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Ekevall, E. and Hayward, L. and Hayward, G. and MacBride, G. and Magill, J. and Spencer, E. (2009) *Engineering - what's that?* In: SEFI Annual Conference 2009: 'Attracting Young People to Engineering: Engineering is Fun', 2009-07-01, Rotterdam. (Unpublished)

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Engineering – What’s that?

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Abstract

Engineering the Future (EtF) aims to develop a sustainable model of activities and interactions among researchers, policy makers and practitioners that develops pupils’ understanding of the nature of engineering, embeds experiences of engineering within the school classroom and curriculum and promotes engineering as a career.

One barrier to young people entering engineering is inadequate awareness of the nature of engineering and its diverse career paths. Many pupils in the participating schools had no awareness of engineering or very limited awareness. 65% had never considered engineering as a career choice.

1st year electronic and electrical engineering students at the universities of Strathclyde and Glasgow identified family links as a key factor in encouraging them to study engineering. They also traced interest in engineering to particular school classroom experiences.

Discussions with careers guidance staff revealed that careers guidance is almost entirely responsive to pupil requests: only occasionally will pupils who are good at science and mathematics be directed towards engineering.

The current situation leaves almost all school pupils uninformed about the nature of engineering. The paper describes how the EtF project seeks to redress the situation by developing classroom engineering experiences, working to embed engineering formally in the curriculum and providing resources for active careers advice.

Keywords: careers, school curriculum, engineering education, engineering awareness, engineering outreach.

1. INTRODUCTION

Engineering is vital to a country’s economy and the everyday life of society. Humankind depends on engineers to create new technologies, to find solutions to practical problems and to shape the world that people live in and the future they rely on. Yet young people have little or no perception of engineering and the understanding they do have is all too often confused with other careers, such as mechanic or repairman. Engineering the Future (EtF), a three year project funded by the Engineering and Physical Sciences Research Council, seeks to explore and address some of the major challenges facing engineering in education. Working with researchers, policy makers and practitioners, the project is developing a sustainable model of activities and interactions that develops pupils’ understanding of the nature of engineering, embeds experiences of engineering within the school classroom and curriculum and promotes engineering as a career.

2. THE ENGINEERING THE FUTURE (ETF) PROJECT

EtF focuses on Electronic and Electrical Engineering (EEE) in Scotland to develop an innovative, sustainable and transferable model of activities which encourage young people to study engineering and to support them as they make the transition from school to university. It will share findings with stakeholders in England, Wales and Northern Ireland to promote uptake on a UK basis and across other aspects of engineering. Essential aims are to:

- embed engineering within national curriculum, assessment and qualifications policies and practice
- provide experience and understanding of engineering activities within school classrooms
- identify and make young people aware of key skills, mind-sets and dispositions needed by engineers to face changing demands through their working life (in the light of information emerging in the project, this aim is being pursued through careers guidance, as well as school engineering experiences)
- support students' motivation and learning across the school-university transition and into engineering at university
- develop pedagogy in university engineering which challenges and supports students to extend their prior knowledge, skills and dispositions.

The project is thus complex, incorporating several strands, each with a range of aims and activities. This paper focuses principally on its work to address young people's lack of awareness and understanding of engineering and to promote engineering as a career.

3. ETF QUESTIONNAIRE DATA

3.1 Attitudes to engineering

At the start of the project EtF obtained questionnaire information from school pupils (in classes selected by teachers participating in the project) and 1st year students taking EEE in the Universities of Glasgow and Strathclyde about factors influencing their ideas about engineering and their choice of it for university study.

- 7 schools (5 state-funded, 2 private)
 - 869 pupils (389 females, 480 males) (approximately 20% of the pupils in years S3-S6 in these schools)
 - S3 (age 14/15) – 418
 - S4 (age 15/16) – 193
 - S5 (age 16/17) – 185
 - S6 (age 17/18) – 75
- 1st Year University students – 177 (9 females, 168 males) (approximately 80/90%)

Many of the pupils surveyed had no awareness of engineering or limited awareness of it as connected to building and fixing things. In response to a final invitation to make other comments or additional points, many wrote "don't know what engineering is" and/or "would like more information". The university student survey indicated that over half of the students had family or friends who were involved in engineering, that this had been a key factor affecting their awareness of it and that young people have little chance of developing well-informed views about engineering without such personal links.

