RDP 16

‘Catching Them Young’: Inspiring Future Engineers, An Exploratory Study

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***Abstract**:*

The requirement that primary school children appreciate fully the pivotal role played by engineering in the sustainable development of future society is reflected in the literature with much attention being paid to the need to spark children’s engineering imagination early-on in their school careers. Moreover, UK policy documents highlight the value of embedding engineering into the school curriculum, arguing that programmes aimed at inspiring children through a process of real-life learning experiences are vital pedagogical tools in promoting engineering to future generations. Despite such attention, engineering education at school-level remains sporadic, often reliant on individual engineering-entrepreneurs such as teachers who, through personal interest, get children involved in what are usually extra-curriculum, time-limited engineering focused programmes and competitions.

This paper briefly discusses an exploratory study aimed at investigating the issues surrounding embedding engineering into the primary school curriculum. It gives some insight into the perceptions of various stakeholders in respect of the viability and value of introducing engineering education into the primary school curriculum from the age of 6 or 7. A conceptual framework of primary level engineering education, bringing together the theoretical, pedagogical and policy related phenomena influencing the development of engineering education is proposed. The paper concludes by arguing that in order to avert future societal disaster, children’s engineering imagination needs to be ignited from an early age and that to do this primary engineering education needs to be given far more educational, social and political attention.

Introduction: Context

Defined by the UK Government as *where science meets society and where scientific advances impact on the health, wealth and wellbeing of individuals* (DIUS, 2008), engineering is widely acknowledged as being the link between science and society. Within this context, it is evident that engineering today faces an unprecedented situation. Frequently called upon to deal with some of the most difficult global, national and local problems including those associated with security, infrastructure and sustainability, (IMechE, 2009; Spinks et el, 2006) the demand for engineers has never been higher. Conversely, whilst the demand for engineers is at an all time high, evidence suggests that skills shortages (a lack of appropriately qualified graduates), and skills gaps (where there are deficiencies in the skills possessed by engineering graduates), results in many UK employers being forced to look overseas to fill engineering vacancies (Spinks et al, 2006). This situation is augmented by the fact that across the UK universities are experiencing significant difficulties attracting young people onto undergraduate level engineering programmes (RAE, 2007). From a professional perspective, whilst the current state of affairs is somewhat dire, predictions regarding future shortages of engineers mean that the situation looks set to worsen over the next two to three decades. Indeed, predicted shortfalls in the numbers of young people entering the engineering profession will represent a notable challenge to future governments’ ability to sustain and maintain society (Spinks et al, 2006).

It may therefore be argued that if engineering education at university level in the UK is to be sustained, then the need to spark the engineering imagination of children as young as 5 or 6 years is pivotal. For this to be achieved a realistic evaluation of the current situation needs to be undertaken and empirically grounded solutions identified. Thus, the possibility of introducing engineering education into the primary school curriculum, needs to be considered.

Although the issues presented in this paper are from a UK perspective, the challenges discussed are global in nature. By bringing primary level engineering education to the forefront of contemporary debate, this paper contributes to critical discussions in both engineering education and pedagogy.

Catching the Young – Elementary Engineering in the UK

The central role played by engineering in maintaining everyday life is discussed in the literature (Wilson & Harris, 2004; Smith & Monk, 2005) with particular attention being given to the need to spark children's engineering imagination from an early age. Numerous policy documents highlight the value of embedding engineering into the school curriculum, contesting that learning approaches which inspire children through the use of real-life learning experiences are important pedagogical tools in promoting engineering to future generations (DIUS, 2008; IMechE, 2009). Despite such attention, engineering education at school level in the UK is extremely patchy; usually dependant on individual *engineering champions* who through personal interest involve children in extra-curriculum, time-limited, engineering focused programmes. Furthermore, current provision tends to be 'competition' based, with school children participating in short term projects whereby they acquire basic engineering skills by developing three dimensional working replicas of vehicles or other models, and then compete against other children (ie. Young Engineers, 2009). Although engineering competitions raise the profile of the profession, the competitive nature of such projects inevitably results in more losers than winners.

That 'engineering competitions' only involve a small minority of children adds to the argument that in order to get children interested in engineering, the curriculum needs to be adapted so that the subject becomes an embedded part of a children's educational journeys. The need to spark children's engineering imagination from an early age through an innovative and inclusive curriculum is evident.

