CROSS-DEPARTMENTAL INITIATIVES FOR A GLOBAL DIMENSION IN ENGINEERING EDUCATION

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Abstract: At Imperial College London the Faculty of Engineering has initiated a number of cross-departmental schemes to help support the broader, inter-professional and skills-focussed development of engineering students, and further place engineering in the context of societal priorities. In this paper, an overview of the cross-departmental schemes is given. The central coordination of the schemes, but in close correspondence with departmental teaching and learning directors, has helped instigate the developments and promote a culture of shared responsibility for engineering education which goes beyond the usual departmental boundaries. A description of the coordination effort, and subsequent mechanisms for promoting strategic educational development, is also given. Examples will be presented to demonstrate the range of learning outcomes which can be achieved through such cross-departmental approaches, such as interdisciplinary communication, real-world engineering experiences, wider technical, social and ethical awareness, and both core engineering and engineering-in-context recognition. Specific schemes to be presented include: the *Engineering Impact* series of lectures; flexible timetabling for shared option courses across departments; a common framework for engineering ethics engagement; creative design approaches; and the set-up of a new academic role for the support of student-led projects.

Keywords; global engineer; cross-departmental engineering education; professional and transferable skills; student-led projects.

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1. INTRODUCTION

Issues of sustainable development, globalisation and poverty reduction have led to much discussion on the changing role of the engineer and, subsequently, engineering education. Within the UK, there is increasing acknowledgement of the need for a *global dimension* in engineering education to address current and future economic, social and environmental challenges; see for example the survey of Bourn and Neal (2008). Many employers themselves are driving such a need through their efforts to create corporate social responsibility programmes and to attract and develop graduates who have an astute global awareness. This global awareness may include: a systems (holistic) understanding and approach to dealing with the complexities of sustainable production, process and infrastructure design, and utility provision (Fenner et al., 2006; Pritchard and Baillie, 2006); training on the skills necessary to actively engage in and contribute to

multidisciplinary and international communities (see e.g. Leitch, 2006; Fallows and Steven, 2000); an understanding of the social and ethical responsibilities of the engineer to meet, for example, human needs whilst minimising resource use (De Graaf and Ravesteijn, 2001; Fenner et al., 2006); a focus on engineering development and design for basal rather than luxury human needs; and an understanding and valuing the natural environments and the interconnectedness of local and global ecosystems. At Imperial College London, it is also observed that students are drivers of this global dimension, i.e. a growing number of projects created by students to tackle specific techno-socio problems in communities in developing countries.

A global dimension in engineering education is seems a natural evolution of the profession in the age of digital communications, given an economically expansionist China, India, Russia and Brazil, and in an era of greater student mobility from the most populous countries. A global dimension may be encouraged by the competitiveness of multinational companies to "exploit location-specific innovation advantages" (Zedtwitz and Gassmann, 2002). However, as global industries slowly respond to sustainable production and development, so too has the premise for international collaboration. Engineering students themselves are entering degree programmes with aspirations of *making a difference*, and primed with the concerns of, for example, climate change, poverty and human inequalities (Alpay et al., 2008). Many University educators have responded to this need by re-evaluating engineering content and pedagogy. Typical initiatives include: creating core courses on sustainable development (see the discussions of Perdan et al., 2000); project-centred learning around complex, real-life and socially pertinent topics (see e.g. Carlson and Sullivan, 1999; Lipson et al., 2007); the provision of service learning and placement opportunities in which students participate in community-relevant work (see e.g. Coyle et al., 1997; Oakes et al., 2002); and the use of multidisciplinary team projects fostering transferable skills and widening the students' perspectives on cultural and stakeholder issues. Nurturing the global engineer requires a broader professional skills base and a wider awareness of, e.g., international, social, cultural, environmental, political and economic issues. In the past, student development in such areas has been supported through *soft courses* in humanities, stand-alone courses in management and business or through ad-hoc work and study experiences. Currently, much motivation exists in enhancing student skills and knowledge, in which there is some explicit or structured developmental plan towards *global competency*. However, the complexity of such training often necessitates a range of learning experiences with adequate opportunities for reflection and feedback. Often, engineering teachers themselves are unclear as to the facilitation and evaluation of such global skills education.

At Imperial College London, the Faculty of Engineering has initiated a number of cross-departmental schemes to help support the broader, inter-professional and skills-focussed development of engineering students. In this paper, an overview of some of the cross-departmental schemes is given, and some initial evaluation data on their impact on the student learning experience presented. Central coordination of the schemes, in close correspondence with departmental teaching and learning directors, has helped instigate the developments and promote a culture of shared responsibility for engineering education which goes beyond the usual departmental boundaries. An overview of the coordination process is also presented, and will be of relevance to institutions who are attempting to organise educational initiatives across multiple engineering departments.