These findings within the EtF project echo those of the Royal Academy of Engineering and the Engineering and Technology Board study 'Public Attitudes to and Perceptions of Engineering and Engineers 2007' [1]. Most participants in that study had a limited awareness and understanding of engineering and engineers. Young people (age 15-18) had a much more limited understanding of engineering than other groups, though they felt they had gained some understanding through science lessons at school and from army advertisements at careers fairs. Participants considered engineering to be a broad and vague term, difficult to define and pin down and often used to make a job or task sound better. Many of their assumptions were based on limited ideas from the media or from talking with other people, rather than from accurate information or personal involvement with the profession. They associated engineering with, for example, gas and photocopier engineers and with repairing and upgrading the rail and road networks. Part of the study included a qualitative workshop designed to provide

participants with better information to think about engineering in more depth. The workshop findings suggest

“that providing people with information about engineering improves and clarifies understanding of the scope and breadth of engineering and importantly, generates interest in the profession” [1:p37].

3.2 Consideration of engineering as a career

Two recent international studies, the Relevance Of Science Education (ROSE)[2] and the OECD Programme for International Student Assessment (PISA)[3], have reported that young people in developed nations recognise the contribution that science and technology make to society and acknowledge their importance now and in the future to make everyday life “healthier, easier and more comfortable”[4:p7]. Nevertheless, only a minority of young people in developed nations viewed study of science and technology as leading to interesting careers. It is not surprising that young people are uninterested in a scientific career when various studies have identified their lack of awareness of the nature of professional career options that science and engineering can offer [4][5][6].

“Pupils’ responses overwhelmingly indicated a lack of knowledge and understanding of the wide range of science and engineering careers. In particular the daily duties, routines and professional practice that scientists and engineers undertake” [5: p1].

In the EtF survey, the views of the pupils on engineering as a career were explored. 65% had never considered engineering as a career choice. Roughly a third (289) stated they had done so and 78% of these pupils were male. It was evident that much careers and subject choice advice came from family and friends: careers advisers, or even school staff, did not feature prominently. Only 10% noted the encouragement of careers advisers; 7% indicated that careers advisers had discouraged them from studying engineering.

The university 1st year EEE students were asked about their route into engineering. 39% first became interested in engineering in S3/4 (age 14-16) and 31% in S5/6 (age 16-18). 61% traced their interest in engineering to classroom experiences in school and 44% mentioned activities in the family. 56% of the students had at least one member of the family who was or had been involved in engineering - one student wrote: ‘my grandmother worked in ballistics’. Most of the students (77%) identified their family and/or friends as the main source of encouragement to study EEE.

The university student survey demonstrates that school-based educational experiences *can* influence pupils’ decision-making about their further study and career choices. However, awareness of the nature of professional engineering and engineering experience related to science and technology courses are absent from nearly all pupils’ school work. Large numbers therefore remain ignorant of the career options open to them and too few go on to study engineering in Higher Education.

4. NUMBERS STUDYING ENGINEERING

Between the academic years 2005/06 and 2006/07 the number of full-time engineering and technology undergraduates in Higher Education in the United Kingdom [7] increased by 2%. However, in the decade 1996/97 to 2006/07 the number fell by 15%. A similar pattern is seen among graduates from higher education engineering and technology courses in Scotland [8][9]: an increase of 3% between 2005/06 and 2006/07, but a drop of 12% over the last decade. During this decade the total number of higher education graduates increased by 28%, with an 18% rise in medicine and dentistry and a 45% increase in social studies (including law), as shown in Figure 1.

