



The Royal Academy
of Engineering

Engineering graduates for industry

February 2010





The Royal Academy
of Engineering

Engineering graduates for industry

February 2010

© The Royal Academy of Engineering

ISBN 1-903496-52-7

February 2010

Published by

The Royal Academy of Engineering

3 Carlton House Terrace, London SW1Y 5DG

Tel: 020 7766 0600 Fax: 020 7930 1549

www.raeng.org.uk

Registered Charity Number: 293074

Acknowledgements

The authors would like to thank all the staff at the case study institutions who gave their time to be interviewed and to contribute data for the case studies. We would also like to acknowledge the advice and valuable contributions from the Study's Project Management and Oversight groups (see Appendix 1 for membership). The funding for the study came from the Department for Business, Innovation and Skills.

Authors

Fiona Lamb

Carol Arlett

Dr Richard Dales

Dr Bob Ditchfield

Beverley Parkin

Professor Sir William Wakeham FEng

Engineering graduates for industry

A commentary

Introduction

Engineering graduates for industry was commissioned in 2008 by the Department for Innovation, Universities and Skills – now the Department for Business, Innovation and Skills to identify how to increase the number of employable engineering graduates with the skills industry needs. Against a background where the UK competitive advantage will depend increasingly on raising the level of our science, technology, engineering and mathematics skills, there was recognition that UK business and industry would be disadvantaged if not provided with an adequate supply of well-educated and motivated engineering graduates¹.

Since then, the banking crisis, the global downturn, the need for transition to low carbon economies and competition from emergent new technologies have created an even more urgent imperative to address this issue and to ‘pull together to come through more strongly and secure Britain’s future economic success’².

Our report reviews current approaches to engineering higher education and provides a detailed review of a range of relevant motivational techniques universities use to meet the needs of business and industry. The study was directed by a committee of people with the highest level of experience and the process of producing the report raised major issues of national strategy as well as the prioritisation of resources which this commentary seeks to highlight.

The new economy

There is growing agreement among policymakers, economic strategists and commentators that the UK’s future prosperity will depend on the creation of a more diverse economic base. In effect, this means that the UK must create more successful high-technology businesses and industries to manufacture, build and maintain the products, infrastructure and services of the future. These innovative enterprises will build on our national strengths in science and technology, address grand challenges, boost GDP and underpin social progress at all levels.

The scale and complexity of the process of neo-industrialisation required is such that it cannot be left solely to the free market to deliver. Creating the hi-technology economy of the future will need government to provide incentives and support of a kind not seen in modern policymaking to unlock investment from business and industry.

Setting priorities

New models of cooperation between industry, government and educators will be needed to transform the politics of production because the prerequisite for this economic refocus is a radical transformation of our national skills base. Over years, much commendable, and in certain areas fruitful, focus, effort and investment have been expended on the drive to create a stronger skills base in science, technology, engineering and mathematics, all of which are clearly key to a successful technology-based future. However, this must now go much further. If the UK is truly to have the skills it needs to compete in the global high technology economy, we must be prepared to prioritise those skills that can “power the new industries and jobs for the future”³. At a time of financial constraint, we need to be prepared to make hard decisions about what higher education choices we can – and cannot – afford to fund.

Engineering skills

The engineering skills base is one of the priority elements needed to bring about this economic transformation. If we are to compete in the new global economy, we will require an adequate supply of high-quality, flexible engineering skills at all levels, developed through a range of routes including the 14-19 diploma, apprenticeships, foundation degrees, undergraduate degrees and postgraduate qualifications.

Engineering degrees aim to provide a firm grounding in the principles of engineering science and technology, while inculcating an engineering method and approach that enable graduates to enter the world of work and tackle “real world” problems with creative yet practical results. The best engineering degrees achieve the right balance between

¹ Sainsbury (2007) *The Race to the Top*, HM Treasury

² DIUS (2009) *New Industry, New Jobs*

³ National Skills Strategy (www.bis.gov.uk/skills-for-growth)

scientific and technical understanding and their practical application to problem-solving. This synthesis calls for such skills as communication and negotiation; teamworking and inter-disciplinary working; and planning, costing and other key business process skills. Graduates with these skills are highly attractive to industry, having the “relevant, quality skills with real market value”³ that government is seeking to promote.

The needs of industry

A 2007 Royal Academy of Engineering publication, *Educating Engineers for the 21st Century*⁴, reported that industry seeks engineering graduates who have “practical experience of real industrial environments”. Specifically, “industry ... regards the ability to apply theoretical knowledge to real industrial problems as the single most desirable attribute in new recruits. ... In descending order of importance other relevant attributes ... include theoretical understanding, creativity and innovation, teamworking, technical breadth and business skills”.

With these needs in mind, our report has focused on the options for encouraging and enabling universities to develop engineering courses that include “experience-led” teaching, designed and delivered mainly in partnership with industry and business. The study took in a wide range of experience-led higher education engineering provision - from intensively research-led programmes to employer-led foundation degrees in a broad range of university types, geographical locations (within England) and engineering disciplines. The 15 exemplars of experience-led teaching featured in this study range in scale from an individual module to a complete faculty and from incremental, small-scale interventions to wholesale, radical change.

Findings

Across these diverse settings and methods of delivery, we found that experience-led teaching:

- makes a valuable, high impact contribution to the education of engineering undergraduates (Section 7; recommendation 1)
- supports a range of skills that industry needs (Section 3.1)
- helps recruit and retain young people in engineering education, a national priority skills area (Section 5)
- should motivate universities to review their priorities and develop new ways of working with one another (Section 7; recommendation 1)
- requires innovative, sustained partnerships between universities, business and industry (Section 7; recommendation 3).
- should, therefore, be urgently adopted, developed and sustained as an integral part of engineering HE (Section 7; recommendation 1).

Investment in the future

The report acknowledges that the introduction of experience-led components into engineering degrees will require funding (recommendation 2), both for capital investment in new facilities and equipment and to cover recurrent costs. In a year when the university teaching budget has been reduced by a further £180M, and with a downward funding trajectory until at least 2013, this clearly poses a serious challenge for universities, particularly as, among those universities we studied, the funding of engineering degree programmes already falls short of what is needed by an average of 15% (Appendix 3). This funding challenge must be urgently addressed through innovative mechanisms, including focusing more funds in centres of excellence and making hard decisions in cutting some lower priority programs.

Our calls to action

1. *We want to see an open debate to identify priority skills for the new economy*

At a time when UK engineering higher education is tasked with delivering a key plank of the UK skills strategy, the potential impact of current and future cost pressures is at odds with the need for a high quality, motivated supply of engineering graduates. The future direction and success of the UK economy is largely predicated on the availability of the right skills: this issue is, therefore, a matter of strategic national importance and, as such, transcends party politics. The nature of the issue and the lead times involved in building the skills pipeline require an urgent, honest, open discussion between all stakeholders about what skills are essential for our future economic growth. In financially stringent circumstances, this inevitably leads to hard decisions about what we can – and cannot - afford.

⁴ The Royal Academy of Engineering, *Educating Engineers for the 21st Century*, 2007

2. *There must be support for priority skills*

In times of financial pressure, there can be a temptation to retreat into timid thinking and to reject innovation as too difficult or costly. We believe that difficult circumstances call for brave thinking and decisive, future-focused action and investment. Our study points to the need for the radical, clear sighted identification of national skills priorities, and the full alignment of policies across government, funding bodies, universities, business and industry to support and ensure delivery of these priorities.

We note that the government has recently signalled⁵ its intention to find a mechanism to identify higher education programmes and activities that “make a special contribution to meeting economic and social priorities” and to redeploy funds, on a competitive basis, to those institutions that are able and willing to develop new or expanded provision in such areas. **We call on the Higher Education Funding Councils to seize this opportunity for focused ring-fenced funding from which universities could enhance experience-led engineering degree courses.**

3. *Engineering degrees need to be fit for the future*

As a relatively small but crucial element of progress towards national aims, we believe that now is the time to grasp the opportunity to introduce experience-led components into engineering higher education. This will create the best possible learning experience and will lead to more skilled and motivated engineering graduates who are ready and able to take up key roles in the workplace. It will require active investment by government. It will require moves to radically increase involvement of industry, both national and local, in engineering education. It will require universities to reconsider their priorities and ways of working to meet strategic needs, where possible sharing knowledge and facilities to allow them to deliver the highest quality student experience and outcomes.

In summary, the UK needs the best possible graduate engineers in order to underpin the future of the UK, as a society, as an economy and as an agent of global progress. Experience-led teaching is, in our view, a vital component of educating the best engineers to support all these aims and needs to be embedded and supported as a matter of priority.

Professor Sir William Wakeham FEng
Chair, Engineering graduates for industry study

Richard Olver FEng
Chairman, BAE Systems

⁵ www.hefce.ac.uk/news/HEFCE/2009/grant1011/letter.htm

Contents

A commentary	i
Executive summary	1
1. Introduction	6
2. Research methodology	7
2.1. Research questions	7
2.2. Data collection	7
2.3. Data analysis	8
3. The needs of industry	9
3.1. Understanding the needs of industry	9
3.2. How do universities know what industry needs?	13
4. Case studies	14
4.1. Aston University, School of Engineering and Applied Science	14
4.2. Coventry University, Faculty of Engineering and Computing	19
4.3. Imperial College London, Faculty of Engineering	23
4.4. University of Liverpool, Department of Engineering	27
4.5. London South Bank University, Faculty of Engineering, Science and the Built Environment	31
4.6. Loughborough University, Faculty of Engineering	35
5. Experience-led components of engineering degrees	40
6. Case study analysis	43
6.1. Institutional profile	43
6.2. Student experience of industry	43
6.3. Student engagement	45
6.4. Industry links	45
6.5. Staff capacity and capability	46
6.6. Implementing change	47
6.7. Learning spaces and technology	48
6.8. Funding	49
6.9. Summary of research findings	53
7. Recommendations	55

Executive summary

Graduates in science, technology, engineering and mathematics (STEM) are key to providing the higher level skills that are required for economic recovery and long-term prosperity in the UK⁶. Engineers play a crucial role in emerging and growth sectors and, critically, engineering expertise is largely made up of 'know-how'. Specifically, companies require more engineering graduates with practical experience of industry. The UK also must continue to be strong in an increasingly competitive global field to win the jobs of tomorrow.

Stronger partnerships between industry and higher education (HE) can ensure that an increasingly diverse student body develops the engineering skills necessary to meet the future recruitment needs of a globally competitive industry.

The study was commissioned by the Department for Innovation, Universities and Skills – now the Department for Business, Innovation and Skills (BIS) – following a recommendation made by Lord Sainsbury of Turville in his review of the Government's Science and Innovation policies⁷ to "... review current approaches to engineering education ... [and] develop, with a number of leading engineering universities, an experience-led engineering degree ...". Sustainable world-class experience-led HE engineering degree programmes which attract the best students are an essential element to meet the graduate recruitment needs of industry.

The study team have taken the term 'experience-led' to describe components of an engineering degree which develop industry-related skills including, but not limited to, direct interaction with industry. Published literature was reviewed and six universities provided in-depth case studies spanning the range of HE engineering provision from intensively research-led programmes to employer-led foundation degrees. The institutions selected cover a range of university types, geographical locations (within England) and engineering disciplines. Most importantly, they provide diverse exemplars of excellent experience-led provision within undergraduate engineering degree programmes. They demonstrate that students obtain the required skills through experience-led degree programmes which also attract and retain the best students.

The report describes these 15 exemplars, ranging in scale from an individual module to a complete faculty and from continuous, incremental, small-scale interventions to wholesale, radical change. Either working directly with industry or delivering industry-related content, the exemplars together highlight a wealth of innovative practice with high impact. Such activities must be more widely adopted and developed by all universities with the simultaneous aims of enhancing engineering degree programmes while maintaining financial sustainability.

The recommendations of this report provide guidance on how to achieve this. Universities, their engineering departments, industry, professional bodies and government need to commit to working together to build, enhance and sustain partnerships of substance.

