Engineering the Future*: Practitioners, Researchers and Policy Makers Working across Sectors

Engineering the Future: working together to enhance understanding, commitment, and participation in engineering.

Workshop

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*Engineering the Future is the working title for the EPSRC Project 'Promotion of Engineering through the Creation of a Structured School – University Interface', G. Hayward, University of Strathclyde (Principal Investigator) and L. Hayward, N. Hedge & J. Magill, University of Glasgow

Overview

Engineering the Future (EtF) is a three year project funded by EPSRC, which became operational in September 2006 and which is based in the Department of Electronic and Electrical Engineering of the University of Strathclyde and in the Departments of Electronics and Electrical Engineering and Educational Studies of the University of Glasgow. EtF seeks to address the challenges posed by the predicted shortfall between the numbers entering university engineering courses and the growing demands for graduate engineers to meet society's needs. To do so it aims to develop a methodology which sustains transformational change in engineering education. Using Electronic and Electrical Engineering (EEE) as a pilot study and located initially in Scotland, the Project's findings will be disseminated to ensure uptake on a UK basis.

Working across disciplines with researchers, policy makers, practitioners and the industrial community, EtF wishes to move beyond one-off events and awareness raising, important as these are, to embed in the education system a sustainable model of activities which:

- develop pupils' understanding of engineering
- provide experience of engineering activities within classrooms in every school
- support learning across the school-university transition
- develop pedagogy in university to build on students' prior knowledge and skills
- promote engineering as a career.

Learning Outcomes

This workshop affords us an opportunity to submit work in progress to the informed scrutiny of colleagues. We invite participants to:

- reflect critically on the effectiveness of the model of change that lies behind EtF and consider its applicability in other engineering education contexts
- examine some of the school/university activities being undertaken and consider their contribution to the development of the skills and mindsets required by graduate engineers
- discuss with the EtF team issues being faced by the team on how to grow the project across and beyond Scotland with a view to developing the robustness of our models and to exploring their validity in other contexts.

Workshop timetable:

1. Introduction / setting the scene: 10 minutes
2. Exercise 1: 15 minutes
3. Exercise 2: 30 minutes
4. Final questions for debate: 35 minutes

Context

Policy makers, academia and industry are seriously concerned about the decline in the numbers of young people studying physics in school and entering university to study engineering. While the decline in the proportion of those studying physics in secondary schools has been less noticeable in Scotland than elsewhere in the UK the decline in the number studying technological studies is marked (Scottish Qualifications Authority 2006, 2007). Participation rates in Higher Education are now approaching 50% of school leavers but the number of students applying for engineering courses is generally falling (Scottish Funding Council 2007; Scottish Government 2007). Retention in the first years of university engineering courses is also an issue. Staff perceive the increasing diversity of attainment and commitment of students on entry to engineering faculties as factors which are difficult to address.

Development model underpinning EtF

Underpinning this project is a clearly articulated view about educational development. There is extensive literature on likely determinants of successful innovation in education (Kirk & MacDonald 2001; Spillane 1999; Triggs & John 2004, Gardner et al, 2008) including research into practice in Scotland (Hayward et al 2004, Hutchinson & Hayward, 2005, Hayward & Spencer, 2008). Successful change results only when staff in schools and universities can harness system change to their own will and capacity (Condie et al 2005). This Project is built upon the collaborative participation of school and university practitioners, researchers and policy-makers (Keys & Bryan 2001). As a project built on the principles of partnership and inclusiveness, EtF also embraces the views of pupils and students (Brownlie at al 2006). Finally EtF considers it crucial that its working be informed by the findings of research on effective teaching and learning.

Putting the model into practice

EtF involves staff in two University EEE departments and teachers from schools in several education authorities as active partners. All participants were asked to complete questionnaires at the start of the project. One major focus of these was to determine the views of colleagues on reasons why pupils are not attracted to engineering, on the defining characteristics of engineering which may motivate young people into considering a career in engineering, and on the factors which lead to successful engineering education.