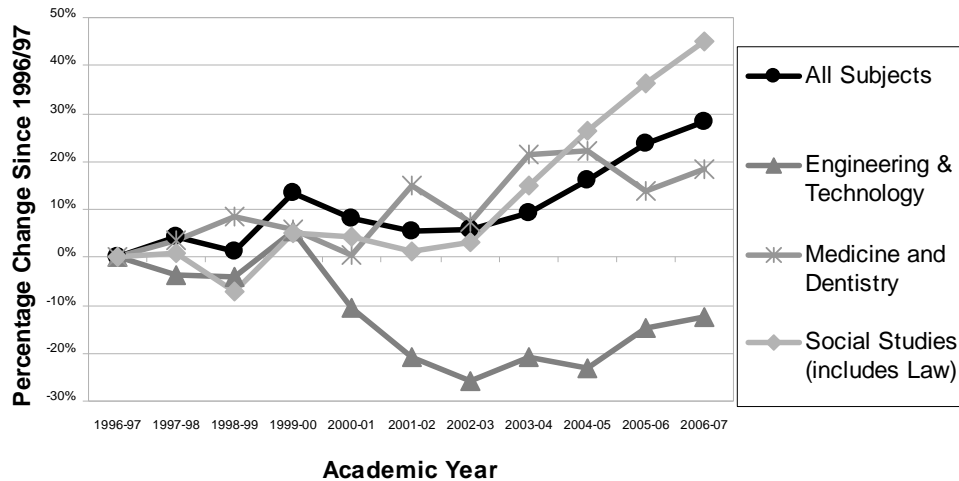


FIGURE 1. Percentage change each year in Scottish Higher Education graduates since 1996/97

The number of full-time undergraduates in EEE in the UK during the last decade peaked in 2002/03 (23,635) and has since fallen by a quarter to 17,640 [7]. In 2006/07 there were 4,637 accepted applicants for EEE Higher Education courses in the UK, but only 58.2% were UK-domiciled students [10].

To foster knowledge and understanding of engineering and promote it as a career, EtF is working with schools, university staff and policy makers to embed engineering in the Scottish curriculum for *all* pupils and to show that motivating engineering activities *can* be developed and fitted into the existing curriculum; it is also investigating careers advice provision. Data relating to the last of these are the central focus of the remainder of this paper. Discussion of careers advice is, however, preceded by brief accounts of action in the other two areas.

5. ETF ACTION TO ADDRESS THE ISSUES

5.1 Embedding engineering in curriculum policy

Despite the widespread UK and Scottish government and academic interest in and concern for all four of science, technologies, engineering and mathematics (STEM), the reality is that engineering is not actively promoted in either policy or practice in school education.

One of the significant problems is the fact that curricular frameworks in the UK place technology in a quite separate area from science and give little or no direct attention to engineering (until, in some English schools, pupils may choose an engineering-related diploma for late secondary school work). There is a danger that simply enabling and encouraging the development of engineering activities in the school curriculum, possibly in cross-curricular contexts, will mean that pupils choosing “pure” science courses will have little or no experience of engineering within science. The majority of these pupils will continue to have a very limited concept of engineering, without appreciation or experience of its essentially creative and problem-solving nature. The essential link between engineering and the application of science and mathematics – science and mathematics in action – will not be emphasised.

To create circumstances where engineering really can contribute strongly to individual pupils’ learning and to economic development requires an explicit and detailed strategy which builds engineering and the associated skills into the learning of *all* pupils – not just those who may pursue post-school apprenticeships or Further Education (non-university) courses or whose teachers take the opportunities available to teach aspects of the science/physics and technology curricula using engineering approaches.

The project therefore argues for the formal inclusion of engineering in the emerging reformed curriculum in Scotland, the Curriculum for Excellence, and its staff are in the process of interaction with those responsible for subject curricular frameworks to this end. The aim is to link engineering explicitly to *both* science and technology at all stages of primary and secondary schools. Such a move would explicitly highlight the many engineering elements within applied science and the study and development of technologies and convey the expectation that the concepts and activities central to engineering should form part of pupils’ school experiences.

5.2 Practical engineering experience developed through school/university partnership

In questionnaire responses completed independently school and university staff involved in EtF identified (a) a set of key ideas that pupils should understand about the nature of engineering and its motivating power and (b) essential characteristics of high quality engineering learning experiences. Research evidence about learning and teaching in general and about effective approaches specifically in engineering education (including that summarised on the websites of the Economic and Social Research Council (ESRC) Teaching and Learning Research project [11] and the Higher Education Academy Engineering Subject Centre [12] supported the ideas proposed by the project participants. Among the characteristics of engineering were:

- Using science (in particular physics) and mathematics principles to make functional, practical, useful products.
- Scientific mindset; understanding principles relevant to problem/need; logic; teamwork, effort, perseverance; responsibility; innovation, invention, creativity. “Hasn’t been done doesn’t mean can’t be done”.
- Solution-oriented; optimising solutions; modelling; understanding systems - how things work together; making and trying out models/prototypes before making products.

Among the motivators were:

- Digital technology and miniaturisation are at the heart of the speed and efficiency of very many modern products, including media devices.
- Human need to investigate, develop, grow, solve problems. Mind stretching; pushes boundaries of science: stimulates continuous advancement
- Improves quality of life. Cornerstone of a successful society; makes a real difference to people’s lives, in particular in developing countries
- Personal benefits. Employability, job prospects (worldwide, developing world...); travel; high professional status; high salary.

