can act to ignite children's engineering imaginations.

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