The responses to the relevant questions were examined by members of the EtF team to discover whether there were any common themes. It proved relatively easy to obtain agreement on these emerging themes; there was considerable overlap in the views and opinions expressed by members of staff in both sectors. The results were synthesised into three diagrams (Figures 1, 2 and 3) which summarised the participants' 'big ideas' about engineering education under the headings: 'characteristics of engineering', 'motivators' and 'principles of learning and teaching'. This process ensured that our planning and development were informed by the views of teachers, both school and university, derived from their experience.

Comparing these views with information from other sources has in general corroborated them. It is important that we continue to ensure that the views of various groups continue to be used to illuminate each other.

The views of pupils and students, derived from their experiences of teaching, assessment, careers guidance and transitions, were gained in year 1 mainly through questionnaires; in years 2 and 3 greater emphasis will be placed on exploring their ideas through focus groups of pupils and students and through involving school pupils themselves as researchers in schools.

The views of policy makers were obtained: through an Advisory Board which includes high level representation from industry, from the education policy community, from the scientific policy community and from educational research, the members of which collectively and individually are active participants in the dialogue among practitioner, research and policy communities; and through an Extended Advisory Network within and outwith Scotland which includes colleagues working in science education, teaching and learning, assessment, careers, economic development and industry who act as critical friends on specific aspects of our work. Further specific information to guide EtF has been obtained through a questionnaire for industrialists. These structures have fostered dialogue with these communities on the policy implications from emerging project findings, have provided advice on effective strategies for EtF to adopt and have ensured that developments are in synergy with other policy developments.

EtF has drawn upon a range of educational research related to curriculum, assessment and pedagogy, in particular the recognition of the difficulty of ensuring for teenage pupils 'deep learning' of complex concepts (Entwistle et al 2005).

Taking practice forward: part 1

To address the issues related to a declining interest in engineering as a graduate career EtF aims to:

- develop pupils' understanding of engineering

- provide experience of engineering activities within classrooms in every school
- promote engineering as a career

Given perceived discontinuities in learning between school and university which required collaborative action; it was necessary to address the ignorance which staff in each sector had expressed of the teaching and course demands made in the other. A workshop was held so that participants could share their experiences of the curriculum in schools and universities. Partnerships were established which brought together the science staff from each school with named member(s) of university EEE departments.

To develop pupils' understanding of engineering, each school-university partnership undertook the task of developing engineering related inserts within school science and physics courses. These inserts sought to provide pupils not only with technical knowledge relevant to engineering but also with fundamental skills and approaches as team working such as problem solving or systems thinking which are attributes of a successful engineer.

To ensure that inserts were informed by policy and research colleagues were encouraged to reflect on and develop the 'big ideas' and to consider their developments in the context of the values of a Curriculum for Excellence (CfE) (Scottish Executive 2004a, 2004b). The inserts created should also be capable of dissemination. Discussion between EtF and CfE team members resulted in an invitation to school-university partnerships to develop their inserts as exemplars for engineering topics to be nationally disseminated to all schools. It is however necessary to consider other means of dissemination both within Scotland and elsewhere in the UK.

A summary of some of these inserts is provided in Table 1.

Exercise 1

Workshop participants are asked to consider the ideas summarised in Figures 1 to 3 and the summary descriptions in Table 1 to respond to the following questions:

1. Do you feel the learning and teaching principles in Figure 3 are comprehensive?. Are there any missing that you use in your teaching practice? Which do you find most effective?
2. Within the summary descriptions in Table 1 is it possible readily to identify the 'big ideas' summarised in Figures 1 to 3 and ways in which these inserts support the development of knowledge, skills and dispositions required to study engineering beyond school?
3. Are learning experiences such as those outlined in Table 1 sufficient to ensure that pupils develop an informed positive view of engineering as a career?

Taking practice forward: part 2

Two of the central aims of Engineering the Future are to:

- support learning across the school-university transition
- develop pedagogy in university to build on students' prior knowledge and skills

The initial survey of lecturers, confirmed by discussions with them, highlighted concerns that students lack systems thinking and problem solving skills which are fundamental to successful deep learning in engineering. Entwistle (2005) highlighted the issue of deep, strategic and surface approaches to learning in EEE.