The needs of industry

Industry seeks graduates who have expertise in technical skills and in the application of complementary skills. The study has not repeated previous research on what industry needs from its engineering graduates but has, instead, reviewed published literature. There is consensus with the findings of *Educating Engineers for the 21st Century*⁸ which are summarised thus: industry wants engineering graduates who have "*practical experience of real industrial environments*". Specifically, "*industry ... regards the ability to apply theoretical knowledge to real industrial problems as the single most desirable attribute in new recruits. ... In descending order of importance other relevant attributes ... include theoretical understanding, creativity and innovation, teamworking, technical breadth and business skills*".

An engineering degree aims to provide a firm grounding in the principles of engineering science and technology and to develop the 'habit of mind' to enable graduates to adapt to future change. To meet industry needs, an engineering degree must achieve the right balance between technical skills and 'soft' skills on the one hand, and between depth of knowledge within a discipline and breadth across disciplines, on the other.

Research findings from the study

Eight key research findings emerge from the case studies, as illustrated in Figure 1 and these provide a perspective from the universities involved with the study. They are described below with their associated opportunities and enablers.

⁶ National Skills Strategy (www.bis.gov.uk/skills-for-growth)

⁷ Sainsbury (2007) *The Race to the Top*, HM Treasury

⁸ Royal Academy of Engineering (2007), *Educating Engineers for the 21st Century*.



Figure 1: Research findings

One size doesn't fit all

Learning takes place in different places and in different ways

- Each university and each engineering department seeks to produce graduates with a particular mix of skills, knowledge and experience to suit specific areas of the graduate jobs market.
- Students themselves are attracted towards engineering degrees for different reasons and at different points in their lives.
- As a consequence, each university must be able to take its own approach to developing and embedding experience-led components.

Experience counts

Students need direct experience of industry integrated within their degree course

- Students with industrial experience are more likely to seek and find employment in engineering and technology related jobs on graduation; are more motivated for the remainder of their course and possibly achieve a higher degree classification; are clearer about their future career options; and have improved management, teamworking and communication skills.
- Some universities are experiencing a decline in the number of industrial placements available to students. Industry must provide more high quality placements and other work opportunities for students to gain direct experience of industry.
- Not all students take up the work placement opportunities available. Their reasons include a lack of awareness of the opportunities and benefits, and concerns about leaving their peer group or 'disrupting' their study.
- Employers report that graduates with worthwhile work experience achieve a higher level of employability.

Opportunities
<ul style="list-style-type: none"> • Placements in industry • Other work experience • Relevant employment for part-time students • Relevant student-led activity

Relevance motivates

Students are motivated and engaged by industrially relevant course content which should be integral within every undergraduate engineering course

- Industrially relevant course content and large scale industrial simulation help students to link theory to practice, enhancing student engagement and improving retention.
- The case studies provide excellent exemplars within programmes and departments yet opportunities for more widespread adoption of good practice exist in all HE institutions.
- Industrially relevant engineering degree programmes can attract candidates towards engineering as a career via open days and other recruitment events.

Change needs champions

Learning and teaching champions play a vital role in driving forward change within engineering degrees

- Change agents who introduce experience-led components into the curriculum must be supported. Excellent teaching and successful delivery should be recognised and rewarded by universities.
- Staff with experience of industry make essential contributions to experience-led components within the curriculum.
- Provision of discipline-based support in learning and teaching that helps staff develop, deliver and share new methods of teaching is valued at both an institutional and national level.
- In recent years, the number of academic staff with prior experience in industry has been declining, particularly in research-led universities. Mechanisms that enable academics to gain insight into industry need to be reviewed and enhanced. This could be through:
 - Collaborating with engineers in industry on the development of the experience-led teaching components
 - Research collaboration with engineers from industry
 - Undertaking secondments in industry
 - Bringing engineers from industry into universities to support teaching.

Responsibility must be shared

Both industry and the universities must commit to championing enhancements to experience-led engineering degrees

- A multitude of successful methods of engagement have been identified by this study. They must be disseminated and exploited wherever possible. Engagement between individual companies and universities should be encouraged and increased, making more use of existing schemes where they exist.
- Encouraged by fiscal incentives, focus should be on the development of stronger, genuine partnerships between universities and industry to stimulate effective change.

Management leads change

The ability to change is heavily dependent on having the right senior management support

- The way in which change towards a more experience-led approach occurs depends on the institutional ethos with regard to industry. Universities with industrial engagement embedded strongly in their institutional mission often have ongoing incremental change while others might go through less frequent but more radical change.
- In either case, change must be aligned with institutional strategy and requires senior management support.
- Engineering departments must consider their current position with regard to the inclusion of experience-led components in their degrees and the need for either incremental or radical change as appropriate. Development of appropriate business plans requires the active support of senior management.

Opportunities

- Industrial simulation such as Constructionarium and pilot plants
- Sponsored programmes
- Industrial liaison boards
- Project-based and other forms of active learning
- Industrial group projects
- Lectures / seminars from engineers in industry
- Case studies from industry
- Influence of part-time and mature students on full-time students
- Site visits and field trips
- National and international competitions

Enablers

- Staff with experience of industry
- Staff secondments to industry
- Staff experience of industry through research collaboration
- Industrial visiting professors

Resources matter

New teaching methodologies require appropriate learning spaces, equipment and supporting technologies

- Group work and project-based learning need flexible rooms; hands-on experiences require traditional laboratories or more contemporary work spaces; students need access to up-to-date equipment and supporting technologies.
- Delivery of experience-led courses will incur additional cost for appropriate resources.
- Collaborative activities and facilities shared between universities or with industry make efficient use of resources.

Enablers
<ul style="list-style-type: none"> • Shared facilities • Contemporary work spaces • Flexible spaces • Laboratories • Up-to-date equipment • Supporting technologies

Financial sustainability

- The introduction of experience-led components into engineering degrees will require start-up funding. Even without the enhancements required to deliver the recommendation made by Lord Sainsbury of Turville, funding of engineering degree programmes already falls short of what is needed by a mean of 15% among the case study universities. This represents a significant challenge to financial sustainability for university engineering departments, exacerbated by the current economic climate.
- Funding required falls into two key categories: start-up or capital funding (new facilities, equipment) and recurrent or project costs (academic staffing, industry input, other staffing including administration, travel, materials, consumables and so on).
- While the need for additional funding to deliver experience-led engineering degrees is undeniable, further consideration of funding sources and potential efficiencies is required. Possibilities include increased industry input, changing priorities at university level, knowledge and facility sharing among institutions and targeted government funding.

Recommendations

The three recommendations are given below. The RAEng and Higher Education Academy Engineering Subject Centre are committed to supporting industry, professional bodies, university engineering departments and government in implementing these recommendations and to disseminating the effective practice highlighted in this report.

Recommendation 1

Experience counts and relevance motivates. Experience-led components must be embedded into every engineering degree, using the effective practice outlined in these case studies as inspiration. Experience-led engineering degrees benefit students and industry alike, supporting economic recovery and future prosperity.

Outcomes	Mechanism	Actioned by
Leadership and commitment to deliver graduates with the required skills	Incorporate proposed changes into business plans including learning space design, equipment, technologies and finances	Universities
The right staff with the right vision and attitude	Provide discipline-based support for learning and teaching and reward for excellent teaching	
More staff with up-to-date experience of industry	Develop, support and encourage use of mechanisms that enable academics to gain insights into industry	University engineering departments
Enhancement of the student experience	Increase opportunities for academics and their students to gain experience of industry	Industry
Universities have the capacity to develop flexible approaches to experience-led degrees	Provide funding mechanisms that enable universities to use available funds more effectively and to focus on the delivery of experience-led engineering degree programmes	Government / the Funding Councils
Active dissemination of effective practice and professional support to implement change	Continue to fund the Higher Education Academy Engineering Subject Centre	
Wider adoption of experience-led engineering degrees by HE	Ensure that degree accreditation requires experience-led components	Professional bodies

Recommendation 2

Preferential ring-fenced investment in experience-led HE engineering is required to deliver the higher skills needed. Innovative mechanisms are needed to focus and prioritise the investment required, in the context of a difficult fiscal period and an existing shortfall in the funding of engineering degree programmes necessary for financial sustainability.

Outcomes	Mechanism	Actioned by
Greater efficiencies and students benefit from a wider experience	Require universities and industry to share knowledge, facilities and equipment	University engineering departments and industry
Less reliance on public funding	Increase income from a wider range of external sources	Universities
Industry takes a more active role in engineering education	Increase financial and in-kind support to universities and students, inspired by the exemplars	Industry
Removal of perceived obstacles related to the development of innovative mechanisms	Further research into how universities and industry can be best encouraged and supported to share knowledge, facilities and equipment – overcoming issues related to access, health and safety, staff resistance and other restrictions on use	Government / the Funding Councils
A focus on the provision of experience-led degrees	Targeted funding for experience-led engineering degree programmes that demonstrate industrial support and greater efficiency	

Recommendation 3

Significant time and energy should be directed towards building, enhancing and sustaining university/industry partnerships. Effective partnerships are a key feature of the most successful exemplars.

Outcomes	Mechanism	Actioned by
Innovative solutions that may involve multiple stakeholders, academic, industrial and professional	Develop effective partnerships and innovative approaches to sustaining relationships	University engineering departments, professional bodies and industry
More experience-led components and work opportunities that enhance the student experience	Increase engagement with industry, including use of alumni and existing national schemes where available	University engineering departments
More industrial input into degree programmes and more work opportunities for students (including high quality industry placements)	Increase engagement with universities, using staff at all levels as appropriate and existing national schemes where available	Industry
Increased industrial relevance within degree programmes	Utilise fiscal incentives for industry to get more involved with enhancing engineering education	Government
Greater interaction and collaboration between industry and academia	Exploit potential of both academic and industrial representation amongst membership through cross-profession working structures	Professional bodies

1. Introduction

Graduates in STEM are key to providing the higher level skills that are required for economic recovery and long-term prosperity in the UK⁹. This is stated in numerous recent government speeches and reports from many organisations. Engineers play a crucial role in emerging and growth sectors and, critically, engineering expertise is largely made up of 'know-how'. Specifically, companies require more engineering graduates with practical experience of industry.

The UK also must continue to be strong in an increasingly competitive global field and win the jobs of tomorrow, a thought echoed in December 2009 by the French President who announced¹⁰ that £31BN "*targeted investments now would help France achieve long-term excellence*", with higher education as the centre-piece of the plans.

Following Recommendation 7.17 of Lord Sainsbury of Turville's Review of Government's Science and Innovation Policies, *The Race to the Top*, RAEng was asked by DIUS (now BIS) to conduct a review of approaches to engineering education. Lord Sainsbury made it clear in his report that this should be focused on taking forward the findings and recommendations of the RAEng report, *Educating Engineers for the 21st Century* (EE21C).

Recommendation 7.17

A leading member of the engineering profession should be asked to set up a working group of experts from academia and industry to review current approaches to engineering education. The group should develop, with a number of leading engineering universities, an experience-led engineering degree which integrates technical, operational and business skills.

The study team have taken the term 'experience-led' to describe components of an engineering degree which develop industry-related skills including, but not limited to, direct interaction with industry.

The principal objective of the study was to identify the options for encouraging and enabling universities to develop engineering courses that better meet the needs of industry and to identify the opportunities, barriers and costs involved.

This report describes the methodology used for the study; provides a brief review of existing reports summarising industry views on engineering graduates and the means by which universities acquire those views; presents summaries of six case studies which describe examples of experience-led engineering degree components, including the benefits to students and industry; draws out key messages from the case studies and makes recommendations.

The terms of reference and membership of the Oversight Group and Project Management Team are shown in Appendix 1; the universities involved in the study are given in Appendix 2.

⁹ National Skills Strategy (<http://www.bis.gov.uk/skills-for-growth>)

¹⁰ www.guardian.co.uk/world/2009/dec/14/spending-boost-for-french-universities

2. Research methodology

This report has been developed using a case study approach to provide an in-depth examination of experience-led engineering activity in six English universities.