One aspect of Engineering, Design and Technology has been part of the UK Primary School curriculum for several years (Davies, 2000; Twyford & Jarvinen, 2000). Aimed at promoting learning opportunities which enhance creative thinking by providing children sufficient skills and knowledge to participate in future technological advances (Rasinen, 2003), Design and Technology differs somewhat from Engineering as a discipline. Indeed, Design and Technology represents only one component of Engineering. Engineering requires the development and application of critical thinking skills in such a way as to bring other areas of the curriculum including Technology, Design, Science, Maths, Social Sciences and Language skills together in order that children are able to identify, understand, analyse and solve a range of socially constructed problems (for further discussion see Vlot, 2000, Mitcham, 2001, Brophy et al, 2008). Although STEM education is often conceptualised as a government priority, particularly at the secondary level (NSF, 2009), in reality engineering education is notable by its absence in current pedagogic practice.

Study Approach

Starting with the research question 'What barriers exist in the provision of primary level engineering education in the UK', an exploratory study into primary level engineering education within the UK was undertaken during the summer and autumn of 2009. The study enabled the researchers to begin to critically identify and analyse various stakeholders' perceptions of engineering education at primary

level. Given the somewhat limited amount of previous empirical study in this area, it was decided that a grounded theory approach was the most appropriate as it provided a useful set of research strategies with which theory could be built out of a constant comparison of the emergent data (Strauss & Corbin, 1992).

An initial literature review allowed for the identification and analysis of the pedagogic, political, academic and social determinants of engineering education. Following this a semi-structured interview schedule was devised, and theoretical sampling techniques utilised to identify suitable interviewees. Thus, the sample was selected in a theoretically grounded manner which encapsulated the requirements of the study and took into account the participants' socio-demographic characteristics. The sample framework comprised; representatives from government bodies responsible for STEM education, individuals working for non-profit organisations that provide *one-off* engineering education projects for school children aged 6-11; and teachers with experience at primary and secondary level (responsible for children aged 12 and under). Questions were grounded in the issues identified in the literature review.

The advantage of this approach is that qualitative interview techniques provide the participants with the opportunity to raise issues important to them whilst affording the researchers the flexibility to explore, in depth, the relevant concepts (King, 1994). However, it should be noted that there are some negative aspects to undertaking qualitative interviews – particularly in relation to the potential for problems with sampling and interviewer bias (Robson:1993). Although such issues did not occur during the exploratory study, the researchers took into account the impact that they, as educators and professionals, had on the research process and remained aware that their own perceptions could influence the research process.

Following the interviews, the data was analysed following a grounded theory approach whereby a system of open coding, in which the data was theoretically analysed and the relationships between the relevant concepts and sub-concepts critiqued was used (Strauss & Corbin, 1991).

A total of 30 people were interviewed from four different schools and various other organisations.

Study Findings

Three main concepts were identified during the analysis of findings, each relevant to primary level engineering education. These were: pedagogic issues; exposure to engineering within the curriculum; and children's interest.

- **Pedagogic Issues**

Just over half of the participants had previously been employed as engineers or teachers. All of these were involved in providing or facilitating engineering education in the form of competitions or initiatives to UK primary and secondary schools. For this group, the most significant pedagogical issue related to teacher training – and the fact that the majority of teachers appear to lack the confidence or skills to provide practical 'hands-on' engineering. Insufficient training in this area was generally believed to be manifest in lack of understanding regarding what engineering actually is amongst those teaching in schools. The solution for some of the participants was, on the surface, relatively simplistic – to embed engineering education into the primary school curriculum. Others however argued that the issue is not about embedding engineering education, but is instead related to the manner in which the curriculum is constructed.

Around half of the sample were teachers currently working in Primary or Secondary Schools. For this group, the constraints placed upon them by the National Curriculum represented a significant barrier to including engineering education within their current teaching. This results in engineering being conceptualised as a 'low priority' and being given little or no attention within the curriculum.

- **Exposure to Engineering Education**

All of the participants discussed the lack of access to engineering education within the current UK school curriculum. However, it should be noted that there is no accurate overall picture regarding the extent to which engineering is offered within UK schools, either as part of the curriculum or as an additional 'competition'. The lack of a consistent and coherent engineering education strategy at school level means only a small minority of primary school pupils have any access to engineering. For most, the nearest they are able to get to anything like engineering is within the Design and Technology curriculum. However, as previously discussed, this only represents a small component of engineering.

All of the participants had some awareness of the engineering initiatives available to schools – although only one of the schools in which the research took place participated in such initiatives. The interviewees that had experience in offering or participating in the initiatives (either as teachers or providers) were all concerned that no real attempt is made to evaluate the effectiveness and pedagogic value of current provision. All of the participants felt that, on the whole, the 'competition model' of engineering education is inappropriate. Indeed, the majority agreed that the possibility that the significant majority of children will be 'turned off' by taking part in such competitions represents a real pedagogical dilemma.

