Time for Action? Elementary Engineering Education – Challenging Teachers, Policy Makers and Parents.

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Abstract

Grounded in the findings of a three year exploratory student whereby teachers' and policy makers' perceptions of elementary level engineering education were analysed, this paper focuses upon three strands of engineering education activity: Pedagogy: Practice, and: Policy. Taking into account the challenges associated with introducing engineering education at an elementary level across the UK, the paper critiques the role played by the 'competition model' in promoting engineering to children and 4 to 11 years. In considering the 'added value' that appropriately developed engineering education activities can offer in the classroom the discussion argues that elementary level engineering has the potential to reach across the curriculum, offering context and depth in many different areas. The paper concludes by arguing that by introducing the discipline to children at a foundational level, switching on their 'Engineering Imaginations' and getting them to experience the value and excitement of engineering, maths and applied science a new "Educational Frontier" will be forged.

Introduction

Focusing on the UK, and further developing the emergent findings of a longitudinal study in which teachers' and policy makers' perceptions of elementary level engineering education were examined[1,2], and in which an ethnographic approach was used to observe and analyse children's activities when participating in extra-curricular engineering education activities, this paper continues the debate around introducing engineering education into the Primary School Curriculum (K-6). Contextualised by the current UK Primary School National Curriculum, from which engineering is totally absent and applied science is only superficially covered, the paper argues that the inclusion of engineering as a foundational level subject could not only enhance children's learning experiences, but could also ignite their 'engineering imaginations' thereby unlocking potential which is currently left mostly untapped.

Background

Looking across modern-day society it is not unreasonable to postulate that the world has reached a 'tipping point'. Indeed, environmentalists warn that continued industrial growth across the developed and developing world, manifested by an apparently insatiable demand for natural resources, has brought our planet to the edge of what some predict will be an unprecedented environmental disaster[3,4,5] . Putting aside arguments for and against the notion of 'global warming' it cannot be denied that the challenges facing our world today are considerable. Moreover, as natural resources continue to be consumed at an almost exponential rate, so public concerns about a number of global issues including poverty, climate change and terrorism rise. The first six months of 2013 alone saw numerous reports of natural disasters, terrorism and war being reported across national and international boundaries including: A tornado in Oklahoma which caused an estimated $2bn worth of damage and killed 24 people[6]; a cyclone in Bangladesh, resulting in the evacuation of over a million people [7]; acts of terrorism in London[8];and the continued war in Syria[9]. Within this uncertain and sometime chaotic environment, the National Academy of Engineering identified 14 'Grand Challenges for Engineering' faced by the world today[10]. Whilst laudable, such challenges are mostly practical, and as such represent only the *tip of the iceberg* from an engineering and engineering education perspective. A bigger and far more urgent problem is found in the question of…. *exactly **who** will solve the engineering problems* *of the future if we don't act urgently to engage more children in engineering*? This question forms the basis of current debates in the UK and much wider[11,12,13,14,15] with some suggesting that the need to attract more young people with high levels of critical thinking skills and problem solving abilities into the engineering profession has never been higher.

Across the UK there exists a large number of non and for-profit education initiatives all aimed at promoting applied 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, most such initiatives tend to be aimed at High School children with few resources directed towards children in Primary School (K-6). When looking at provision overall, it is apparent that most of the initiatives focus on science & technology with engineering & maths receiving considerably less coverage. This lack of exposure is augmented by the almost total absence of engineering within the school curriculum; meaning that for most young people, upon leaving High School, engineering fails to register as a potential future study or career choice[16,17,18] . In considering this issue, this paper provides a brief analysis of the second stage of a longitudinal study in which the researchers sought to gain an insight into the operational issues faced by one of the UK's largest for-profit non-governmental engineering education providers in promoting engineering to children aged 4-11 years.

Methodology

Focusing on three strands of engineering education activity; pedagogy, practice and policy, the longitudinal study has two primary aims the first of which is to analyse the issues around introducing engineering to children between the ages of 4 and 11 years. The study also aims to develop a primary level engineering education pedagogy that may be adopted and adapted by UK schools.