2.1. Research questions

The study identified a key research question, derived from the project brief:

How can we enhance a sustainable world-class higher education engineering sector that meets the graduate recruitment needs of industry?

This led to a further six subsidiary research questions:

1. What does industry need from engineering graduates?
2. How do universities know what industry needs?
3. What are universities currently doing, or developing, within their teaching that meets these needs of industry, and why?
4. What difference are these activities making?
5. What more/else could be done to better enable universities working together with industry to meet these needs in the future?
6. How can universities and industry cooperate effectively and be best supported in this process?

These research questions provided the focus for the investigations and framed the case study approach.

2.2. Data collection

The first two of these subsidiary research questions were primarily addressed through existing literature, in particular the EE21C report. Additionally, the study team (see Appendix 1) examined all recent relevant publications, both UK and international.

The questions also informed the structure of the more than 85 in-depth interviews that were conducted with academic staff, students, industrialists, graduates and other relevant university units (e.g. staff support) at each of the case study universities. In addition, the study team used a wide range of sources to provide additional evidence and for validation purposes. These included internal institutional documents, published papers, marketing materials, HE Statistics Agency data, student satisfaction data, accreditation reports, external examiner reports and programme reviews.

The selection of the case study universities, shown in Table 1, was informed by examples of effective practice presented at a RAEng Visiting Professors' Workshop on experience-led engineering degrees held on 9th September 2008. The workshop attendees represented a wide range of universities and professional bodies, and the discussions about issues and the impact of experience-led approaches on both students and industry helped to inform the resulting study. Universities were selected to cover a broad range of university types, geographical locations (within England), engineering disciplines, range of industrial activity / involvement / skills provided. All cases were focused on undergraduate studies only.

Table 1: Summary of case study institutions

University	Faculty/School	Engineering disciplines covered in this study	Exemplars
Aston University	School of Engineering and Applied Science	Chemical, Computer Science, Electronic, Engineering Systems and Management, Mechanical	1. Industrial placements 2. Foundation degrees in power engineering
Coventry University	Faculty of Engineering and Computing	Aerospace, Automotive, Built Environment, Civil, Computing, Electronic, Knowledge Management, Mechanical	3. Activity led learning
Imperial College London	Faculty of Engineering	Aeronautics, Bioengineering, Chemical, Civil, Computing, Electrical, Electronic, Environmental, Materials, Mechanical	4. Industrial simulation (Constructionarium and chemical pilot plant) 5. Discipline-based support (enVision) 6. Large group projects 7. Student-led activities
University of Liverpool	Faculty of Engineering	Aerospace, Civil, Materials Science, Mechanical	8. Active learning (adapted from CDIO) 9. Visiting professors
London South Bank University	Faculty of Engineering, Science and The Built Environment	Applied Sciences, Engineering and Design, The Built Environment, Urban Engineering	10. Understanding stakeholder needs 11. 'Live' experimental laboratory (CEREB)
Loughborough University	Faculty of Engineering	Aeronautical, Automotive, Building, Chemical, Civil, Electrical, Electronic, Manufacturing, Mechanical	12. Industrial placements (Diploma in Industrial Studies) 13. Industrial group projects (Teaching Contract Scheme) 14. Sponsored degree programmes 15. Discipline-based support (engCETL)

Pilot case studies were first conducted at Loughborough and Coventry before the data collection method was finalised for the remaining four universities. Desk-based research was done at the same time as the collection of the interview data.

Part way through the data collection, a symposium for engineering academics entitled 'Meeting the Needs of Industry in Higher Education' was held on 10th June 2009. This event enabled validation of initial findings and also identified additional material, especially from seven presenters from further universities across England, Northern Ireland and Australia. University College London, who discussed the radical curriculum changes implemented for undergraduate programmes in their Civil, Environmental and Geomatic Engineering Department, was subsequently invited to provide an additional mini case study. All symposium abstracts are available at www.engsci.ac.uk/nef/events/meeting-the-needs-of-industry.asp.

2.3. Data analysis

The resulting six case studies are snapshots of what was observed during the study and as such do not cover all of the respective universities' activities in the areas of interest. The case studies were analysed by identifying cross-cutting themes and then systematically going through each case study to find evidence to support these themes. The findings from the case studies were triangulated together with the other materials collected and the results used to prepare the final report.

3. The needs of industry

3.1. Understanding the needs of industry

What does industry need from engineering graduates?

The needs of industry are well catalogued in numerous existing reports which address the question of what it wants from engineering graduates. This section summarises the literature.

The literature reveals that it is not realistic for graduates to be fully equipped with all the knowledge and skills required by industry but it is fundamental that graduates understand what other people do and how it all fits together. There is a general consensus of agreement with the findings of the EE21C report that can be summarised thus: industry wants engineering graduates who have: *“practical experience of real industrial environments”*. Specifically, *“industry ... regards the ability to apply theoretical knowledge to real industrial problems as the single most desirable attribute in new recruits. ... In descending order of importance other relevant attributes ... include theoretical understanding, creativity and innovation, teamworking, technical breadth and business skills”*.



There is no requirement for a universal generic graduate and hence engineering should not be taught in one single way. Graduate recruiters will continue to target different universities for different roles and career routes but would like more clarity as to what type of graduate each university is producing and why.

Engineering graduates: future supply and demand

The EE21C report summarised the findings from a survey of UK industry conducted by the Henley Management College¹¹ alongside views from universities. The findings concluded that:

- The best of UK graduate engineers are still world class and industry is generally satisfied with their overall quality, but there are simply not enough of the best.
- Unless action is taken a shortage of high-calibre engineers entering industry will become increasingly apparent over the next ten years, with serious repercussions for the productivity and creativity of UK businesses.

Looking to the future, there are indications that the number of engineering graduates will not be sufficient to meet the longer term skills demands of industry. The economic rationale is set out in the government's white paper *Innovation Nation*¹² which responds to recommendations made by Lord Sainsbury and Lord Leitch¹³. The paper sets out plans for investment in areas that will require key innovative engineering components, including tackling major societal challenges and maintaining a world-leading position. The BIS Advanced Manufacturing Strategy, announced by the Rt Hon. Lord Mandelson on 28th July 2009, also underlines the importance of maintaining an expanding workforce with cutting edge skill sets¹⁴. The role of HE in building British competitive strength through higher level skills is identified in *New Industry, New Jobs* (2009)¹⁵ and the government's view on how this will be achieved is set out in the new framework for HE, *Higher Ambitions*¹⁶, which promises “enhanced support for the STEM subjects – degrees in the sciences, technology, engineering, and mathematics – and other skills that underwrite this country's competitive advantages”.

¹¹ Spinks, N. et al., (2006) *Educating Engineers for the 21st Century: The Industry View*, www.raeng.org.uk/news/releases/henley/pdf/henley_report.pdf

¹² DIUS (2008) *Innovation Nation*

¹³ Leitch (2006) *Review of Skills*, HM Treasury

¹⁴ <http://interactive.bis.gov.uk/advancedmanufacturing/lord-mandelsons-speech-at-advanced-manufacturing-launch-event/>

¹⁵ DIUS (2009) *New Industry, New Jobs*

¹⁶ BIS (2009) *Higher Ambitions*

Employers have recently expressed concerns about the shortage of graduates in STEM subjects¹⁷. The number of graduate engineers in particular is a long-term concern. Data from *Engineering UK 2009/10*¹⁸, shows there has been a modest 5% rise over the last six years in the overall number of engineering and technology graduates with first degrees (with large rises and falls within individual disciplines). Of these graduates, 71% who entered employment went into an engineering and technology occupation. Although applicant numbers in engineering and technology are up 16% since 2007 and net job losses in industry are expected over the next few years, the number of engineering graduates is unlikely to be sufficient, partly due to the need to replace engineers who are retiring.



Studies by Sector Skills Councils and professional institutions report a diverse picture of current and future needs. The IET reports that 33% of respondents were experiencing problems recruiting graduate engineers and identified civil engineering and energy as areas with high recruitment needs¹⁹. Forecasts on Construction and Built Environment also show that, despite the current downturn, there will be significant recruitment requirements up to 2013, mainly due to strong demand for infrastructure projects²⁰.

Although not the focus for this study, it is recognised that widening participation is vital to the long-term health of engineering and that women, black and minority ethnic students and some socio-economic groups are under-represented²¹. Attractive courses that are relevant to the needs of industry help to attract more and better applicants, possibly impacting on the widening participation agenda and improving retention.

Employable engineering graduates

The quantity of engineering graduates is just part of the concern. The government has set out its aims for “more, and more employable graduates”²², in particular to address current concerns about the supply and quality of graduates in the STEM disciplines. *Higher Ambitions* states that it is a top concern for business that students should leave university better equipped with a range of employability skills and that universities should demonstrate how they prepare students for the modern workplace.

Similarly, the CBI in two recent reports *Emerging Stronger*²³ and *Stronger Together* suggest that business places a high value on graduates in STEM disciplines in particular and they are clear that graduates need to leave university with better employability skills.

World-class engineering graduates

As the world’s sixth largest manufacturer, a strong engineering base is essential if the UK is to secure competitive advantage in the global economy of the future. Our transition to a low carbon economy will on its own require thousands of high-quality engineers to make our sustainable future a reality. Hence engineering graduates have a vital role to play in creating wealth and underpinning the UK’s international competitiveness.

Graduates from UK universities also need the skills to compete in the international recruitment market both within the UK and elsewhere. To maintain international competitiveness, companies in the UK recruit graduates from across the world (for example, Rolls Royce actively recruit approximately 20% of their graduates from other countries, including Spain, Italy and Germany). The CBI acknowledges in *Stronger Together* that ‘The UK’s best STEM graduates are world-class

¹⁷ CBI (2009) *Stronger Together: Businesses and universities in turbulent times*

¹⁸ ETB Engineering 2009/10

¹⁹ IET (2008) *Engineering and technology skills and demand in industry*

²⁰ BESA (2009) *Towards a Construction and Built Environment Higher Education Strategy*

²¹ London Engineering Project, www.thelep.org.uk

²² DIUS (2008) *Higher Education at Work*

²³ CBI (2009) *Emerging Stronger*

but the overall number and quality should be raised' and in an earlier report²⁴ stated that larger firms continue to look far and wide to recruit STEM talent to help them to position themselves for new market opportunities, as well as counteracting skills shortages in the UK labour market.

Small to medium-sized enterprises

The voices of major graduate recruitment companies can dominate the discussions of 'what industry needs', and the ongoing needs of small and medium-sized enterprises (SMEs) are less well understood. Small firms (10-50 employees) employ more than 58% of the private sector workforce, but only 15% of their employees are degree level educated, compared to over 30% in the biggest companies. Research from the Federation for Small Businesses states that more than 20% of small firms would take on a graduate, yet nearly half are unaware that they can run internship schemes²⁵. EE21C found little difference between the requirements for graduate engineering skills of major companies and SMEs. However, as SMEs prefer to take on graduates with some experience of the commercial world, they often prefer to employ graduates that have gone through the training schemes of larger companies. Nevertheless, these training schemes are becoming fewer in number and smaller in size than they used to be, therefore SMEs may look increasingly to universities to supplement their courses with industry-based experience.

Large employers

Some large employers warn against universities being too elaborate in what they teach and do not want universities to overload degrees with non-technical content at the expense of mathematics and engineering science. Whilst acknowledging that softer skills are important to career success, they have the resources to teach them as required on the job and believe the hard maths and engineering science are best suited to the university environment.

Employability skills

The attributes that industry is looking for in graduates from engineering degree programmes have been debated across the world, with tension between the need to educate students as specialists whilst developing them as generalists. Accounts of historical changes in engineering education describe the swinging pendulum over the decades between theoretical knowledge and practical skills²⁶.



In an attempt to achieve a balance, the Conceive, Design, Implement and Operate (CDIO) initiative²⁷ has a requirement that "the education emphasises the technical fundamentals, while strengthening the learning of personal and interpersonal skills; and product, process, and system building skills."