2. THE CO-ORDINATION OF ENGINEERING EDUCATION DEVELOPMENT

The Faculty of Engineering at Imperial College has committed significant resource to support and develop strategy for Teaching and Learning across all nine engineering departments. Specifically, in 2007 a dedicated group, referred to as EnVision, was formed to support engineering teaching in several ways, including:

- support for departments in course strategy and development
- the attraction of external funds in engineering education
- support for flag-ship projects
- the design and organisation of *teaching celebrations* for recognising and rewarding outstanding teaching contributions or support
- the collection, dissemination and implementation of good practice in engineering education

The core EnVision group consists of 4 engineering academics, 2 learning technologists, a timetabling officer and 2 administrative staff. The group works closely with the Faculty Teaching Committee (FTC), which constitutes the Directors of Undergraduate Studies from each engineering department, and is chaired by the Deputy Principal (Teaching) for the Faculty of Engineering. The EnVision group thus provides consultancy on educational matters to the FTC, as well as administrative, technical and project support for subsequent teaching and learning developments endorsed by the FTC. Unlike many educational support units, EnVision is engineering-specific, led by engineering academics who teach in departments, directly involved in curriculum development, offers core courses to students and does not run staff training on educational development (Imperial's Educational Development Unit provides such training for staff in all faculties). EnVision is embedded in the normal structure of educational strategy and delivery within the specialist Faculty of Engineering.

In the context of global competency for engineers, much opportunity exists for inter-professional skills development through inter-disciplinary, extra-curricular or real-world activities. An advantage of the coordination effort described above was for the set-up of common guidelines, procedures and formats for such activities so as to maximise the student learning experience. Likewise, the coordination helped facilitate new teaching initiatives in which mixed cohorts of engineering students can experience the challenges and rewards of inter-disciplinary work. Central to many of the initiatives is dedicated learning technology support to help in. e.g., activity administration, materials organisation and web-resource development.

In addition to the EnVision/FTC inspired projects, two further schemes are used for the generation and development of cross-departmental initiatives: the Faculty of Engineering Enabled Projects scheme and the Student-Led Projects scheme. The former gives support and funding to innovative projects that have the potential to benefit students and staff in terms of motivation, learning and teaching satisfaction and engineering know-how and skills development. Academic staff are invited to submit proposals on an annual basis, but open-call submissions are also possible to accommodate timely teaching development opportunities. A key condition for proposal support is for multi-departmental involvement or significance. Since 2007, 13 projects have been funded, several of which have direct relevance to global engineering competencies; see section 3 below.

The Student-Led Projects provides students with academic, administrative and financial support in the development of extra-curricular projects of interest to them and, where relevant, advice on continued project funding and management. The range of support is broad and varied, including advice on insurance and legal matters, project dissemination and national and international cooperation. The motto for the scheme is "by the students, for the students", and encapsulates EnVision's desire to encourage students to undertake activities which broaden their professional and transferable skills base, raises their awareness of global citizenship and further inspires them towards their role in society as future engineers. The scheme has a dedicated academic tutor for student support and liaison.

In the following section, examples of schemes being supported by EnVision are presented. These are organised under the abovementioned themes of 'EnVision/FTC inspired', 'Faculty of Engineering Enabled' and 'Student-Led projects'.

3. CROSS-DEPARTMENTAL INITIATVES

3.1 EnVision/FTC-Inspired Initiatives

Two examples of EnVision/FTC-inspired activities are presented to demonstrate the value of coordinated and strategic teaching planning across the Faculty of Engineering. The first involves a change in teaching culture to enable senior-year students to experience a broader range of technical courses, and to engage in group and project work with peers from other engineering disciplines. The scheme was made possible through the set up of a common timetable for one day of the week. The courses, referred to as Flexible Friday Option Courses, are deemed to be of relevance to broader engineering understanding and are offered to students from across the Faculty of Engineering. Examples of courses include Computational Finance, Environmental Impact Assessment, Optimization, Sustainable Electrical Systems, Nuclear Reactor Physics and Design-Led Innovation and Venture Creation. In some cases, the interdisciplinary nature of the learning group has motivated staff to develop innovative courses to capitalise on the potential for creative and non-discipline bounded project work. Current examples of courses being developed include Design of Rehabilitation Systems and Assistive Devices, in which mechatronics, human factors and computer theory are integrated to develop life-quality enhancing devices for an ageing population, and Natural Engineering, in which novel approaches to engineering design and problem solving are considered through analogy with natural physical and biological processes, structures and materials. To date, more than 200 students from across the Faculty of Engineering have undertaken Flexible Fridays Option Courses, and a high level of student satisfaction reported; see Table 1.