Examples of effective teaching and learning approaches in science and engineering included:

- Teaching that enables learning how to learn: reflection on, thinking about strategies for problem-solving, design, evaluating; drawing on science and mathematics knowledge; explanations by learners of intentions, processes, solutions...; and teaching focused on what the learner does.
- Assessment for learning - constructive feedback, self- and peer-assessment in respect of: knowledge needed for an engineering problem/project and the design – build/make – evaluate – adapt process.
- Learners gradually control and manage their own learning/problem-solving processes and projects.

The school/university partnership teams (one or two members of staff from each of 10 schools working with up to three EEE lecturers) developed curricular inserts keeping in mind the principles thus agreed in advance among them.

In all the project schools activities were developed for the general science course in the first two years of secondary education or in the physics courses at S3/S4 and S5/S6; in one school the technology department is involved, as well as science/physics. Examples from among the sixteen developments currently being trialled in the project are: wireless technology devices that can tell when plants need water and send a signal to a mobile phone; taking part in a Mars Rover challenge combining astronomy and electronic engineering; using ultrasound to measure distance and learning about other engineering applications; building radios from everyday materials; learning about engineering applications through practical activities, for example using the Wheatstone bridge equipment to measure strain on a model bridge; the compressed physics, economics and technological studies course newly designed by one school specifically for pupils who are interested in an engineering career.

Both teachers and pupils involved in the developing and trialling have expressed very positive views about the inserts. Almost unanimously teachers perceived them to be interesting and motivating for pupils, because of the practical work, more interactive teaching and learning and relevance to everyday life. One teacher said:

“... not only will it promote engineering but it will improve the quality of the ... teaching within the classroom, because you’re using activities which are real and relevant and that’s going to improve the kids’ motivation and interest.”

The pupils responded very positively and enjoyed the engineering experiences. They were aware of the science and mathematics content in them and became more aware of engineering and the applications of science in the environment. Some expressed a new interest in engineering as a possible future study and career route.

The EtF curriculum inserts demonstrate that there is scope for engineering within science (and, though in only one school in the project, technology), successfully integrating process with content and context and enhancing pedagogy.

5.3 Investigation of careers provision in the project schools

Both the lack of awareness among pupils of the breadth and scope of engineering disciplines for further study and career opportunities and the apparent lack of influence of school careers guidance staff on the university engineering students' choice of engineering prompted investigation of guidance materials and provision.

Seven project schools (five state-funded and two private) were visited to establish the careers guidance pattern and the availability of careers materials in each. Teachers identified by the schools as having a careers guidance role were engaged in discussion (the number varied from one up to ten). They included careers guidance teachers, local authority careers staff, science and technology subject teachers and school managers (head, deputy head).

Whilst some science teachers in each school (and also technology teachers in one) were already involved in the project, the careers guidance teachers and the local authority careers staff assigned to each school were not. In advance of the meetings these teachers were given brief information about the project – essentially its principles in respect of the nature and value of engineering and the kind of pedagogy associated with successful teaching of it, described in 5.2 above. Questions to be discussed were also sent in advance. These were open-ended, designed to provide a clear picture of guidance practice in each school.

- 1 What is the careers guidance pattern in the school?
 - i. When provided?
 - ii. Linkage to subject choice?
 - iii. Linkage to post-school destinations?
 - iv. Do all pupils have an individual interview with a careers adviser? When?
- 2 Who provides this guidance?
 - i. In school?
 - ii. Outside contributions?
 - iii. Visits, open days, etc?
- 3 Types of resource available?
 - i. Types of resource used?
- 4 To which curricular areas and post-school courses are pupils oriented who express or reveal interest in creative activities?
- 5 How does engineering feature within this pattern of guidance?
- 6 To what extent is the nature of engineering explained?
- 7 Are there any specific engineering-related materials or initiatives that are drawn on?
- 8 Engineering work experience?
 - i. How are pupils selected for this?
 - ii. Suggestions for post-school work experience, prior to Higher (national school-leaving certificate) examinations or Further Education?

9 What steps are taken to enable pupils to obtain detailed information about the following areas of study?

- Physics
- Medicine
- Veterinary Medicine
- Forensic science
- Law
- Engineering

In the discussions, similar points were made in all the schools, but with some local variations. The information obtained provided the basis for the development of the careers aspect of the project.