The overall importance of generic employability skills (or 'soft' skills) is widely reported in the literature. Definitions of employability skills can vary between employers and universities but the CBI definition is: "A set of attributes, skills and

knowledge that all labour market participants should possess to ensure they have the capability of being effective in the workplace – to the benefit of themselves, their employer and the wider economy." These attributes include self-management, teamworking, business and customer awareness, problem solving, communication and literacy, application of numeracy and information technology, all of which are underpinned by a positive attitude.

The CIHE²⁸ reports that 86% of employers consider good communication skills and teamworking to be important and many are not satisfied that graduates can express themselves effectively. The largest gaps between importance to

²⁴ CBI/UUK (2009) *Future Fit: Preparing graduates for the world of work*

²⁵ FSB (2008) *Small Businesses in the UK: New Perspectives on Evidence and Policy*

²⁶ Jorgensen in *Rethinking Engineering Education* Crawley et al, Springer (2007)

²⁷ The CDIO™ initiative is an innovative educational framework for producing the next generation of engineers, www.cdio.org.uk

²⁸ CIHE (2008) *Graduate Employability: What do employers think and want?*

employers and their satisfaction with graduates are in commercial awareness and relevant work experience – which raises concerns about the decline in undergraduates taking up placements. Similarly, employers who took part in the IET skills survey identified practical experience as most wanting in graduates and also identified the need to improve the curriculum and degree content.

Employers in the CIHE report also value graduates who have a global perspective, as global issues such as environmental sustainability and social responsibility are becoming increasingly important, with a need for more integrated, multi-disciplinary teams to tackle problems such as climate change and poverty. Recognising that the engineering curriculum is already overcrowded, skills such as critical thinking, multi-disciplinarity, teamworking, working across cultures and contexts and systems thinking, as well as strong interpersonal and communication skills, need to be embedded across it²⁹.

It is important to emphasise that seeking this balance for which all argue does not mean simply increasing course content. The two sets of skills can be, indeed are best, taught alongside each other using ‘soft’ skills in the context of technical skills.

Other stakeholders in engineering education

It is worth noting that industry is just one of the key stakeholders, and engineering education also needs to meet the needs of the students (as the direct beneficiaries) and staff involved with delivering the curriculum.

The final stakeholder group is society, which has its own goals for engineering education. Issues such as sustainable development and globalisation need to be addressed by engineering educators. In addition, changes to engineering degrees in the UK must meet requirements for quality as set by universities and external bodies such as the Quality Assurance Agency (QAA), professional standards for accreditation and the compatibility of qualifications within a common educational framework in Europe as indicated by the Bologna Declaration (1999)³⁰. For engineering courses, the Accreditation Standard (UK-SPEC)³¹ is a valuable tool available to the profession and employers in degree accreditation, under the auspices of the Engineering Council. The emphasis of the Standard is on the value of design as a means to integrate knowledge and understanding and universities have the freedom to plan and resource programmes, provided they achieve the required outcomes. Accreditation by professional bodies could be used as a lever to encourage the adoption of experience-led components.

Although the focus of this study is on changes to the undergraduate curriculum as delivered on the campus, it is acknowledged that the focus for the future, as set out in *Higher Ambitions*, is for “a greater diversity of models of learning: part-time, work-based, foundation degrees and studying whilst at home”. The demographics of students are already



changing, with UCAS acceptances for Engineering and Technology (E&T) 2007/08 showing 26% mature entrants (over 25 years old)³² and the most recent HESA figures show a total of 103,760 E&T undergraduates of whom 23,335 are part-time (22%)³³. The number of work-based students is set to rise with the predicted low point in the number of 18 year olds by 2020. Work-based courses are already being developed, such as the Engineering Council’s Gateways Scheme³⁴ which provides flexible pathways to becoming a professional engineer.

²⁹ Bourn and Neal (2008) *The Global Engineer – Incorporating global skills within UK higher education of engineers*

³⁰ www.bologna-bergen2005.no/Docs/00-Main_doc/990719BOLOGNA_DECLARATION.PDF

³¹ www.engc.org.uk/ecukdocuments/internet/document%20library/AHEP%20Brochure.pdf

³² www.ucas.ac.uk

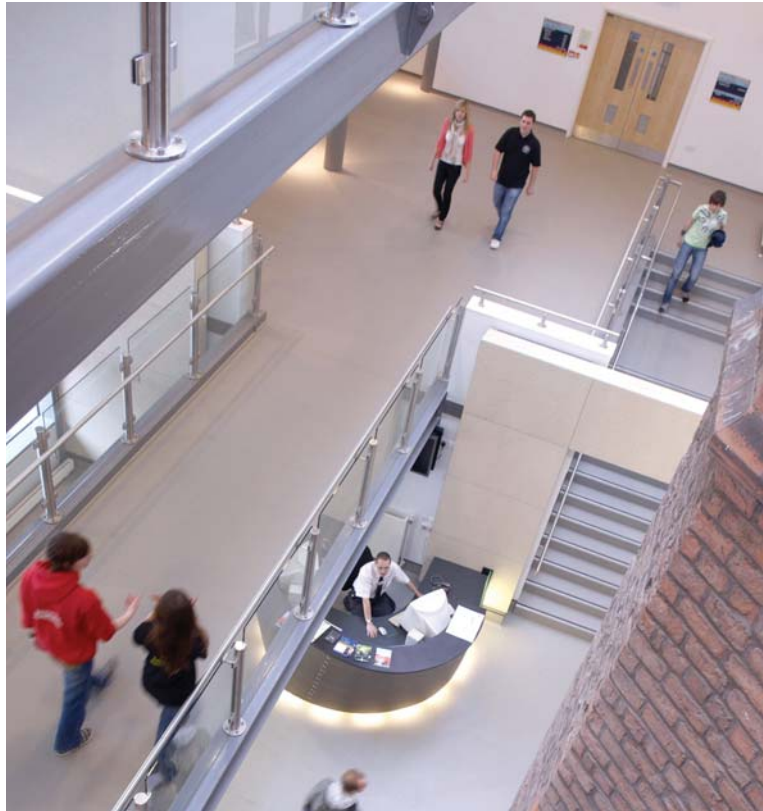
³³ www.hesa.ac.uk

³⁴ www.engineeringgateways.co.uk/

3.2. How do universities know what industry needs?

Consultation with industry and academia undertaken by this and previous studies has shown that there are a range of communication channels that help to inform universities about the skills requirements for engineering graduates. The universities participating in this study all believed that they were well informed about the needs of industry through a range of formal to informal interactions and were working to embed this into the engineering curriculum. These include:

- Recruitment of staff into academia from industry
- Point to point contacts between academics and engineers from industry at all levels, including lunchtime conversations and other informal links
- Industrial advisory/liaison boards
- Strategic partnerships, including research and knowledge transfer partnerships
- Employer links through careers services and recruitment processes
- Staff secondments to industry and visits by academic staff to students on placement
- Students reporting to their departments following placements
- Effective use of alumni through well organised alumni organisations and inviting recent graduates to give talks to students
- Sector Skills Councils who provide information about skills requirements and bring industry together with academia
- Reading reports and studies, both national and regional.



The particular means of information exchange between industry and universities depends markedly upon the overall balance of the mission of the university; but it is universally true that the communication must be up to date and relevant.

4. Case studies

The six full length case studies and additional mini case study from University College London can be found on the accompanying CD or online at www.engsci.ac.uk/graduates-for-industry. This section presents shortened versions of the six main cases.

The case studies are a sample of effective practice in experience-led engineering degree programmes and cover a range of university types, geographical locations (within England) and engineering disciplines. They illustrate selected experience-led activities at each university, based on the observations made by the study team and from interviews conducted, and as such do not cover all of the respective universities' activities. It is intended that they will inspire wider adoption of experience-led engineering components.

4.1. Aston University, School of Engineering and Applied Science

Background

Aston University is a research-led institution with strong links to industry. The University is relatively small, with around 9,500 undergraduate, postgraduate taught and research students. Aston has categorised its strengths into three main areas: research, learning and teaching, and community engagement. It has succeeded in establishing strong links to the local community, with 39% of undergraduate students in 2007/08 coming from the West Midlands³⁵. The National Student Survey (NSS) shows that overall student satisfaction for Aston University's undergraduate degree programmes was 89% in 2007/08, above the UK average of 82%, giving them the top ranking of universities in the West Midlands³⁶. The University as a whole also ranks well in a number of university league tables³⁷.

The School of Engineering and Applied Science (EAS) is made up of six discipline groupings: Chemical Engineering & Applied Chemistry; Computer Science; Electronic Engineering; Engineering Systems & Management; Mathematics; and Mechanical Engineering & Design. At undergraduate level, the usual patterns of study are 3-year BEng or BSc and 4-year MEng or MChem degrees with the option to take an industrial placement. Nearly all of the programmes are accredited by the appropriate professional institution. The School has a strong graduate employability record, with 91% of the E&T graduates in 2006/07 either in employment or further study within six months of graduating, with 31% in E&T related jobs. There is also a low attrition rate from courses, the figure being just 4.0% for 2005/06 full-time first degree students no longer in HE (the national average being over 7.0%)³⁸: *"small but perfectly formed is how Aston sees itself and how students and employers feel towards it. A low dropout rate coupled with the highest graduate employment rate of any UK University speaks volumes"*³⁹.

Overview of industry-related components within the undergraduate engineering programmes

One of the School's key strengths is employability: *"Through investing in our staff, and curriculum development, we will produce ever-more relevant and desirable programmes with an emphasis on employability, and involve industry in design and assessment."* (EAS - Learning and Teaching, Strategy 2012). Local industries have assisted in the development of the curriculum.

An example of multi-disciplinary activity is Aston's involvement, since 2001, in Formula Student⁴⁰. Their main entry is as a Class 1 team, which involves developing and entering a new car built that year. The Formula Student team (15 students in 2008/09) are mainly final year BEng or BSc undergraduates in Mechanical Engineering and Design and these students do their individual final year research project on a particular aspect of the Formula Student project.

In order to maintain continuity, two graduates who worked on the Formula Student entry in the previous year provide the managerial expertise for the current year's entry. They are enrolled onto an MSc programme in Mechanical Engineering and Product Design and receive a scholarship to cover their fees and a bursary to cover some living costs.

³⁵ Aston University at a Glance - www1.aston.ac.uk/about/facts-figures/

³⁶ www1.aston.ac.uk/about/news/releases/2008/september/080915/

³⁷ www1.aston.ac.uk/about/rankings/

³⁸ Guardian Performance Indicator Tables 2006/07:
<http://education.guardian.co.uk/universityaccess/table/0,,2283706,00.html>

³⁹ The Times Good University Guide, 2008.

⁴⁰ www.formulastudent.com/

Other members of the team are 1st and 2nd year undergraduate students, encouraged to join the team on a voluntary basis, as it is seen to add to their experience-led learning. In 2008/09, a satellite volunteer group of twelve 1st and 2nd year undergraduate students also prepared a design for a car to enter into the Formula Student Class 3 competition. The School also offers the Competition Preparation Module, a 10 credit final year module which allows students (about 35 students in 2008/09) to be assessed for submissions to national and international student engineering competitions. Students write their own analysis of the competition entry for assessment and all the supporting work and calculations that are not submitted to the competition can be included in that analysis.



Aston is trying to enhance the number of group work design and build projects with industrial involvement, as they believe these projects improve student motivation. In terms of simulated industrial experience, the Chemical Engineering and Applied Chemistry students spend time in a pilot plant and make an annual industrial visit. Electronic Engineering students are all members of the Institution of Engineering and Technology (IET) and are encouraged to attend local events.

Looking forward, Aston is developing a CDIO approach for the 2011/12 academic year, with an associated space redesign and refurbishment. This will be in a new Department of Mechanical Engineering and Design, which will include power engineering. The University also has plans to develop the Aston Engineering Academy – a single co-educational, non-selective Academy to be established in Birmingham City Centre as part of the wider Transforming Education agenda. The Academy will cater for 14-19 year olds, offering students apprenticeships, diplomas in Manufacturing, Engineering, Business and other appropriate qualifications.