The first stage of the study which was conducted from 2009-2012[1] found that the majority of engineering education on offer at primary level within the UK is based around a series of disconnected 'STEM initiatives' most of which follow a "competition format" centred around extra-curricular activities (STEM clubs) and one- off initiatives. Building on this add following an action research design, the part of the study discussed in this paper relates to case-study fieldwork conducted mainly during April 2013 whereupon a fieldwork visit was undertaken in one of the UK's largest primary level engineering education for-profit providers *"Engineering-First"*. Prior to visiting the case-study organisation, the researchers conducted non-participatory observations at three separate 'Annual Engineering Education Final' competitions sponsored by *Engineering-First* (occurring in 2011, 2012, 2013). During the competitions, an observational framework, developed out of the findings of the first stage of the study, was used to record children's participation. It should be noted however, that at each competition, the somewhat chaotic nature of the event, in which between 50 and 250 children, their siblings, class mates, parents and teachers were present within a single school facility meant that the observations did not provide any useful data other than a reflective narrative account written by the researchers in which a number of relevant factors were recorded.

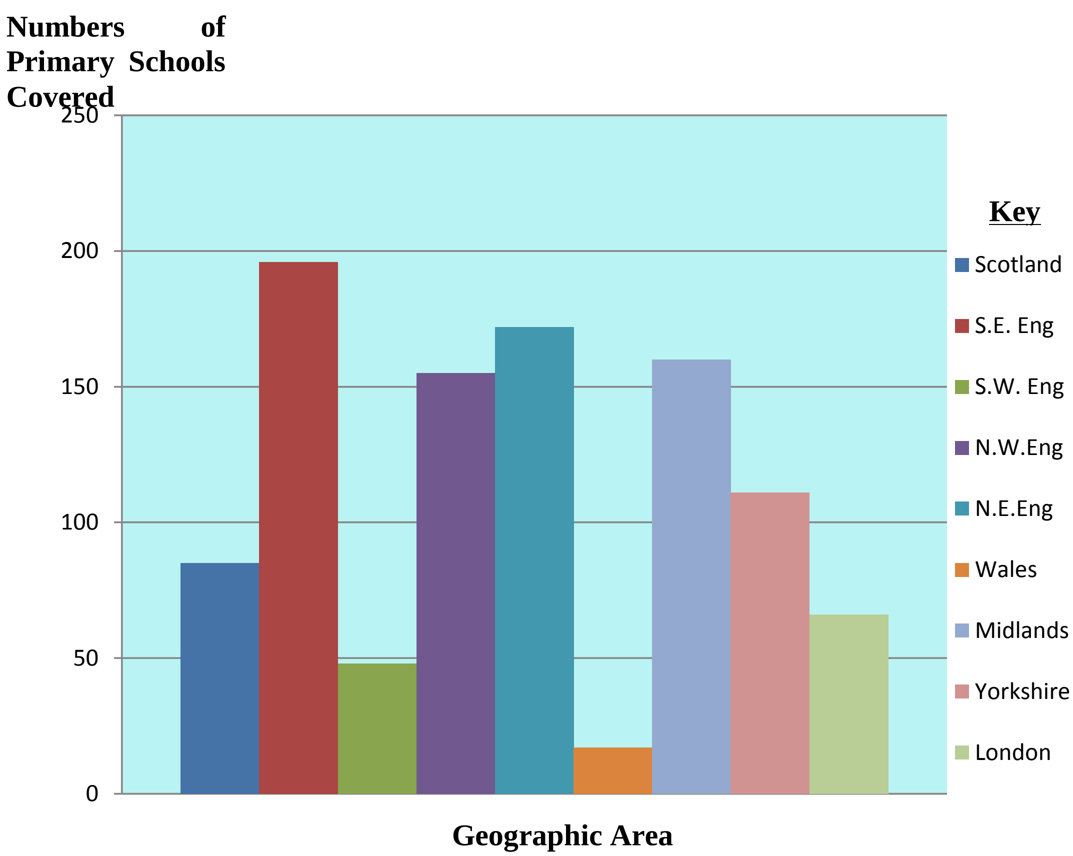
The case-study 'organisational' fieldwork conducted in 2013 commenced with a document analysis of various internal documents, looking at coverage in terms of provision as well as examining the initiative itself (in terms of tools used). Six in-depth semi-structured interviews were then conducted with six members of staff responsible for delivering and facilitating training activities to teachers. The interviews were contemporaneously recorded, transcribed and the data thematically analysed. Whilst the data uncovered in relation to the nature of the intervention provided is not the topic of this paper (as this is subject to organisational confidentiality) it should be noted that a large number of organisational documents, papers, websites and other resources were accessed and analysed. The findings of the document analysis, together with the qualitative data discussed below, and the narrative record of the observations, will be used to guide and inform the next stage of the project – meaning that each stage of the longitudinal study continues to be used to inform and guide the next. Throughout the study, data-analysis is on-going, reflecting a purposefully designed flexible approach that enables the research team to make strategically grounded empirical decisions regarding the suitability of each research tool on a contemporaneous basis.