The theoretical sampling techniques utilised in the study meant that all of the participants had an interest in the provision of engineering education to schoolchildren under the age of 12 years. Whilst all of them viewed exposure to engineering as a vital component in sparking children's engineering imagination – they were all aware that 'competitions' merely 'scratch the surface' and that the vast majority of schoolchildren in the UK receive no exposure to engineering whatsoever.

- **Child's Interest in Engineering & Science**

Most of the participants felt that the majority of schoolchildren have no awareness whatsoever regarding engineering. One of the main barriers identified by the participants in respect of getting children interested in engineering related to misconceptions regarding what engineering actually is. Around a quarter of the participants felt that children's lack of understanding was made worse by gender stereotypes. Whilst others discussed difficulties in developing and then sustaining initiatives, including after school engineering clubs. The lack of attention given to engineering education within the school curriculum was reflected in the fact that most of the participants discussed engineering education within the wider context of science. Whilst many identified the transition between primary and secondary education as marking a significant decline in interest in science education amongst school children. This makes the need to spark children's interest in engineering during primary education particularly important.

Discussion

The main pedagogical issue identified in the study related to the curriculum and teachers lack of training and awareness of engineering as a discipline, and the impact that this has on children's learning. Learning is often conceptualised as a permanent change in behaviour resulting from direct experiences (Coon, 1983; Anderson, 1995). Therefore, it is important that children are provided with exciting learning opportunities which are flexible enough to take account of individual learning approaches whilst meeting the demands of the wider school curriculum. Such approaches are needed

to effect a change in children's perceptions of engineering, and to provide them with the opportunity to begin understanding the main principles of engineering and its role in supporting wider society (IMechE, 2009; RAE, 2007, 2009).

One important factor shaping teachers attitudes towards engineering education, and subsequently impacting children's exposure to engineering, relates to teacher education. At a post-graduate level, out of 1865 Teacher Training courses currently being offered in the UK aimed specifically at secondary level teaching, only 4 offer a specialism in engineering (GTTR, 2009). Furthermore, with regards to primary level education, the UK Quality Assurance Association Benchmarks for the Bachelors in Education fails to mention engineering (see QAA, 2009, for further details). It may therefore be argued that the lack of attention given to engineering education by government agencies at primary level does little to reinforce government rhetoric about the importance of engineering as part of the STEM agenda. Indeed, whilst the National STEM Programme, which was launched in the UK in 2009 may have a positive impact, at present Engineering is missing from STEM education (National HE STEM Programme, 2009).

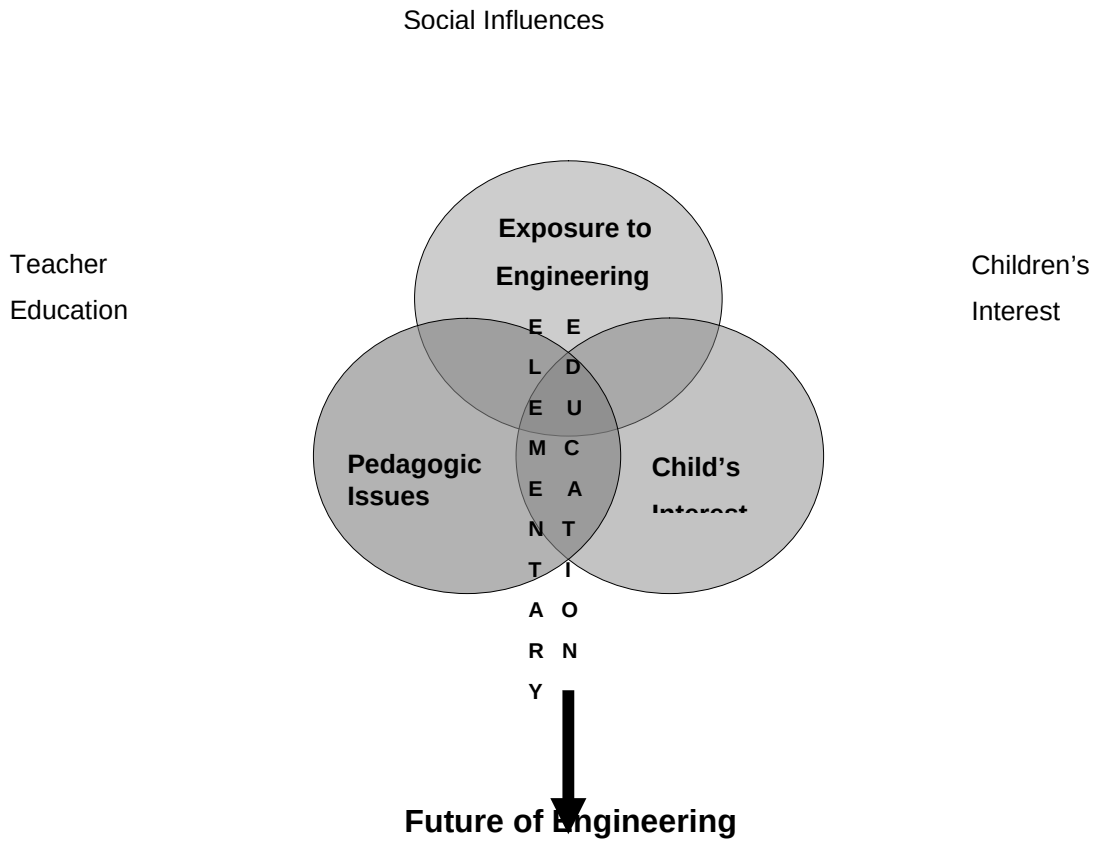
The study revealed that, for children of primary school age, **exposure to engineering** is often dependent on individual school priorities. Exposure is generally dependent on individual teachers with an interest in engineering running 'after school clubs' and competitions. Indeed, it seems that the *random* and *disjointed* nature of primary engineering education across the UK means that the majority of children having little or no exposure to engineering in any form. Consequently, interest in this area is likely to be severely restricted, or non-existent.