Understanding the needs of industry

Aston's strong employability record provides evidence that it understands the needs of industry. In addition to the normal industrial liaison committees, many staff have extensive industrial experience, both prior to their academic career and through research and Knowledge Transfer Partnerships (KTPs). This input is enhanced by industrial visitors contributing to the curriculum, providing several industry-sponsored project prizes and industrial projects and making informal presentations.

In October 2009, Aston started a new route to supporting the needs of industry with the appointment of Mike Wood as a Visiting Professor in Design and Innovation in the Department of Engineering Systems and Management. His role is to perform a facilitating function between small and medium-sized enterprises (SMEs) in the Birmingham catchment area and the University. The visiting professor post is part funded by the RAEng for academic aspects and by Birmingham City Council for going out to SMEs to establish links and build relationships within the local industrial community. The visiting professor's objective is to enable local SMEs to benefit from student research through utilising them to address urgent but also strategic needs of the companies. The activity aims to benefit both parties as the students gain industrial experience and the companies will have a specific need addressed. It is possible such collaboration may yield future employment prospects for the students involved. The longer term aim, in conjunction with Aston's Business Partnership Unit, is for the SMEs to start to utilise universities as a resource and to develop the interaction through MSC research projects providing at least six months of mutually beneficial research activity.

For several years the Computer Science Group has, in collaboration with external partners, delivered several successful client-based final year projects. This approach is now being developed as a company (due to be operational by July 2010) that will be a beacon for clients wanting to commission high quality small scale software projects.

Effective Practice Exemplar 1: Industrial placements at Aston

Aston University pioneered placement years - one year work experiences in an industrial setting - over 50 years ago. All of the School's six discipline groupings have a placement scheme and whilst placements are not compulsory, students are actively encouraged to take up a placement year in industry and during 2008-09 approximately 30% of EAS students found a placement. The placement year in industry allows students to better appreciate the workings of professional engineers and the applicability of their theoretical knowledge. The placement year is integrated into the curriculum, so students are prepared for it during the first two years of their degree programme by building up their employability skills. When looking for an industrial placement, students are in competition with each other and often with other universities.

Typically, placements are taken after the second year of the Bachelors programmes, or occasionally at the end of the third year for MEng students. There is a dedicated Placement Office which handles administration and also supports companies wanting to make presentations to students to raise their profile or to hold interviews on campus.

Often placement opportunities come from alumni and these relationships are nurtured by the School with help from the Alumni Office.

The School does have students placed abroad and grants are available for those going to European countries. Occasionally, students go to companies outside Europe. Currently, around 5% of placements are to European countries and one or two a year to countries outside Europe.

Whilst on placement, students have an industrial supervisor and an academic supervisor who is often their personal tutor at Aston. Academic supervisors normally make two visits to each student on UK placements and one visit to overseas placements. Reporting depends on the discipline but usually includes an interim report or log followed by a final report. In Product Design, students also have to prepare a poster that is judged for a book prize funded by one of the companies. The placement administrative support team keeps in regular contact with students, reminding them of submission dates and informing them of what is going on at the university.



The minimum requirement is for the student to spend 45 weeks on their placement. All participating students who pass their placement have 'with professional training' appended to their degree certificate as recognition of their industrial experience. Making the placement year a creditable element in the degree programme has recently been considered. However, this raises issues including those of assessment, as it is difficult to assess placements comparably and fairly when each is unique, supervision is mainly by an industrialist and tasks vary considerably.

Students obtain a financial award from the University for taking up a placement. This is currently £1,000 for paid domestic placements and £1,500 for international placements or unpaid domestic placements, although the universal nature of these payments is under review. Typically, students will be paid by their company while they are on a placement with the average amount being about £15,000. The salary level does not seem to have too much bearing on the choices made by students.

Perceived Benefits

Most staff report seeing increased levels of enthusiasm for the subject and of self confidence among returning students, correlated with grade improvements.

Students recognise the career benefits that can follow from a well chosen placement⁴¹: *"The experience I have gained is experience that I couldn't have gained in an academic setting and will be extremely beneficial for my future employability. I have had the opportunity to work with people around the world in a global working environment and I have had the responsibility of working on worldwide, important projects."* (BSc Computing for Business placement student, Intel). For the company, effectively the placement is a year-long interview and many students subsequently receive offers of employment from their placement company.

Challenges

Running a placement scheme is resource intensive, in terms of both placement organisation and administration and finding the time for academics to make supervisory visits. The main challenge in the current financial crisis is the difficulty of finding enough placements for all those who would like to go on them. Some sections of engineering are considering two placements of six months at each, as this can reduce the financial burden to individual companies. Students are also willing to make sacrifices themselves: *"Some of the students having known about the advantages of placements have been going for unpaid placements."* (Sudha Vaidya, School Placements Officer).

Future developments and ideas

The PVC External Relations has a role to increase the opportunities for placements in all areas of the University. *"By 2012 every student will have the opportunity to have integrated work experience."* (Helen Higson, PVC, External Relations). The University already works hard at finding suitable placements and has recently appointed three business development managers to assist in this. It has been observed that students who take vacation placements after the end of the first year and/or part time jobs with employers often obtain year long placements with the same company. Consequently, the provision of grants for summer jobs could help prime the placements process.

Effective Practice Exemplar 2: Foundation degrees in power engineering at Aston

Foundation degrees (Fds) are generally two year qualifications accredited by universities. In November 2005, Nagi Fahmi, a member of academic staff at Aston with extensive experience in the electrical power industry, developed a vision and a template for a Fd to address a perceived skills shortage at technician and junior project manager level. The only other university to develop Fd programmes in this field is London South Bank University (LSBU) and these have been developed totally independently. However the projected demand for Fd power engineering graduates is so high (500 plus per year) that the two universities do not believe themselves to be in competition but see instead an opportunity to co-operate to their mutual advantage.

Rapid implementation of the power engineering Fd programme at Aston followed with validation in April 2006. Aston now works with three utility companies: National Grid, E.ON UK, and Scottish and Southern Energy and has run workshops to incorporate their precise needs into the programmes: *"When we get people like Steven Holliday, who's Chief Executive of National Grid on a public platform stating that 'Foundation Degree graduates make an impact quicker on the business than conventional graduate entry', now that's fantastic news."* (Malcolm Booth, Director, Foundation Degree Centre).

The Fd programmes are 240 credits over two years. The students are all employed by one of the utility companies and are day release or block release students. The delivery of the programme and the demand on the students is intensive with 432 contact hours per year plus 768 expected hours of self and work-based learning.

The Fd programmes were developed by the Foundation Degree Centre, established through funding from the HEFCE Strategic Development Fund employer engagement initiative. The Centre has used its funding to leverage developments, bring in personnel for teaching and administration, student support and to provide a co-ordinated method of talking to stakeholders.

All Fds have to show how progression to an honours programme can be achieved. For the power engineering students it is possible to progress to the existing BEng in Electromechanical Engineering. However, demand for progression to a tailored power engineering honours programme has resulted in Aston developing such a programme to start in 2010. Between 10 – 20% of Fd graduates are expected to make this progression.

⁴¹ www1.aston.ac.uk/eas/placement-year/student-profiles/

Two of the utility companies involved with the power engineering programmes use the Fd as the academic component of the first two years of their training programme. In their third year the graduates move from the training post to a substantive post. Graduates from the first cohort are now providing feedback about how their Fd has impacted on their work.

Perceived benefits

The evidence that these programmes in power engineering meet a real industry need is indicated by the increasing number of students coming onto the programmes (from 10 in the first year to 94 due to graduate next year). Early indications are that one reason for the success of the Fd programme is that it offers the right level of industry involvement with regards to time and effort for development and employee release. It is also believed that Fds widen participation in HE: *"We've suddenly identified a whole group of people who wouldn't have had the opportunity to get into HE"* (Malcolm Booth, Director, Foundation Degree Centre). In addition, the Fd associations bring the potential for research opportunities with the sponsoring companies.



There is concern at Aston that they may not be able to meet the future demand for these Fds. There is also an ongoing challenge to handle the conflict arising from a student's wish to proceed to an honours degree and the employing company's wish for the student to return to the workplace. Financial rewards and the opportunity to join a professional institution may be incentives to retain people at this technician level.

Challenges

There is concern at Aston that they may not be able to meet the future demand for these Fds. There is also an ongoing challenge to handle the conflict arising from a student's wish to proceed to an honours degree and the employing company's wish for the student to return to the workplace. Financial rewards and the opportunity to join a professional institution may be incentives to retain people at this technician level.

Future developments and ideas

The Foundation Degree Centre will continue to expand its Fd programmes. Aston is also pioneering distance learning delivery with FE colleges, enabling attendance on campus to be further reduced, which also reduces the cost to businesses of releasing their employees for study. Developing distance learning approaches requires additional resources for specialised staff and for the new technologies involved. These courses will not be totally distance learning but will be blended with laboratory support and residential weekends on campus.

4.2. Coventry University, Faculty of Engineering and Computing

Background

Coventry University has consistently maintained strong links with industry with all of its first degrees on offer being sandwich courses. The Faculty of Engineering and Computing at Coventry University comprises five departments of which four run undergraduate engineering programmes and are included in this study: Computing and the Digital Environment; Engineering and Knowledge Management; Mechanical and Automotive Engineering; and The Built Environment. Engineering is known for the longevity of its industrial and commercial relationships, especially for Automotive Engineering and the Built Environment.

The most recent teaching quality assessments carried out by the QAA have indicated that teaching at Coventry University is “excellent” in a number of subjects, including building (scoring 22⁴²). According to data from the NSS, overall student satisfaction is 79%⁴³. Well over half of E&T graduates go into engineering careers and 93% are employed or in further study six months after graduating.

Overview of industry related components within undergraduate engineering programmes

Since 1989 there has been a drive to incorporate more problem-based activities into the degree programmes. This has recently developed into Coventry’s over-arching activity led learning approach. The Faculty also has a tradition for encouraging placements and has a dedicated Faculty Placements Office to facilitate this.

The Department of Computing and the Digital Environment has an Aerospace Systems Engineering degree that is particularly industry-focused, designed by a member of staff with a strong industrial background. All graduates from the 2006 cohort have remained within the discipline (Lambert, 2008⁴⁴). The degree has input from various industries, mainly to final year projects, as is also true for the Electronics and Communications courses within the department. Industry can provide mentors for students and further experience-led input is gained from visiting lecturers.

The Mechanical and Automotive Engineering Department also has strong industrial links, particularly with motorsport companies. The Engineering and Knowledge Management Department has industry contacts who come in as guest lecturers to provide underpinning support for the taught programmes. Occasionally this process also leads to industrial visits. The final-year projects are industrially focused and often industrially sourced, particularly for those students that have been on a placement year. All the courses within the Department of the Built Environment have industrial relevance, often with input from long-standing industrial partners.

Understanding the needs of industry

Coventry has good links with industry and has a strong desire to continually enhance them. Recent curriculum changes have been particularly influenced by the Skills4Auto report, ‘Skill Gaps in the Automotive Supply Chain in the West and East Midlands 2004/5’⁴⁵. The validity of the proposed activity led learning approach is supported by evidence from Aalborg University in Denmark⁴⁶, where employers comparing graduates from a traditional Danish engineering university with those from the entirely problem-based engineering faculty at Aalborg rate the Aalborg graduates much more highly.

Direct communication with industry is also seen as important, either formally (industrial advisory committees, etc.) or informally such as through placement visits.

Engineering at Coventry University has a high proportion of part-time students. There is a part-time route to the Engineering and Knowledge Management Department’s Engineering BSc degree, mainly attracting students employed in companies within a radius of approximately 25 miles of the University. Many of the part-time students are sponsored by their companies and the department has built up a bank of senior-level industrial contacts from these companies that it can draw upon for input into the programmes. The Built Environment Department comprises 50% part-time

⁴² wwwm.coventry.ac.uk/university/awards/Pages/Awardsandaccreditations.aspx

⁴³ NSS Data from Unistats website: www.unistats.com (full-time students only).⁴⁴ Lambert, C., Basini, M. and Hargrave, S. (2008) Activity Led Learning within Aerospace at Coventry University. Proceedings of the Higher Education Academy Engineering Subject Centre’s Innovation, Good Practice and Research in Engineering Education (EE2008) conference, 14-16 July 2008, Loughborough, UK.