Findings: Interviews with *Engineering-First* Staff

- **Organisational Portfolio**

The initial exploratory study identified *Engineering-First* as one of the main Primary School level engineering education for-profit providers in the UK[1]. The organisation is unique in that it does not directly provide any engineering education interventions, but instead trains teachers to do so. In this way, the organisation's aim is to make engineering education part of the teacher's professional portfolio, theoretically enabling the activity to be sustained year-on-year. This approach is markedly different to many of the other initiatives which tend to offer 'direct' interventions whereby volunteers go into schools and work with children on a one-off or 'single-term' basis. Prior to looking at the organisation's remit the researchers first sought to gain insight into its potential impact by mapping the geographic locations from which the teachers who attended the training programme originated. The results of this are shown below in Figure 1

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



In looking at the organisational records, the researchers discovered that since its foundation in 2005, *Engineering-First* has trained teachers from 1010 schools. The potential number of children who could, as a consequence of the training, have had the opportunity to participate in engineering activities is difficult to gauge; although an estimate of 50 children per teacher puts the figure at 50,500 over an 8 year period. Whilst this number is somewhat impressive, it is likely to be a vast over-estimation as the organisation's records in terms of whether or not the initiative was offered to children following the training, and if so how often and over what time span, are very limited. Furthermore, given the wider context of the UK Primary School population, this number is simply a 'drop in the ocean'. According to Government records there are currently 21,398 publically funded schools in the UK[1] [19] and 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[19] .

Having examined the potential geographic coverage of *Engineering-First,* in-depth interviews were conducted with six of its staff responsible for running the training activities with teachers. The staff interviewed were also responsible for facilitating an Engineering Education Competition between Primary Schools offered by *Engineering-First* to all schools whose teachers attended the training and subsequently adopted the initiative. In analysing the interviews two main themes were identified: The value of engineering education activities in primary schools; and, barriers to Engineering Education at primary level.

- **The Value of Engineering Education in Schools**

Possibly the most important educational outcome from the training and subsequent activities offered by teachers and *Engineering-First* in the form of competitions, reflects the teaching of Design and Technology (D & T), Maths & Physics. One of the trainers explained how the initiative helps teachers teach subjects they perceive to be difficult suggesting that:

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

The remark about Design & Technology was not entirely unexpected as the subject is exceptionally diverse, with activities ranging from more traditional 'art-based' activities such as pottery and drawing to food technology, acting as a 'catch-all' subject into which applied science and practical science-based activities have been 'slotted'.

Another trainer pointed out the benefits of introducing 'real' engineers into the classroom:

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

Whilst the organisation's Managing Director discussed the value of engineering education as a subject within the Primary School curriculum:

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

[1] 16,971 – England: 866 - North Wales: 2,099 – Scotland: 1,462 - Wales

with those subjects.

Sam

The question of engagement was also mentioned by other interviewees one of whom summed up the wide appeal of engineering to those children who are usually difficult to engage:

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

Two of the interviewees discussed how engineering can potentially '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. Science, maths, practical learning.

Kate

In looking at the teaching materials used by *Engineering-First*, the potential value that engineering education could add to the curriculum was evident. Incorporating maths, science, literacy, history, design & technology as well as art, engineering can bring together different areas of learning in a 'real-life' situation to provide children with an exciting and interesting learning opportunity.