Assessment practices impact notably on students' approaches to learning. There is an apparent mismatch between the approaches to learning inculcated by the school qualifications system and the expectations of university staff; in particular the model of problem solving which many students have internalised seems limited to neatly specified problems. Analysis of upper secondary mathematics and physics examination papers supported this view. More generally the pressures imposed by high stakes assessment on learners lead to their developing strategies to pass rather than to learn with understanding: candidates may seek to do little more than insert figures into appropriate formulae. There is evidence that these patterns can be further promoted by assessment practices within universities.

The EtF team sought information from those most directly involved: the learners in both school and universities. Pupils at various stages in the partner schools and students in Year 1 of EEE courses in the two universities were asked to complete questionnaires which, inter alia, sought information about their views of their experiences as learners in relevant subject areas in school and their university course. A focus group of 4^{th} year students provided further insights into learning in the University. Findings from the analysis of these questionnaires were compared with the views of lecturers and largely confirmed them.

While the EtF team has continued to address these ideas through dialogue with policy communities, change will not be immediate; university lecturers must address the learning needs of an ever more disparate entry group. Since the major determinant of future learning is one's prior learning, one major issue is the establishment of means by which lecturers can build on the learning (broadly defined) which their students bring with them. Another issue concerns the important roles played by the contexts within which participants work and the ways in which contextual catalysts and inhibitors can be used or countered, including the role of student expectations as a key contextual factor (Yerrick et al 1997).

Within this context meetings EtF has sought to develop and sustain the dialogue on improving teaching and learning to support students over the transition from school to university and to develop the mindsets and deep learning required by engineers.

An illustrative extract from a discussion paper is included as Table 2.

Exercise 2

Workshop participants are asked to consider the extract from that paper in Table 2 and to use the questions below to reflect and report on issues arising from the assumptions built into it:

1. What aspects of the university environment are likely to impact on student learning and should be considered by lecturers?
2. What aspects might be susceptible to influence from staff?
3. How can university staff gain knowledge of students' prior learning including:

    a. content knowledge and understanding
    b. skills in applying content knowledge and understanding
    c. dispositions and ways of thinking
    d. broader skills (eg team working, perseverance)?
4. How do we promote personal development planning as a means of supporting learning as well as employability?

Final questions for debate

Workshop participants are asked to develop answers to these questions with the team members:

1. How can we most effectively use collaborative practice among practitioners, researchers and policy makers to promote and support critically informed development of our practice?
2. How can the model here developed be utilised in other education policy frameworks in the UK?
3. How can the model here developed be utilised in other engineering education contexts?