⁴⁵ Source: www.skills4auto.org/Employer/Motivation/Full%20Report.pdf

⁴⁶ Source: www.hum.aau.dk/video/2008/pbl/anettekolmos/

students. It is believed that a host of informal learning is absorbed by the full-time students from the industrial experience of the part-time students. A formal mechanism, run for the first time last year (2007/08), has now been developed for part-time students to obtain credits for sharing their industrial experiences with their full-time student colleagues.

Again in the Built Environment Department, there is an example of responding to the needs of part-time students. The time taken from the end of an HNC to an honours degree is two years full-time study, traditionally equating to four years part-time study, a long period which was found to be an issue. Changes have enabled the students to complete two-thirds of the full-time programme in a year and they can now graduate in three years. It has taken a great deal of effort, particularly in course design, to establish the type of degree programme that is dedicated to the needs of part-time students.

Effective practice exemplar 3: the development of activity led learning at Coventry

Activity led learning is a process that derives from student-led discovery and problem-based learning that is employer and profession focused. Activity led learning is about incorporating activities that have previously been seen as standalone into the whole learning approach. These include the Formula Student project; IBM mentoring programmes with Computer Science students; and the Heavy Lift Aircraft Challenge amongst many others.

Drivers for change

The Faculty of Engineering at Coventry University "*wish to establish an international reputation for high quality professionally focused graduates and the learning experience that is provided*"⁴⁷. This approach to learning and teaching is motivated by the desire to produce graduates who have confidence in their ability, capability to achieve and capacity to reflect, innovate and renew. In addition, it is believed that this type of educational experience will encourage more students to stay and complete their programmes.

While problem-based approaches have been in use for around 20 years within sections of the Faculty, there is now a concerted drive towards implementing activity led learning across the whole Faculty. This is linked to the ultimate construction, by 2011, of a new engineering building (at a cost of £60 million) specifically designed for activity led programmes. The new building will bring together teaching space, project learning spaces and laboratory spaces in a way that encourages a professional linkage of these activities. This move towards activity led learning is a journey that is only partially complete and much of what is discussed here concerns perceived potential outcomes of the process.

Implementing Faculty-wide change

The four Associate Deans have spent a great deal of time and effort in researching and developing their activity led learning approach including first hand observation of programmes developed elsewhere in the world. These observational visits have been effective in informing the pedagogical decisions surrounding the nature of activity led learning and the design of the new building. During these research 'discovery' visits to other universities, one point was forcibly made: "*for goodness sake don't copy what we've done. Don't copy what anybody's done. It has to be something that works for you*" (Peter White, Associate Dean).

Two Teaching Development Fellows have been employed to work towards implementing the vision – the 'change agents'. They have established an action research framework so that implementation can be an evolutionary process of continuous improvement, combining a top-down vision with bottom-up project-led initiatives – a 'continuous improvement change management model'⁴⁸.

Pilot learning, teaching and assessment projects have also been introduced. Departments have been given £2,000 to supplement their part-time staffing budget to provide time-release for a dedicated member of staff to introduce one learning and assessment exercise that would come under the umbrella of this type of activity led pedagogy, or could be targeted towards desirable outcomes such as improved student retention. This has identified six interesting projects and a group of individuals that could act as champions.

⁴⁷ A vision for learning and teaching in the Faculty of Engineering and Computing by the Associate Deans and LTA sub-group working party, Nov 2007.

⁴⁸ Wilson-Medhurst, S., Dunn, I., White, P., Farmer, R. and Lawson, D. (2008). Developing Activity Led Learning in the Faculty of Engineering and computing at Coventry University through a Continuous Improvement Change Process. Proceedings of Research Symposium on Problem Based Learning in Engineering and Science Education, 30 June -1 July 2008, Aalborg, Denmark.



The first 'new' activity led learning component has been the introduction of a pilot project for 100 first year students from Mechanical and Automotive Engineering in which they took part in six one-week related exercises, forming one of the six modules studied during the year. The students worked in teams of 8 with 18 timetabled hours per week comprising two to three hours of key note instruction, 14/15 hours of facilitated activity and one hour of assessment, with results and feedback being given at the end of each week. These six week projects were rolled out across the Faculty in October 2009.

Early feedback⁴⁹ from both staff and students has indicated that this has been a very successful approach, with drop out rates for term one falling from 3% to 0.9%, survey data showing a 26% increase in satisfaction and the students finding it an exciting introduction to university life. The downside would appear to be the intensity of the process for both staff and students and the need for space and equipment resources, all of which will be compounded when all student year groups are involved in these types of activities.

Finally, a Steering Group of (initially) three international colleagues has been established, aiming to meet face-to-face annually and separately with colleagues from Coventry in between. The primary purpose for the group is to help inform developments at Coventry, but it also seeks to build knowledge together and disseminate effective practice.

Supporting the staff through change

Staff within the Faculty are already under significant pressure to deliver, particularly with higher than desirable student:staff ratios for the pedagogical changes being made (a maximum of 17:1).

This is being partially addressed through additional staff recruitment from 160 to 200 academic staff which has been facilitated by the Faculty adjusting its business model to focus funds in this direction. Development of teaching teams will also have an effect on the recruitment of new staff and the distribution of staff within the Faculty.

As well as adapting to new staffing structures and increased numbers of staff, existing staff will also need to learn new skills: *"a key thing within activity led learning ... is the group work and the facilitating of that group work"* (Duncan Lawson, (Associate Dean).

To work towards these aims, the existing team of academics, technicians and Technician Instructors is being used in a much more active way and a new staff category, Graduate Intern, has been added. Since September 2009, the Faculty have approximately 60 Graduate Interns who act in a 'teaching assistant' type role. The Faculty will increase this number to 200 in September 2010, in order that each member of academic staff has a teaching assistant to work alongside them.

Curriculum design changes have been made with support from the national Higher Education Academy Engineering Subject Centre⁵⁰ who have made visits and run a range of workshops for staff.

Supporting the students in a new way of learning

An integral part of the development of the activity led process is ensuring that the students are given the best opportunities to learn. The Faculty therefore offers extensive 'drop-in' tutorial support for students, modelled on the highly successful SIGMA CETL in Mathematics Education. A Student Experience Enhancement Unit has also been established

⁴⁹ The initial findings are being presented at the 38th IGIP Symposium – Q2 of E2 Quality and Quantity of Engineering Education. 6-9 Sept 2009, Graz, Austria, with a full paper on these findings being prepared for Engineering Education: Journal of the Higher Education Academy Engineering Subject Centre.

⁵⁰ The Higher Education Academy Engineering Subject Centre provides discipline-based support for learning and teaching across the UK, www.engsc.ac.uk

that provides a much broader form of support than simply academic help. It provides a 'one-stop-shop' to assist students with all of their potentially problematic interactions with the University.

Perceived benefits

- Better engagement of students and staff in the learning experience
- Improved student retention and progression
- Enhanced standards of student achievement
- Increased graduate employment rates
- Confident, self-motivated and successful members of society
- Enhanced reputation leading to increased student recruitment
- Greater staff and student satisfaction
- A vibrant learning community attractive to students and staff.



Of this list, the opportunity to improve student retention and progression rates is seen as particularly important: *"certainly the research visits that we've done internationally would confirm that this kind of hands-on approach to pedagogy actually does, if you do it right, stimulate the student so it does improve attendance, and improve engagement, and if you improve those two you automatically improve retention and progression rates"* (Duncan Lawson, Associate Dean).

Challenges

- A need to refocus the operation of the engineering workshops
- There are student issues with the assessment of group work. WebPA⁵¹ has been used successfully in the introductory six week pilot
- Some staff have concerns with the extent of activity led processes within the programme.

What potential difference will activity led learning make?

The hope is that the activity led learning process will engage and stimulate student interest which will, in turn, enhance student performance and ultimately produce graduates that are confident in their ability and 'completely employable'.

⁵¹ WebPA, www.webpa.ac.uk

4.3. Imperial College London, Faculty of Engineering

Background

Industrial applicability is stressed in both Imperial's Supplemental Charter of 2007 and its Mission Statement. Both the University and Engineering achieves highly in league tables. Engineering and Information Technology at Imperial is rated seventh in the world in 2008, according to the QS World University Rankings⁵² and for the UK, all Imperial engineering subjects rank in the top five of the Guardian University League Table 2010, with Civil Engineering ranked in first place⁵³. Results from the NSS indicate that students are very satisfied with their courses at Imperial, with an overall average of 85% (above the UK average of 82%). 43% of E&T graduates go into a profession related to their subject area and 16% go on to further study, including E&T related subjects.

The Faculty of Engineering has a very strong research focus with over 79% of research assessed as being 'world leading' or 'internationally excellent' in the latest 2008 Research Assessment Exercise⁵⁴. The Faculty is large, with approximately 1,200 staff and over 3,300 undergraduate students and comprises nine discipline-focused departments that cover the whole spectrum of engineering. Each Department has a Director of Undergraduate Studies (DUGS) who is responsible for overseeing the undergraduate courses and maintaining excellence. In some engineering aspects, where expert knowledge is considered crucial, Imperial has introduced 'Mastery' exams with a pass mark of 80% that students have to negotiate successfully in order to progress.

Overview of industry related components within the undergraduate engineering programmes

There is no common core introduction to the engineering programmes at Imperial. Since 2008, a lecture series of invited speakers has been provided for the whole engineering first year to highlight major engineering developments in a range of areas and ensure that students get an overview of the breadth of the field.

Industrial placements of varying length are offered by most of the engineering departments and are compulsory for some courses in the Departments of Materials and Computing. Informal networking has traditionally provided most of the industrial placements, although this year both Materials and Mechanical have struggled to place all the students. It is felt that incentives may help: *"Government support for companies to honour placement offers would be useful in the present climate"* (Jason Riley, DUGS, Materials). Industry experience is considered to benefit students significantly. Internships offered by some departments usually in the summer of the third year also enable students to experience industrial projects. In the Department of Computing, the arrangement of placements and internships is achieved by dedicated administrative support.

Finally, engineering at Imperial has well organised and dynamic alumni associations. For the last five years a faculty unit, the Engineering Chapter, has served to simultaneously enhance and harness the benefits of the different associations.

Understanding the needs of industry

The relatively new Department of Bioengineering has an intriguing problem in terms of engaging with industry as not all the relevant industries are established in the UK, particularly for emergent technologies. This can make it difficult to find industrial partners and relevant placements. However, as Bioengineering has a broad subject coverage, students still remain extremely employable.

One major curriculum development within the Department of Materials that has been driven by perceived and informed industrial needs is in bio-materials, an area that is believed to be about to



⁵² www.topuniversities.com/worlduniversityrankings/

⁵³ Guardian League Table 2010 - www.guardian.co.uk/education/university-guide-2010-subjects

⁵⁴ Imperial College – news and events; Faculty of Engineering homepage and RAE 2008 website

expand in the UK. Another development area is for the resurgent nuclear industry and a Materials and Nuclear Engineering course has been implemented, receiving strong support from companies.

Many of the departments at Imperial stress how important their informal links with industry are in understanding their needs. The Department of Civil and Environmental Engineering does not have an industrial advisory board, but it has very strong informal industrial links and these communication networks are used effectively to gain feedback on industrial requirements.

Visiting professors and bought-in retired engineers from industry have also been used significantly to help understand and address industry needs. Responsibilities have included enhancing practical design on courses, integrating design projects in each year of the programme and for design teaching.

Another way of understanding the needs of industry is through research links. For example, four recently appointed academic staff are on Research Council (UK) positions. These are half-sponsored by industrial companies for five years and have a six month agreed placement in industry.

Electrical and Electronic Engineering's involvement with the Power Academy⁵⁵ is an example of working nationally to understand and address the needs of industry.