- **Barriers to Engineering Education in Schools**

Whilst the potential value that engineering education could add to the Primary School Curriculum was discussed by all of *Engineering-First's employees*; the difficulties created by the National Curriculum in terms of how teachers manage their time 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

The somewhat 'compact' composition National Curriculum was one matter discussed by all six of *Engineering-First's* employees, each one of which noted the frustration experienced by teachers at being given such a restrictive yet highly formatted Curriculum to teach – with little room for manoeuvre. Another, perhaps more significant barrier to *Engineering-First* was getting access into schools:

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

Whilst the subject of 'access' seemed to be an intractable barrier, one reason suggested for this was, conversely, that there are too many similar initiatives on offer. With so much choice schools do not know which initiative to select:

> *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

Having analysed the data the two main emergent concepts, the value of engineering education in primary schools and barriers to engineering education in primary schools, were critiqued within the findings of the wider longitudinal study. The following discussion provides an overview of this critique.

Discussion of Findings

- **Pedagogy**

The issues covered in the above case-study, whilst representing a small part of the much larger study, raised a number of interesting questions. There is little doubt that within the context of the UK, the need to attract young people into engineering has never been greater[20,21] . Yet despite this, the fact that engineering education is almost exclusively offered in isolation of other subjects and usually on a short-term or one-off extra-curricular basis, means there is little chance for children to gain any longer-term pedagogical value out of participating in engineering education activities such as those sponsored by *Engineering-First*. For most of the children who engage with *Engineering-First,* the activity involves building a model vehicle and taking part in a competition (this takes around 8 hours in total). Having built their vehicle, the majority become quickly excluded by the competition model, with only one or two teams per school continuing to the next stage. Although the need to engage children in science and maths is widely acknowledged to be key to the future of engineering within British Society[22,23,24] the main weakness of the competition model is that by providing a short-term 'fun' activity in which no deep learning seems to take place it is merely scratching the surface. Whilst the research conducted thus far has not uncovered any opposition to the argument that the wider curriculum would benefit greatly from having engineering education activities embedded within it (potentially aligning with, and providing context for, a number of academic disciplines including maths, science, humanities, arts and literacy), the fact is that *Engineering-First's* initiative, like most of the other engineering education on offer across the country, is offered in isolation of the main thrust of education. Furthermore, what is offered has not been rigorously evaluated or examined – meaning that there simply is not any evidence about what does, or does not work!

Taking a slightly wider perspective it is important to note that although engineering does not form part of National Curriculum, design & technology (D & T) does[25,26]. On the negative side, D & T has a somewhat vague remit including amongst other subjects 'food technology' (incorporating cookery) and art & design. Furthermore, whilst it is an important aspect of engineering, the focus on technological advances given in D & T[27] means that it is very different from engineering as a discipline. In sum, engineering potentially has a much wider, and yet more focused, remit; meaning that if taught correctly it could potentially have a much greater impact on a child's education than D & T.

- **Practice**

In looking at the activities of *Engineering-First* and other similar national engineering education providers, all of which vie for business within an increasingly impecunious marketplace, one commonality stands out amongst the majority of larger providers – the use of a 'competition model' to engage children. Whilst the value of competitions within education has been the subject of some debate[28,29] knowledge about the impact of competitions on younger children's learning experiences is somewhat limited. However, in the case of *Engineering-First*, the fact that the majority of children are effectively excluded from the intervention at an early stage means that the level of engagement is at best short-lived. Furthermore, in looking at the intervention itself, there is the possibility that by focusing on building a model vehicle, *Engineering-First's* approach may be more appealing to boys than girls. Although the ratio of boys to girls captured by the *Engineering-First* initiative is not possible to determine (the organisation does not keep statistics on the number or gender of children engaged in the competition), similar numbers of both genders were observed participating in the competition finals. In looking at the vehicles displayed by the children in the 'Finals' the researchers noted that the models built by all-girl teams generally reflected feminine interests and perspectives – most 'all-girl' team vehicles were decorated with flowers or animals and painted in pastel colours with pink and pale yellow being the most popular. "All-girl" teams generally selected to theme their vehicles around popular cartoons or 'girls' toys including dolls. Whereas "all-boy" teams tended to theme their vehicles around either war or space; with military vehicles (mostly tanks), and space ships being popular. On the whole boys seemed to prefer to paint their vehicles in either military colours (mainly green or khaki), or in silver or black, decorating the vehicles with symbols of war, flags or other masculine images. Conversely, mixed gender teams built a range of vehicles, although a tendency towards emergency vehicles was noted with fire-engines and ambulances proving popular. Additionally several mixed teams selected a theme based on television characters.