The second activity also involves the common timetabling of teaching sessions, but in this case all first-year engineering students are encouraged to attend. The sessions are referred to as the Engineering Impact Series of Lectures (EI) and are aimed to further inspire first-year students towards the role of engineering on society and human development. The sessions cover a broad range of topical themes, and have included presentations on climate change and sustainable development (Jonathon Porritt – Broadcaster and Environmentalist), technology and health (Lord Ara Darzi – surgeon and former Junior Health Minister) and the profession of engineering (Sir Robert Malpas – former ICI and Eurotunnel Chairman). An underling theme of EI is engineering ethics and culminates in a final debate session on controversial issues of relevance to student engineers, e.g. military-related work. Where possible and appropriate, EI is integrated with other

departmental ethics or professional awareness activities. To enable maximum student access, and a resource for future teaching, all sessions are recorded on video and made available to the staff and students through the EnVision website.

Table 1 - Descriptive Statistics for the student experience with Flexible Fridays Options Course (N = 43).

	Mean Score (max=10)	Std. Deviation
Overall, I am satisfied with the Flexible-Friday programme.	7.8	1.4
More 4th year options like this should be offered to students.	8.5	2.0
Attending such a course has given be a broader understanding of issues relevant to the different engineering disciplines.	8.5	2.0
Attending such a course has improved my identity as a member of the Faculty of Engineering as a whole.	6.3	2.5
Attending such a course has improved my motivation towards an engineering-related career.	6.6	2.4

3.2 Faculty of Engineering-Enabled Projects

As mentioned earlier, the Faculty of Engineering-Enabled Projects scheme is a way of encouraging academic staff to further engage in teaching developments, especially when this has potential value to students across the Faculty. Some of the funding has been used for the development of new courses for mixed cohorts of engineering students. One such course, the Design of Rehabilitation Systems and Assistive Devices, has been described above. Another major course is Engineering Ethics. Here, effort was given to the development of core teaching material relevant to all engineering disciplines, but with the additional development or identification of materials for discipline-specific contextualisation. Historically, the teaching of ethics has been regarded as falling within the realm of Humanities, but this creates difficulties in establishing teaching content which engages the interests and motivation of engineering students. However, clear Faculty-level commitment to such a course led to much engineering staff motivation for its context-specific development.

In a similar way to Engineering Ethics, some projects have helped to give greater clarity on Faculty-wide aspirations on animating and enhancing the lecture experience of the students. For examples, one project has involved the set up and evaluation of in-class electronic voting devices (i.e. *clickers*). Another project has involved the set up of mobile and large-scale mechanics demonstration equipment enabling students to translate 2-D descriptions of problems into 3-D understanding in Bioengineering, Aeronautics, Mechanical Engineering and Civil Engineering contexts.

Other initiatives have focussed on the development of interdisciplinary design projects, such as designing paediatric orthopaedic devices and zero-emission vehicles (the *Racing Green project*). Currently, generic student resources are being prepared to further support a positive and informed (skills-based) approach to creative design through a project titled *Creativity Engine*. In one project, the emphasis has been to further raise student awareness of Engineers Without Borders (an international student organisation) and, where possible, identify models for incorporating multi-disciplinary development projects into the engineering curriculum.

As a means of further promoting high quality and uniform teaching across the Faculty, several projects have focussed on either teaching and assessment approaches or the recognition and dissemination of good teaching practice. Examples of projects include the use and evaluation of *undergraduate* teaching assistants, the Faculty-level training and support of graduate teaching assistants (GTAs) and an award scheme for outstanding GTAs.

3.3 Student-Led Projects

Student-led projects have a long history at Imperial and take many forms. Imperial has many more student societies than the average university (at least twice as many as average) and a growing number of student societies concern international development projects. Imperial has an award-winning *volunteer centre* brokering volunteer labour for charitable projects, and recent surveys show that engineering students are over-represented in the ranks of Imperial volunteers (and, further, women are over-represented as volunteers). But in addition to these formal structures, there are small student groups who recognise a need in society which their engineering skills, knowledge and goodwill can help address, and do take action without seeking formal assistance from the College. Recognising that these informal activities of students are important as inspiration/motivation for students and staff, the Faculty of Engineering designated an EnVision lecturer as the "tutor for student-led projects", giving her a remit of fostering extracurricular activities which may occur in the summer vacation. Some current examples of student-led projects include:

- e.quinox: for the provision of solar energy in villages in Rwanda, where the main form of energy is paraffin for lamps and stoves. This originated with electrical engineering students. The project immediately attracted official support from the Minister for Energy in Rwanda and the UN Development Programme. The students have been invited to expand the project and are currently investigating how to create a Rwandan NGO specific to the work.
- El Salvador project: where civil engineering students work with an El Salvadorean NGO to provide earthquake resistant homes and infrastructure in villages, or remediate flood damage. This project has run since 2003, and participants who have graduated are now setting up a UK Charity to bolster fund-raising, provide mentoring advice to current participants and access to chartered engineers who can sign off designs.
- Women in SET: i.e. a student society within Imperial which aims to shift the culture so that Imperial's women (staff and students) become more visible and foster the next generation of scientists and engineers. Successes include commissioning 100 portraits of Imperial women staff and students, which was invited to exhibit at the Greater London Assembly; an annual Open Day for schoolgirls which is persistently oversubscribed, wholly run by the students for future students and specific to engineering; a Robogals project where Imperial students get schoolgirls building robots, to challenge the idea that computers/robotics is for boys; plus a variety of events, lectures and photography competitions aimed at celebrating the successes of women in engineering.