5.3.1 Information from the careers guidance discussions

The single most important finding from questions 1-4 (and also question 9) was that in almost all cases the pattern of guidance was entirely responsive and not directive. All teachers reported that, in keeping with advice from the national body, Careers Scotland, their role was to respond to pupils' requests and to provide generic tools for them to use in researching an area of interest.

A formal careers element in Personal and Social Education (PSE) was common in each year of the secondary school from S2 (age 14, when subject choices are usually made) to S5 (age 17); interviews with local authority careers staff took place in S4/S5 in most schools; and pupils had the opportunity to request careers information or guidance whenever they liked. Careers activities included visits to local careers events, visiting speakers in schools from various employers and from universities, Higher Education open days and extensive use of the Careers Scotland software resource, PlanIT, designed to help pupils identify their areas of interest and natural strengths. Overall, however, the "responsive" approach was prevalent in all this range of activity. The implication is that, to receive detailed and appropriate career information related to engineering (or any subject), pupils must already know something about it and have at least enough interest to prompt further investigation of career potential. The result is that careers are inevitably disadvantaged if they are not well known or if the relevant subject disciplines are not in the school curriculum. This finding may help to explain the finding from the pupils' and students' questionnaire data that careers teachers contributed little to subject and career choices. They may be seen primarily as providing access to generic material and search facilities, rather than giving detailed individual guidance and opening up possibilities.

In response to the questions 5-8 on the nature of engineering-related careers guidance within the general pattern, the teachers indicated that, though the approach was normally responsive to pupils' expressed interests, engineering might be occasionally mentioned to pupils who were very good at science or mathematics. Careers guidance and materials did not normally explain the nature of engineering – indeed, it was evident that some careers staff were not very familiar with it themselves: several said they needed support to be able to provide detailed advice. The only specific engineering "resource" mentioned in several schools was a road show, Make it in Scotland, run by Careers Scotland [13]. This gave S2 pupils (age 14) an opportunity to take part in hands-on workshops offered by manufacturing companies and other organisations, to inform career choices just before they make subject choices which influence future career paths. However, this event was discontinued in 2006 and no similar opportunity has replaced it. Some schools mentioned occasional "engineering events" involving invited speakers. One of the private schools regularly invited parents, including engineers, to speak about careers and argued that this was an important and effective aspect of their careers guidance. Clearly this type of opportunity, whilst it is a very useful adjunct to careers provision, depends heavily on the nature of the school's intake.

The reliance on pupil's families was also apparent in responses to question 8 about workplace experience in engineering. No school specifically offered placements in engineering and several cited difficulties in finding any industrial placements because of perceived health and safety constraints. Pupils were encouraged to find their own placements. Some with parental engineering connections were said to gain relevant work experience through this link.

This point about the significance of family links to engineering reflects the finding from the university engineering students' questionnaire that a large majority had a parent, relative or family friend who was an engineer. The prominence of this influence on future engineers' career decision-making might have an unfortunate consequence. The pool of qualified engineers in the UK is diminishing, but it seems to be precisely these people who, either as family members or as occasional visiting speakers at careers events, at present

influence the decisions of young people choosing engineering as a career. If this situation persists, it might be expected that the number of engineers will continue to decline. There is an urgent need for action not only to give young people knowledge about engineering and experience of it in school work but also to ensure that careers guidance explains and promotes it properly.

At the meetings the schools requested DVD resources that could be used directly and without preparation in classes for PSE and printed information with the specific requirement that this be up-to-date, suitable for the age range, attractive and engaging.

5.3.2 Further EtF action

A study of the available engineering careers material carried out by the project team revealed a range of resources. Many are provided by specific organisations and companies presenting information about that organisation or industry. However, they are disparate, not always fully comprehensive, frequently not age-specific and often inappropriate for younger pupils. They rarely explain the duties and professional practice of engineers. Other problems are the multiplicity of locations and the difficulty of finding some.

These findings suggest that the current careers advice arrangements give pupils too little information on engineering and too late to develop an interest in an engineering career before they choose their subjects for upper secondary school study. The EtF project has therefore developed two up-to-date printed resources providing fuller explanations about engineering in general and orientation to sources of information about specific types of engineering. These are now being tried out in project schools as the basis for a different, possibly more proactive, model of careers advice for engineering in the first two years of secondary schooling, before subject choices are made. The evaluation of this initiative will be the subject of a subsequent paper.

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