In looking at the activity itself it is difficult to say whether focusing on something other than a model vehicle would prove more appealing to the children; although the fact that that those at the competition finals had made their models based upon their own personal preferences and tastes suggests that irrespective of the nature of the activity, given the freedom to choose, children will focus their creativity on what interests them.

Despite the fact that all of the children engaged in the competition seemed to enjoy themselves, and that all were "tokenistically" rewarded with a certificate of attendance and baseball cap, in observing the children during the National Competitions the researchers became increasingly concerned that participation in the competition could not only potentially the majority of children who had already been excluded but that it could also damage the learning experiences of those who were participating in the Finals. Indeed, it seemed that the majority of children who had 'made it' to this stage were focused on 'winning' rather than on learning[30,31]

- **Policy**

The need to inspire more children to take an interest in engineering, science and maths has, over the past 12 months, been much discussed within UK policy circles. One example of this is a speech given to the Policy Exchange early in 2013 whereupon 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"*[32] . A few weeks later MP Peter Luff put forward a '10 Minute Bill' in the House of Commons arguing that there is a need to get engineers and scientists into schools[33] . On the same day, a lively debate chaired by Hugh Bayley MP discussed the need to promote engineering at primary level as a way of ultimately encouraging more young people to consider becoming engineers[34].

The debate was continued a few weeks later with Peter Luff MP raising the point that whilst there is a dire need to get more children engaged in engineering, this cannot be achieved by more non-profit initiatives… "*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*" [35].

In considering the arguments put forward in the literature and by policy makers there can be little argument that action needs to be taken urgently. In bringing together the findings from this stage of the study together with the data collected earlier, it is evident that there is not one simple solution as to *how* engineering should be embedded into the curriculum. In considering the various issues, that engineering is currently offered as an extra-curriculum activity means that it is generally reliant on 'engineering champions' and the goodwill of parents. Moreover, the competition model, popular with *Engineering-First*, but also with the majority of other providers, means that in in the schools covered by extra-curricular engineering education initiatives, after a few weeks many more children are excluded from engineering activities than are included. This is an anomaly that urgently needs addressing. Parent, teachers, engineers and academics need to work together to lobby policy makers. The vital role of engineering to our society is recognised by all – what is in dispute is how we make engineering accessible to all of our school children.

Concluding Remarks

In conclusion, engineering is traditionally a 'frontier' discipline, by its very nature challenging the norms of society through the development of what are often innovative, and sometimes previously un-thought off, solutions to a range of 'everyday' problems. By introducing engineering to children at a foundational level, switching on their 'Engineering Imaginations' and getting them to experience the value and excitement of engineering, maths and applied science a new "Educational Frontier" will be forged. Professional engineering educators are currently standing at the edge of this Frontier – what we need to do now is lead the way by convincing teachers, parents and policy makers that engineering education should not be confined to the edges of the curriculum, taught only in after-schools clubs and other superfluous initiatives, it should instead become part of children's everyday school experience – embedded across and within the curriculum.

Recommendations

Six main recommendations, based on the emergent longitudinal study findings, are made:

1. **Policy Makers** need to address the issues in teacher training – making engineering a core subject for trainee primary school teachers.
- Throughout the study the notion that teachers are 'afraid' of engineering, science and maths has been repeated. This is an issue which urgently needs addressing. By making engineering a core subject, teacher trainers will in effect enable new teachers to learn, and then teach maths and science in an applied practical, relevant and fully contextual manner.
2. **Government** should take responsibility for funding a full evaluation and overview of what is currently offered in terms of engineering education in primary schools
- The lack of evidence regarding what does and does not work is extremely concerning meaning that the quality of current engineering education is at best intermittently engaging and at worst potentially damaging to children's learning.
3. **Teachers** need to look at embedding engineering into the curriculum by adopting an 'active learning' approach in which engineering education provides the context for learning across a range of different subjects and disciplines.
- This needs to be driven by creating a simpler educational landscape within which engineering education becomes an integral part of the National Curriculum.
- Across the curriculum, relevant and empirical evaluation that supports needs to be conducted in such a way so as to provide evidence of what works, how and why.
4. **Extra-Curricular Providers** of engineering education initiatives need to undertake a full and in-depth evaluation of the value of their work, adopting a much more empirically grounded and pedagogically sound approach.
- In particular the competition model needs to be properly studied and a wider range of options be developed that appeal to a wider range of children. A global study, perhaps in conjunction with the US and other EU countries, would provide a range of evidence of different approaches that could be used to develop a model of best practice.
5. **Professional Bodies** need to establish a National Accreditation Scheme to regulate and monitor the quality of engineering education and other STEM related extra-curricular activities.
- At present people simply propose an activity and act with no scrutiny beyond a 'child safety' police check (and the willingness of a teacher / school to participate).
- Professional bodies must not promote 'even more' interventions, but should be more restrained.
6. **Parents** need to lobby government about the lack of engineering and applied science in the primary school curriculum.
- All parents, but particularly those who are engineers, have a responsibility to educate themselves and their children about the value of engineering in our society.