These are just some examples of the type of activity. Other groups include Students in Free Enterprise, the Malawi Bridge Project, the Bolivia Altiplano project, Engineers without Borders, the Rail and Transport Societies work on rebuilding the Welsh Highland Railway, plus various educational, entrepreneurial and volunteering activities. The tutor's function is to give advice, foster good management practices, play devil's advocate on feasibility, foster knowledge transfer, suggest apprenticeships for future leaders, assist with writing grant applications, liaise

with other staff, encourage dissemination and to encourage students to appreciate the level of sophistication they have achieved in their personal development. Building relations with alumni, negotiating on insurance, coaching on risk assessments, and promoting the activities as inspirational and motivational are all part of the tutor's activities. Networking with key players in the College administration and academic staff transpires to be a fundamental function and work is progressing on creating appropriate administrative support in the College for this somewhat amorphous student activity. Evaluation of the activities tends to come from the end-user of the student efforts and the continued funding of activities is a measure of the esteem in which the projects are held. Students are encouraged to run their own evaluation processes, in keeping with the "by the students, for the students" ethos of these activities.

A different approach to student-led projects is where students are recruited by EnVision to help create materials that will be made available to all students online. An example is the EPOD project. The use of podcasts is challenging traditional communication methods in higher education, with the potential for creating engaging and flexible resources for learning and development. Likewise, podcasts are helping to facilitate a stronger student identity and community within learning environments, replacing traditional student newsletter and website approaches. In this work, an innovative podcasting approach is presented in which there is a strong student-centred and student-led premise to foster and advance engineering education related uses. Podcasts are intended to cover a range of relevant engineering topics such as sharing student views on global, institutional and scientific developments, and disseminating information on unique educational opportunities. Details on the design, set-up and implementation of the initiative are presented (e.g. resource requirements; management and organization structures; maintenance of balanced educational outcomes). An evaluation of the experiences of the team-members is also presented, showing favourable outcomes in skills development, community identity and broader educational awareness.

4. FURTHER DISCUSSION

The examples of cross-departmental initiatives given above illustrate a range of methods and approaches to engage students in skills development and knowledge awareness which goes beyond the discipline boundaries. Central Faculty of Engineering coordination, with distinct support structures and mechanisms, has allowed for a unified strategy in engineering education. For example, the value of extra-curricular activities which have a strong *real-world* engineering or skills-development premise, is better recognised, and students and staff given support in the set up and development of such activities. Currently, efforts are also in place to help students better reflect on their learning experience and capture distinct learning outcomes. Programmes which foster creative design and ethical consideration naturally cross discipline boundaries, and are positively enhanced by student experiences of interdisciplinary projects and sessions. Such programmes also help to create a common identify for engineering, and potentially further student motivation for an engineering career given the range of professional roles and interactions that exist.

The Faculty Enabled projects provided an interesting shift in staff attitudes towards internal funding. Past attitudes were very much based on a competitive bid, with a "getting something for our department" approach. However, the condition for multiple department involvement and value, as well the necessity for a careful appraisal of possible shared resources, has helped foster

a more collegiate approach to teaching development. Furthermore, several instances have occurred where academic staff have recognised the possibility of enhancing their course through the involvement of other engineering disciplines, and thus much motivation for such development work. This of course, is to the benefit to both the teacher and the students alike.

Given the multifaceted approach of cross-departmental initiatives for global engineering education, a multifaceted approach on the evaluation of the initiative as a whole is also needed. An example of programme evaluation has been presented in Table 1. In due course, student feedback on specific courses and projects will also be collected. However, ultimately, the question is: does the College produce engineering graduates who have the skills and knowledge to better succeed and lead in global work contexts? One measure of this is the implicit student motivation for ongoing professional development in engineering, as well as the professionalism they exhibit in working with peers within their department and Faculty. Some data on motivational changes and career intentions has been reported for Imperial College students in the past (see Alpay et al., 2008), and will act as a datum for the impact that the above activities have had on student motivation. Other approaches will consider self-efficacy measures (self-reported and observational) in situations involving, e.g., ethical, complex or person-centred issues.

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