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Fig 1

Characteristics of Engineering

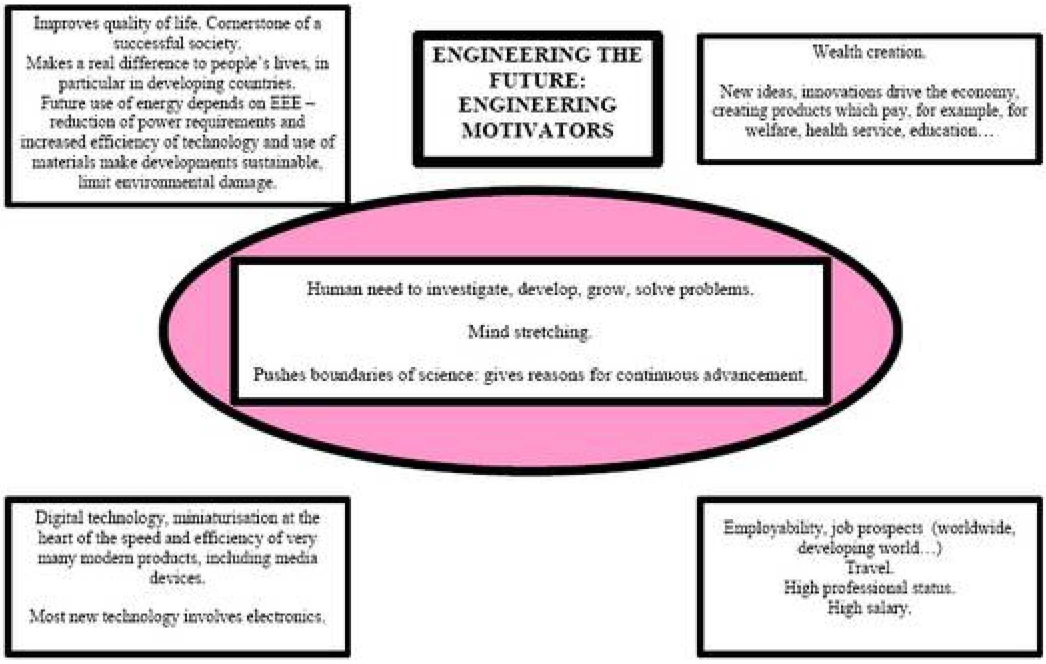


Fig 2

Motivators

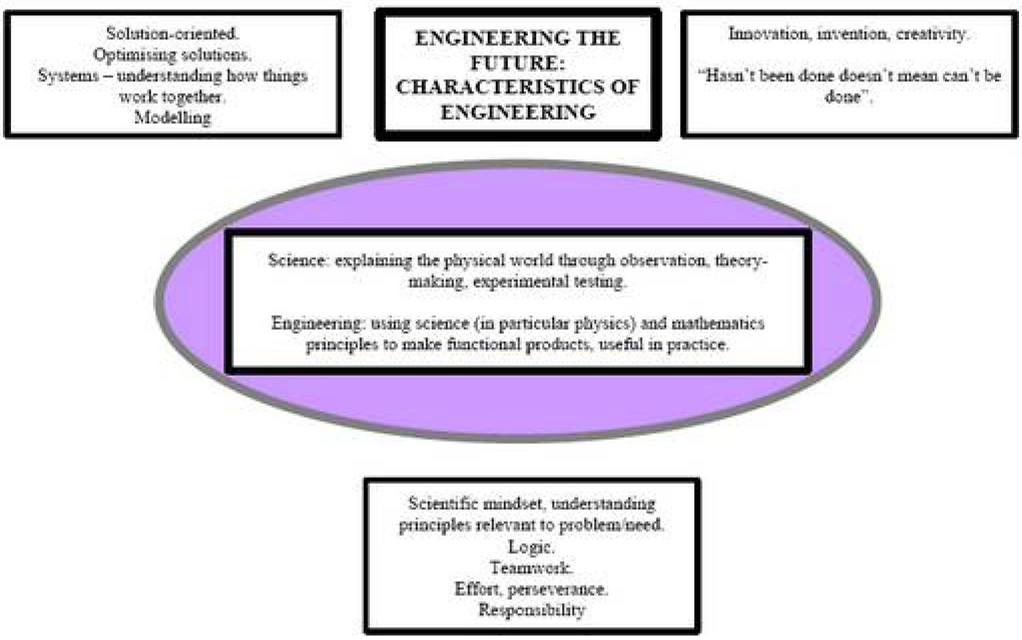
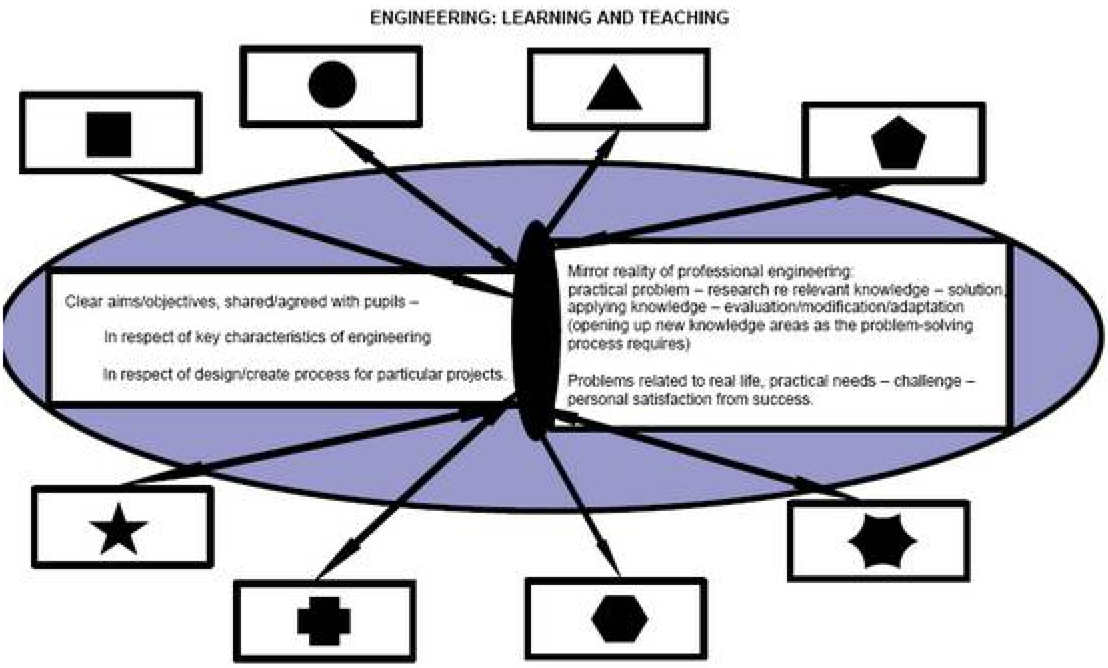