References

1. Clark, R., & Andrews, J. (2010). 'Researching Primary Engineering Education: UK Perspectives'. *European Journal of Engineering Education.* 35. 3. pp. 585-595.
2. Andrews J. & Clark, R. (2013). "Challenging Frontiers: Early Engineering Education as a Force For Change". SEFI Annual Conference. Available from: http://www.sefi.be/conference-2013/images/133.pdf Accessed: 12/3/2014.
3. Lovelock, J. (2013). "Environmental Crisis: We are past the point of no return". In the Independent. 30/5/13. Available from: http://www.independent.co.uk/environment/environment-in-crisis-we-are-past-the-point-of-no-return-523192.html Accessed: 12/3/2014.
4. Collins, M., An S., Cai, W., Ganachaud, A., Guilyardi, E., Jin, F., Jochum, M., Lengaigne, M., Power, S., Timmermann, A., Vecchi, G. & Wittenberg A. (2010) 'The impact of global warming on the tropical Pacific Ocean and El Niño'. *Nature Geoscience* . **3.** pp. 391-397

5. Nordhaus, W.D. (2010). 'Economic aspects of global warming in a post-Copenhagen environment'. *Proceedings of the National Academy of Sciences of the United States.* June 2010. 107. 226. pp 11721–11726 . Available from: http://www.pnas.org/content/107/26/11721.full Accessed: 12/3/2014.
6. BBC (2013). *Monster Tornado Hits Oklahoma.* BBC News 22/5/13. Available from http://www.bbc.co.uk/news/world-us-canada-22605020. Reported 22/5/13. Accessed: 12/3/2014.
7. Sky News (May, 2013). 'One Million Flea Cyclone Mahasen'. Sky News. 16/5/2013. Available from: http://news.sky.com/story/1091578/bangladesh-one-million-flee-cyclone-mahasen Accessed: 12/3/2014.
8. BBC (2013a). *Woolwich Murder Suspect [ ] in Court* http://www.bbc.co.uk/news/uk-22713349. Reported 30/5/13. Accessed: 12/3/2014.
9. CNN (2013). *Near Lebanese Border: Desperate choices in treating Syrian wounded.* http://edition.cnn.com/2013/05/29/world/meast/syria-civil-war/index.html Accessed: 12/3/2014.
10. NAE (2013). *Grand Challenges for Engineering.* National Academy of Engineering. Available from: http://www.engineeringchallenges.org/cms/challenges.aspx Accessed: 12/3/2014.
11. Broughton, N. (2013). *In the Balance: The STEM Human Capital Crunch.* London. Social Market Foundation & Engineering UK.
12. RAEng (2010). *Engineering Graduates for Industry.* London. Royal Academy of Engineers. Available from: http://www.raeng.org.uk/education/scet/pdf/engineering_graduates_for_industry_report.pdf Accessed: 12/3/2014.
13. RAEng (2012). *Jobs & Growth: The importance of engineering skills to the UK economy*. London. Royal Academy of Engineers. Available from: https://www.raeng.org.uk/news/publications/list/reports/Jobs_and_Growth.pdf Accessed: 12/3/2014.
14. RAEng (2013). *Engineers for Africa: A literature review.* London. Royal Academy of Engineers. Available from: http://www.raeng.org.uk/international/activities/pdf/RAEng_Africa_Literature_review.pdf Accessed: 12/3/2014.
15. Peacock, L. (2013). *One in Five Must Become and Engineer.* The Telegraph. Reported 18/3/13. Available from: http://www.telegraph.co.uk/finance/jobs/9936226/One-in-five-must-become-an-engineer.html Accessed: 12/3/2014.
16. Gill, J., Sharp, R., Mills, J., & Franzway, S., (2008). 'I Still Wanna be an Engineer! Women, Education and the Engineering Profession', *European Journal of Engineering Education.* 33. 4. pp 391-402.