Effective practice exemplar 4: simulated industrial experiences at Imperial

A. Constructionarium (Civil Engineering)

Constructionarium⁵⁶ is a hands-on six day Civil Engineering construction experience, where groups of students take control of a construction site, in association with an industrial consulting engineer and a contractor, and build scaled down (typically 1:10) engineering projects. It is currently running for students in their third year but from 2010/11 it will be moved to the end of the second year programme.

The concept of Constructionarium was developed at Imperial College and is now run at the National Construction College in Norfolk, where there is a dedicated six hectare site providing a range of challenging conditions, from a lake to mountainous terrain.

Up to five teams of approximately 16 to 24 students act as construction companies, with individuals assuming different roles from labourers to managers. After an initial safety briefing, they have use of the site for six days to construct a project design. They have to cost and time manage the project using specially developed rates for labour and any plant used. The students have to pay between £250 and £300 each for travel and accommodation, unless they can obtain sponsorship support. The contractor spends approximately £250 per student for materials, plant and labour. Student feedback describes Constructionarium as a life-changing experience.

B. Pilot plant (Chemical Engineering and Chemical Technology)



The pilot plant is four storeys high and is effectively a fully-functional, full scale plant. *"It is basically a fully-working piece of chemical plant in the middle of London, which the students have to work in groups on and they are given, essentially, no instructions"* (Stephen Richardson, Principal, Faculty of Engineering). The pilot plant provides an experience that is regarded as essential by Imperial. The pilot plant was originally built in 1973 and now needs to be replaced. The total cost of this will be upwards of £8 million, providing a state-of-the-art facility with control room, laboratory and other associated areas.

⁵⁵ www.theiet.org/about/scholarships-awards/power-academy/background.cfm

⁵⁶ www.constructionarium.co.uk/

Perceived benefits

These types of experiences are enormously character-building and can have a dramatic influence on enthusiasm for the subject. Students also gain a level of confidence and understanding which helps them to familiarise themselves quickly in generically similar industrial situations. Educational experiences such as these also impact positively on employability.

Effective practice exemplar 5: EnVision at Imperial

EnVision⁵⁷ was started as a project five years ago and is now the Development and Support Group for Teaching and Learning for the Faculty of Engineering at Imperial College. It is primarily involved with curriculum development, teaching and learning issues and student projects.

EnVision is faculty-funded, currently at approximately £0.5 million per year. Initially, this was earmarked for project activity but a significant proportion is now diverted to resource administrative and learning technologist support within a defined structure. Envision works with the Faculty of Engineering in four key areas: direct departmental support; development of the educational ethos to ensure that excellence in engineering education is rewarded, supported and celebrated; development of the public areas and learning spaces; and funding of projects.

Perceived benefits

One example is the facilitation of multi-disciplinary routes for students. On 'Flexible Fridays', final year students from any discipline can take certain modules, with clearly-defined pre-requisites, offered by each department. To make this possible it has been necessary to carry out a complete rationalisation of the timetables. For 2009/10, just over 70 students (approximately 10% of the fourth year cohort) took up an extra-disciplinary option. Creating these more multi-disciplinary routes has given rise to a new degree in Nuclear Engineering.

Challenges

Developments in teaching and learning are not regarded in the same way as advances in research. Take up of EnVision's activities has varied significantly between departments.

Effective practice exemplar 6: Large group projects at Imperial

The Chemical Engineering Department at Imperial run final year projects over a ten week period with teams of ten students. (Aeronautical Engineering also runs large group projects in the third year but these are not reviewed here).

There are 12 to 14 groups, each containing ten students, working on six or seven projects. Consequently there is a competitive element as there are two teams working independently on each project. Prior to the start of the projects, time is spent in structuring the composition of the teams in order to try and make each team as representative as possible of the whole cohort and an algorithmic approach is used to achieve this.

The first day of the project is an externally organised team-building day designed to promote team spirit. Each project has an academic member of staff associated with it as a facilitator with competing teams having the same facilitator. Additionally, all the projects have access to a range of staff, both academic and industrial visiting professors, who undertake individual consultant roles as experts in various areas. The student teams have to negotiate contracts for buying and selling utilities, raw materials and chemical products which form part of the ultimate project report. The teams are also provided with any state-of-the-art computer software they might need, including costing and chemical property databases and various simulation packages, as would be the case if doing similar project work in industry. Any programmes developed during the project, for example reactor or separation simulations, are assessed.



⁵⁷ www3.imperial.ac.uk/envision

During the running of the project, the teams have a formal meeting every week with their facilitator and each member of the team takes a turn to chair this meeting, which is assessed. The teams produce specific reports for each component of the project, plus a summary report. The students are required to append their percentage contribution to each report and these reports are assessed by the respective experts. All of the assessments are moderated to try to eliminate discrepancies and scoring differences between facilitators. There is a strong peer assessment component to the projects.

Effective practice exemplar 7: student-led activities at Imperial

Student-led activities are organised by the engineering students themselves. There are active student societies for many of the engineering disciplines and many of these additional activities arise out of, or are supported by, these societies. Many of the student-led activities provide a high level of experience-led learning and involve intensive and extensive organisational, management and communication capabilities.

The El Salvador project⁵⁸

A group of around 11 Civil Engineering student volunteers makes an annual six week trip to El Salvador to involve themselves in construction projects such as building earthquake-safe housing and schools in the country. Students have to pay £400 and source the remaining required funding themselves each year for materials and accommodation, supported by the department. The additional funding generally comes from industry and alumni, but recently a group was awarded a JP Morgan Good Venture Award. Other similar expeditions go to different countries.

Racing Green⁵⁹

This is a project to design, build and race in international competition a zero-emissions car. It was spearheaded in 2006/07 in response to the predicted need of automotive companies for graduates specifically trained in these new technologies. A small core group of 13 students was assembled and, with seed funding of £30,000 from EnVision, they made a fuel cell powered go-kart over the summer vacation in 2007. This was well received by the students and a further £70,000 was obtained from EnVision to build a second generation go-kart for Formula Zero⁶⁰ and also to build a hydrogen fuel cell racing car to enter into the Institution of Mechanical Engineers' (IMechE) Formula Student competition. In 2008/09 this attracted 100 students from eight departments. In order to make the activity sustainable it has been handed over to the students who raise the funds (about £100,000 per year) and run the project themselves, reporting on a monthly basis to a Steering Group of academics from each of the departments. Students participate in Racing Green on either a voluntary basis or as part of the curriculum.



Perceived benefits

Involvement in student-led activities demonstrates key qualities of graduates to potential employers. Proactive student-led activities can provide direct benefits to departments too. For example, the Department of Materials no longer takes students on visits to industry but sponsors the Materials student society (MatSoc) to organise such visits. The various alumni associations are often financially supportive of student-led activities. The students benefit from the funding and the alumni associations benefit by recruiting students once they graduate.

Challenges

Involvement in these sorts of activities costs students both time and money. This may put some off getting involved, or only attract the most motivated.

⁵⁸ www.elsalvadorproject.org.uk/

⁵⁹ www.union.ic.ac.uk/rcc/racinggreen/

⁶⁰ www.formulazero.nl/

4.4. University of Liverpool, Department of Engineering

Background

Engineering has been part of the University of Liverpool almost since it was founded and today has established links with industry, collaborating with some 400 industry partners⁶¹ and producing research on an international level. This is reflected in the recent Research Assessment Exercise (RAE) 2008, with Materials Science ranking second overall in the UK⁶².

The Faculty of Engineering currently has two departments: The Department of Electrical Engineering and Electronics and the Department of Engineering. The Department of Electrical Engineering and Electronics has only been peripherally involved in the change processes described here. The information presented here is predominately limited to the Department of Engineering and covers aspects of the following:

- Aerospace Engineering (BEng; MEng)
- Civil Engineering (BEng; MEng)
- Materials Science and Engineering (BEng); BEng with Foundation Element; MEng)
- Mechanical Engineering (BEng; BEng with Foundation Element; MEng).



Results from the NSS show that the majority of engineering students are satisfied with their courses, with 86% satisfied in Aerospace and 83% in Mechanical. Engineering subjects have also fared well in the Times Good University Guide 2010⁶³. More than half of the E&T graduates go into engineering careers and the majority are employed or in further study six months after graduating.

Overview of industry related components within the undergraduate engineering programmes

All the discipline sections organise a range of external lectures, many by professional engineers and run design courses that may include industrial input. Students are encouraged to take up industrial placement opportunities, either as an optional year out or during summer vacations. These are not offered formally, but students have access to these through a dedicated point of support for engineering in the University's careers service.

Drivers for change

The initial drivers for change were a desire to increase the quantity and improve the quality of undergraduate recruits, as well as enhancing the student experience to improve retention on the programmes. A strategic approach to change has been adopted that started with a ten-year plan drawn up in 2002, updated in 2006/07 and aligned with the University's strategic plan. Initial work involved marketing initiatives, including promotion through UCAS. This led to increases in intake for three consecutive years from 2004 and an improvement in intake quality from 2005. A key element of the ten-year plan was the total refurbishment of the Department of Engineering, including the construction of 250-place active learning laboratories at a cost of £36 million. These spaces, opened at the start of 2009, are extremely flexible, permitting multiple combinations of operational layout.

The Department of Engineering at Liverpool has recently launched its 'Liverpool Engineer' initiative and defines the Liverpool Engineer as: *"a person who is highly adaptable, infinitely resourceful, a good communicator, someone who can work comfortably within a team, and someone who has the perfect blend of theoretical knowledge and practical skills to meet the stiffest challenge"*. It is hoped that this will further enhance the quantity and quality of student recruits and should also provide a strong sense of identity amongst the future Liverpool Engineer graduates, encouraging the professional Liverpool Engineer alumni of the future to re-engage with the University.

The process of change has been championed by two successive Heads of Department who felt that change was important and provided the necessary leadership to 'sell' the approach to both senior management and academic staff. It is doubtful whether the change process would have occurred without the enthusiasm of these two individuals.

⁶¹ www.liv.ac.uk/about/facts_and_figs/

⁶² www.liv.ac.uk/news/press_releases/2008/12/rae.htm

⁶³ Times Good University Guide 2010

Understanding the needs of industry

An important additional stage in the development of a restructured and re-focused engineering programme has been the rejuvenation of the Industrial Liaison Committee which had previously been under-utilised. After the Industrial Liaison Committee has met, follow-up discussions are arranged with the industrial members of the committee to maintain an active dialogue between the participants and the Department.

Effective practice exemplar 8: Active learning and CDIO at Liverpool

To enhance the student experience, 'active learning experiences' have been incorporated throughout all the undergraduate programmes. Active learning occurs whenever a student actively participates and engages in a learning opportunity, as opposed to passively receiving information. It is felt that this type of learning will allow students to appreciate the qualities of a contemporary professional engineer and, ultimately, provide the calibre of graduate in demand by industry both nationally and internationally.

To achieve this aim of incorporating active learning experiences into the courses, fact-finding missions were carried out to observe and appreciate effective practice from other countries. In particular, there has been an alignment with the CDIO philosophy. The CDIO standards and syllabus provide a context in which engineering education is delivered. It does not prescribe syllabus content or teaching approach, rather it recommends elements of engineering programmes, such as a minimum of two design-build-test exercises for every student.



The Department believes that staff development is an essential component of the adoption of a CDIO approach. Staff attend regular away days with learning and teaching themes, many of which have contributors from outside the Department, and more than a dozen staff have contributed to, and attended, international CDIO conferences and meetings.

First year active learning experiences

The initial course on entry to the first year is effectively 'what is engineering?' and every afternoon of the first week is the 'icebreaker' project. The cohort is split into assigned tutor groups of five or six students who can start to get to know their tutees. The cohort is around 280 students, so there are about 50 teams. The groups compete against each other to produce the strongest small cardboard bridge structure from a specific design, whilst simultaneously learning much about the Department itself. The icebreaker project is not assessed but it does seem to increase the confidence of the students.