Fig 3

Principles of Learning and Teaching



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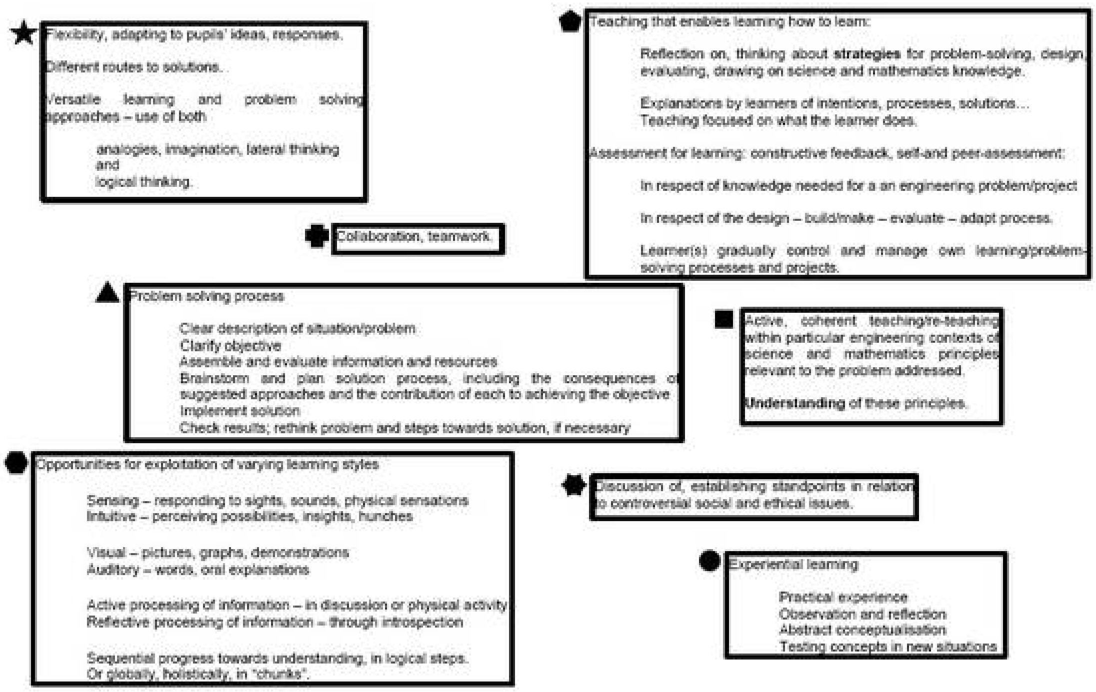