17. Ekevall, E., Hayward, E.L., Hayward, G., MacBride, G., Magill, J. and Spencer, E. (2009). *Engineering – What's that?* Proceedings of SEFI (European Society for Engineering Education) annual conference, Attracting Young People in Engineering, Rotterdam, NL, September 2009
18. NSF., (2009). *Closing the Gender Skills Gap: A National Skills Forum Report on Women, Skills and Productivity.* London: National Skills Forum.
19. CILT (2013). *How Many Primary Schools and Primary Pupils are there in the UK?* http://www.cilt.org.uk/home/research_and_statistics/statistics/primary_statistics/how_many_schools_and_pupils.aspx Accessed: 12/3/2014.
20. Spinks, N., Silburn, N. & Birchall, D. (2006). *Educating Engineers for the 21st Century: The Industrial View.* London: Royal Academy of Engineers.
21. IMechE., (2009). *Education for Engineering: IMECHE Policy Summary*. London: Institute for Mechanical Engineering.
22. DIUS.,(2008). *A Vision for Science and Society.* London: The Royal Academy of Engineering. Department of Innovation, Universities & Science.
23. IMechE., (2010). *When STEM? http://www.imeche.org/knowledge/policy/education/policy/when-stem* Accessed: 12/3/2014.
24. MacBride, G., Hayward, E. L., Hayward, G., Spencer, E., Ekevall, E., Magill, j., Bryce, A.C. and Stimpson, B. (2010). Engineering the Future: Embedding Engineering Permanently Across the School–University Interface. *IEEE. Transactions On Education*, 53, 1.
25. Twyford, J., & Jarvinen, E.M., (2000). 'The Formation of Children's Technological Concepts: A Study of What it Means to Do Technology from a Child's Perspective'. *Journal of Technology Education.* 12. 1. pp 32-46
26. Mitcham, C. (2001). 'Dasein Versus Design: The Problematics of Turning Making into Thinking'. *International Journal of Technology and Design Education.* 11. 27-36.
27. Rasinen, A. (2003). 'An Analysis of the Technology Education Curriculum of Six Countries'.
28. Verhoeff, T. (1997). *The Role of Competitions in Education.* Eidenhoven University of Technology. Unpublished paper available from: http://olympiads.win.tue.nl/ioi/ioi97/ffutwrld/competit.html Accessed: 12/3/2014.
29. Lawrence, R. (2004). 'Teaching Data Structures using Competitive Games'. IEEE *Transactions on Education.* 47. 4. pp 459-466

30. Lam, S-f., Yim, P-s., Law, J.S.F. & Cheung, W.Y. (2004). "The Effects of Competition on Achievement Motivation in Chinese Classrooms". *British Journal of Pschology.* 74. pp 281-296
31. Vockell, E. (2004). "Social Aspects of Motivation: Classroom Goal Structure". *The Role of Competitions in Education.* Eidenhoven University of Technology. Available from: http://education.purduecal.edu/Vockell/EdPsyBook/Edpsy5/edpsy5_social.htm Accessed: 12/3/2014.
32. Twigg, P. (2013). *Speech to Policy Exchange.* Available from: http://www.labour.org.uk/a-blueprint-for-one-nation-education-vocational-education,2013-01-23 Accessed: 12/3/2014.
33. Luff, P. (2013). 10 Minute Bill. Available from: http://www.bbc.co.uk/democracylive/house-of-commons-21431154 Accessed: 12/3/2014.
34. House of Parliament (2013). *Engineering Careers.* Debate under the chairmanship of Hugh Bayley. Available from: http://www.publications.parliament.uk/pa/cm201213/cmhansrd/cm130213/halltext/130213h0001.htm#13021373000353 Accessed: 12/3/2014.
35. Luff, P. (2013). *Science, Technology and Engineering (careers information in schools.* Available from: http://www.peterluff.org.uk/speech.php?dataID=1464 Accessed: 12/3/2014.