The importance of exposing children to a range of learning opportunities in order to promote cognitive development was raised by Piaget (1963). Piaget argued that a child's development is a gradual and continuous process of change. Therefore, to capture children's interest in this area, engineering should be introduced at an early age. From this perspective, the wider role of society in sparking a child's interest is central. Social influences pivotal in sparking a **children's interest** and shaping their development. Thus, it may be contested that engineering should be introduced into the curriculum in a deliberative manner which exposes children to the discipline throughout their school careers.

- **Engineering Education at an Elementary Level: A Conceptual Framework**

With one or two notable exceptions (see for example English et al 2009), previous empirical investigation in this area is somewhat scarce. Thus, the researchers have found themselves on relatively new ground. Moreover, the lack of previous empirical research in this area, combined with the seemingly random nature of any meaningful activity, makes the need to clarify the key conceptual, theoretical and practical phenomena of great importance. A conceptual framework has therefore been developed with which further research into primary engineering education may be conducted. Three main concepts have been identified: pedagogic issues: exposure to engineering education; and children's interest. Figure 1, below, depicts the relationship between these concepts, identifying various sub-concepts and showing how they may impact and influence the future of engineering in the UK and beyond.

Figure 1: Primary Engineering Education: A Conceptual Framework



The above conceptual model, developed out of the study findings, supports the conclusions of earlier academic arguments from the USA and elsewhere (see for example English et al, 2009; Schunn, 2009; Mehalik et al, 2008). However, the limited and somewhat disjointed nature of primary level engineering education in the UK means that prior to conducting further investigation it is necessary to gain a detailed and accurate picture of current provision of primary engineering education. Therefore the next stage of the research process will be to undertake an in-depth mapping and critical analysis of primary level engineering education across the country.

Following this, a critical analysis of current provision will be undertaken in order to capture the perspectives and experiences of a wide range of various stakeholders. Building upon the approach adopted in the exploratory study, semi-structured interviews will be undertaken the aim of which will be to consider how engineering may be introduced into the pre-secondary school curriculum in a manner that enhances current teaching across a range of subjects.

Conclusion

This paper has briefly discussed some of the current and future challenges associated with conducting research into engineering education at a primary level. The authors acknowledge that the small size of the study sample (30 participants) means that the research has its limitations in terms of generalisability. Indeed, it is acknowledged that the issues raised in this paper only begin to scratch the surface, and that other influences on children, including parents attitudes (for further details see

Hirsch et al, 2005) and the manner in which the media portrays engineering as a career, means that there is much further work to be done in this area. However, that 30 people were interviewed in some depth would suggest that the issues raised in this paper could well be of interest for those working in Engineering and Education – both in the UK and more globally. Indeed, the opportunity to make a real difference to children's education by stimulating their engineering imagination, and in doing so impact the future of engineering in the UK in particular, but also more widely, makes this subject area of particular value.

In conclusion, if we are to avert future societal disaster the need to ignite children's engineering imagination from an early age is vital. In order to achieve this it is paramount that primary engineering education be given far more educational, social and political attention.

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