Table 1

Year	Insert
S6	The planned investigations in Physics at Advanced Higher level involve (i) characteristics of engineering {understanding how things work, employing logic, taking responsibility}; (ii) engineering motivators {human need to investigate, solve problems, using digital technology and exploring miniaturisation}; (iii) learning principles {employing different routes to solutions, problem solving, evaluating, checking results then rethinking the problem, observation and reflection. For the Speed of Light Investigation, c will be measured using (i) Foucault's method, (ii) an electronic timing technique and (iii) by measuring ε_0 and μ_0 and inserting their values into Maxwell's equation. For the Mobility of Charge Carriers Investigation, methods employed will be the use of the characteristics of a n–channel Mosfet Transistor and examination of the Hall Effect in a n–Ge semiconductor.
S5	Students experience an active and practical approach to their learning, using state of the art equipment to motivate them. Students gain an insight into engineering principles that are applied to bring solutions to real situations. Students are given opportunities to improve their practical skills through participation, observation and recording. This includes experimental use of strain gauge/Wheatstone Bridge/amplifier applications.
S3/4	Discussion with Strathclyde University links highlighted the need for Engineering pupils to have business skills to maximise their chances of success when running their own business raised the possibility of a new compressed S3/S4 course (3 subjects are linked and taught in the time usually allocated to two) : Physics, Economics and Technological Studies (PETS) with an engineering emphasis, addressing issues associated with global warming. Streamlining the teaching of Physics and Technological Studies may free up teaching time to run additional activities and organise trips and speakers.
S3/4	Several tasks being developed related to Standard Grade Physics (Using Electricity and Electronics topics), with an emphasis on engineering concepts. S3/S4 pupils will use signal generators, CROs, LEDs, coloured filters, fibre optic cable and parabolic reflector.
S1/2	'Bat Monitoring' (building a device to monitor inaudible sounds made by bats); through links with RSPB bat boxes will be put up which will be monitored over time using monitoring devices built by pupils. Teaching will incorporate cooperative learning techniques and pupils must gain an insight into the problem solving nature of electrical engineering. Renewable Energy (energy generation and storage and design of wind turbines) is linked to the development in the school of a wind farm as part of its "Eco-school" identity.
S1/2	An S2 electronics module, enabling pupils to learn about the concepts of input, process and output, devices associated with input and output and the use of logic gates in creating and using a "Mars Rover" vehicle to explore surfaces at a distance; pedagogy stresses co-operative learning work. The work is solution-oriented, adopts a systems approach, uses simulation and team work. The learning is driven by a particular need and pupils are given specific responsibilities.
S1/2	Pupils learn first hand in a practical way how to solve problems relating to home security. They will learn about basic input-process output systems and the use of certain electronic components as the basis for many different systems. They use Alpha boards to make practical circuits and micro controllers to design systems that use sensors (heat, motion, etc.) to trigger alarms. Pupils work in groups each addressing a different problem. The pedagogy stresses group work, modelling before building the system, and presentation skills.
S1/2	The partnership is developing curricular elements based on the existing out-of-hours Engineering Club activities. A key idea will be to have pupils develop their own ideas for projects which would be undertaken by other pupils.
S1/2	The focus is on engineering in the S1 broad-based science course where there is potential for building practical, engineering projects into an expansion of the Energy section of the S1 course book which includes work related to such topics as renewable energy sources (wind turbines, bio-fuels, solar power, fuel cells).

Table 2

Engineering the Future **University EEE Year 1 Meetings** **Purpose of the day:** Participants are asked to share with Engineering the Future team members their experience and expertise in promoting effective learning and to begin to identify means of improving learning, using the following questions as guidance to provide a structure. In so doing participants are asked to consider not only their own face to face interactions with students but also the university environment within which students learn and the students' previous experience of learning. 1. …. 2. How do we meet the demands posed by the diversity of the student group and provide support and challenge to all students? How do we recognise and address different levels or types of student motivation? How do we build on the knowledge and understanding they have developed in school study? How do we build on the skills and dispositions they have developed in school? How well do we make provision for students whose subject attainments at different levels? How do we make use of personal development planning to support learning? 3. … 4. … 5. …