Spanning the weeks prior to and immediately following the Christmas break are the 'two week creation' full-time, total immersion group projects. These are aligned to disciplines and are designed to assess how much the students have learned over the first three months of their course. The students are given a design brief and provided with equipment and materials. Aerospace students have to develop and test a remote-controlled model aircraft; Civil Engineering teams have to design, build and test a model truss bridge; and Mechanical Engineering students carry out two one-week projects, firstly to produce a water-powered rocket and secondly to design and make a wind turbine-powered model car.

Second year active learning experiences

The year two Civil Engineering students spend seven days on a 'Constructionarium' project. One day is spent on campus and six days at the National Construction College completing a large scale building project. The Constructionarium project is run in conjunction with external professional contracting and consultant engineering firms who provide significant resource input. The students obtain first-hand experience in a number of areas, most notably project management, time management, teamwork, communication skills and construction methods. They also gain an appreciation of site safety, good practice and personal risk. Students pay £250 each towards accommodation costs.

Second year Aerospace Engineering students have a one-week course at Cranfield. This involves flight simulation activities as well as flying experience in a real plane. The cost for this activity is in the region of £20,000 per year.

In addition to all of these 'real' experiences, a number of virtual projects are included in the undergraduate programme which use Liverpool's on-line learning environment, VITAL. These projects include designing and delivering facilities for a developing country and developing a steel car door that can compete with an aluminium specification.

Final year Capstone projects

Capstone projects are final year group projects:

- **'Formula Student'**. This is run by the Mechanical Engineering section, although the project is multi-disciplinary and has involved some students from the Department of Electrical Engineering and Electronics this year. The project is to design, build, test and race a fully functional racing car at an international competition held at Silverstone in July each year. Students have been successful in obtaining sponsorship to offset costs.
- **A Mechanical Engineering group project with the National Nuclear Laboratory**. This is run in conjunction with a Visiting Professor, Richard Taylor, who identifies specific problems such as clearing debris from a nuclear pressure vessel.
- **A structural design project in Civil Engineering that has input from professional design engineers** and deals with problems such as designing new motorway junctions or combined heat and power generation schemes.
- **A Mechanical Engineering design activity in conjunction with Jaguar Cars, Halewood, Liverpool.**
- **Aerospace Engineering 'heavy lift aircraft challenge'**. This is a design, build and test project for radio controlled model aircraft and, like Formula Student, it is a competition against other student teams from around the world.

Perceived benefits

For students, the Department intends that active learning will:

- Emphasise the application of engineering science
- Provide horizontal integration of knowledge and skills within programmes
- Encourage awareness of life cycle processes
- Allow them to develop and apply a range of important personal and professional skills
- Motivate them by treating them like professional engineers.

The alignment with CDIO brings benefits in terms of sharing and 'borrowing' effective practice between the growing group of CDIO participating institutions.

Challenges

A lack of further resources would seem to be a serious barrier to :

- Increasing the number of academic staff to reduce current workloads so that tutorial group sizes could be reduced and so that staff would need to supervise fewer projects
- Developing teaching teams. There is a need for more teaching and learning academics and technical staff with a role in supervising project work
- Meeting a perceived need for at least two staff with a dedicated industrial liaison role
- Increase the number of academic staff with a teaching-only remit
- Taking groups of students on more site visits.

The take up of new pedagogical approaches by academic staff has not been universal.

What difference does active learning and CDIO make?

Students gain an understanding of applying their theoretical knowledge to solve practical engineering problems. The Department is not yet in a position to gain quantitative data on the effects of active learning and CDIO, as curriculum reform was implemented only a few years ago. However, the active learning and CDIO concepts have given transparency and coherency to teaching activities and have allowed these activities to be systematically enhanced.



Effective practice exemplar 9: Use of visiting professors at Liverpool

The Department of Engineering at Liverpool currently has eight visiting professors all senior active or retired professional engineers. Five of these visiting professors are, or were, supported by the RAEng. Visiting professors are used in many different ways, ranging from helping to make strategic change to direct teaching input. Visiting staff typically give from one to eight days per month to the Department. Three of the Liverpool visiting professors who have been funded through the RAEng scheme are discussed here.

The first is Richard Dodds FREng, retired from an extensive 30 year professional career with Unilever and a RAEng Visiting Professor in Engineering Design for Sustainable Development in the Department from 2000. The funding from the RAEng was £20,000 for the first three years (2001-04) and £15,000 for a two-year extension to 2006. As part of his visiting professor role he was asked to facilitate seminars and industrial liaison committees. After the RAEng funding terminated he was retained by the Department as a visiting professor and is still involved with engaging industry at a senior and working level.

The second is Derek Bamber, the RAEng Visiting Professor in Innovation who has a senior role at Serco. He has opted to remain with the company and gives his time free of charge to the Department. The RAEng visiting professor funding is used to employ a Teaching Fellow (Shane Bathurst) whose role is to facilitate and optimise the interaction between the visiting professor and the engineering students.

The third is Richard Taylor, a visiting professor from the National Nuclear Laboratories who works with Liverpool to bring industrial relevance into 'Capstone' projects in the final year. This visiting professor has been instrumental in the loan of expensive equipment to the Department, in the supervision of undergraduate research projects and in encouraging some of his more junior staff to act as Engineers in Residence.

Perceived benefits

Liverpool believes that this scheme is an effective way of using professional engineers to provide industrial relevance to undergraduate programmes at relatively low cost and low risk. These industrialists act at a high level, advising and helping with strategic change and curriculum development or simply providing the students with ready access to senior-level industrial experience. The scheme is easy to implement and has wider benefits such as its regular workshop programme.

Challenges

For the Department, challenges can arise when considering how to continue contact once the funding ceases. Another issue is the availability of the visiting professors to students, as they are only on campus for a few days each month. The situation with Shane Bathurst acting as an on-campus facilitator for a visiting professor is an interesting way in which the interaction between students and a visiting professor can be optimised. Forming a good relationship and getting the most from the industrialist requires good planning and communication.

What difference does the use of visiting professors make?

The key difference is that the visiting professors are able to increase both industrial input and relevance to the undergraduate programmes. This is particularly true in important areas such as the development of nuclear energy and in innovation. Being externally funded, the scheme provides particularly good value for money to a university.

Future developments and ideas

The visiting professors and others, such as emeritus staff and alumni, are currently being brought together as 'Engineers in Residence'. This will help to promote the role of the visiting professor to the students and will also allow the visiting professors to interact with each other. It is hoped that participants will be willing to contribute time, ranging from a few days per year to a few days per month, so there can be a continual presence of professional engineers on campus.



4.5. London South Bank University, Faculty of Engineering, Science and the Built Environment

Background

With over 25,000 students, LSBU is one of the largest universities in London and has an unusual demographic when compared with other UK universities. In 2007/08, 48% of students were part-time, 68% were aged 25 or over, 50% were from ethnic minorities and 86% were from the UK⁶⁴. *"We do and must continue to accept students who are able to benefit from higher education from the widest range of backgrounds and develop our skills at assessing their real potential"* (Corporate Plan, 2009–2012⁶⁵). The Faculty of Engineering, Science and the Built Environment contributes just over 20% of the student body and comprises the Departments of Applied Science; Engineering and Design; Built Environment and Urban Engineering. This case study is mainly restricted to a detailed review of Building Services Engineering in the Department of Urban Engineering. The unusual student demographic of the University applies equally to the Faculty. For example, Building Services Engineering attracts a student profile that is over 80% part-time with an average age of around 30. The part-time students attend courses one day per week. Almost all of these students are 'non-standard' entry, rather than school leavers with A-levels. The Faculty provides flexible interconnecting pathways through various educational ladders that include HNC/D, foundation degrees, undergraduate and postgraduate taught programmes through to PhD level research.

LSBU is ranked in sixth place for graduate starting salaries in the Times Good University Guide 2010, demonstrating the high value employers place on the skills of LSBU graduates⁶⁶. 87% of E&T UK graduates from LSBU are employed or in further study within six months of graduating and almost half have entered engineering related careers. When only part-time students are considered then the numbers employed or in further study increases to 90%, with nearly 60% in engineering related careers.

LSBU was chosen as the lead university for the London Engineering Project. This is a HEFCE-funded, RAEng project aimed at promoting STEM subjects in London schools and colleges. The chief aim of the project is to attract into engineering groups that have been under-represented, particularly women and ethnic minorities. Recruitment of students to engineering programmes at LSBU has been enhanced by its involvement in the London Engineering Project.

Overview of industry related components within the undergraduate engineering programmes

LSBU provide the largest number of Building Services Engineering graduates in the UK⁶⁷. Building Services Engineering deals with the analysis, design and operation of the internal built environment, whilst maximising sustainability, and has a very wide ranging remit, covering lifts, heating, cooling, lighting, drainage and the energy generating systems necessary to power these processes.

Building Services Engineering is considered to be a fairly buoyant industry and will have an increasingly crucial role to play in the development and implementation of energy efficiency within buildings. Recent local, national and EU policies on energy efficiency also impinge upon the discipline. For example, the EU has defined an *'energy performance of buildings directive'* that requires the energy certification of buildings. This is establishing a new tier of consultants in the industry.

Consequently academic staff are confident, particularly in the longer term, that students are highly likely to find jobs at the end of their courses and that there will always be a healthy requirement for the good students in this area.



⁶⁴ www1.lsbu.ac.uk/about/factsAndFigures.shtml#65

⁶⁵ www1.lsbu.ac.uk/about/documents/corporatePlan/corpplan0912.pdf#66

⁶⁶ extras.timesonline.co.uk/pdfs/highestgraduatestartingsalaries.pdf

⁶⁷ www.lsbu.ac.uk/esbe/engineering/BS.shtml

There are major redevelopments occurring in the immediate vicinity of LSBU that will be in the front line for the implementation of new energy strategies. For example, the South Bank Employers' Group⁶⁸ has a project looking at how combined heat and power (CHP) systems could be put into all buildings from Blackfriars to Westminster and how this experience can be delivered to students. This involves more than technical skills and a Visiting Professor in Employer Engagement is involved in developing leadership and management issues.

Effective practice exemplar 10: understanding stakeholder needs at LSBU

Direct interaction with employers

Part-time UK students are attending LSBU because they and their employers find the courses are pertinent to their work. In return, the Faculty gains feedback from the students and their employers about what course content is appropriate and what technologies they are applying in their industry. The University is also able to influence employers through the technologies that their employees become familiar with while studying at LSBU.

LSBU has the most KTP activity of any London university and is currently ranked third in the UK for the number of KTP programmes it runs⁶⁹. Around 75% of this practical applied research is conducted within the Faculty of Engineering, Science and the Built Environment. The intercommunicating network of employers, their employees and academics provides a rich source of knowledge, talent and expertise that can provide the impetus for new associations and projects.

Within the Faculty as a whole, a number of Foundation degrees, including one in Power Distribution, have been established in association with relevant Sector Skills Councils to address the specific skills requirements of industry. These Fd developments benefit from the input of the Employer Engagement Unit at LSBU. There are pathways by which students who obtain a Fd Eng can progress to the respective honours degree programmes.

Informing curriculum development

The Faculty has established Industrial Liaison Panels (ILPs) which are consulted through specific questioning about the nature and content of its courses. The panels feed back vital information on where they feel provision may be lacking and what the future needs of their industry may be. The ILP for Building Services Engineering courses has strong representation from professional engineering alumni and is considered to work extremely well: *"There was clear evidence that the ILP seeks to play an active part in course development and that their input was both valued and acted upon by the University"* (Report on Moderation of Building Services Engineering Courses, LSBU, 2004).

Modules in the Faculty naturally evolve slightly each year, but sometimes a need emerges that requires complete restructuring of an existing programme or the development of a completely new one. This is achieved through a formal planning team that holds extensive consultations with academic staff, industrial advisors and professional institutions. The Faculty has recently conducted a wide-ranging review to identify future teaching opportunities and specific subject areas that could be targeted. Key areas such as water and energy have already been identified.

The linked iterative cycles of attracting part-time students from industry, adding educational value, enabling them to utilise the latest technologies and then returning them to their workplace on the one hand; and the involvement of graduate alumni in the processes of recommending and accrediting the competences required by professional Building Services Engineers through their ILP and professional institutions on the other, would seem to be an organised process of continual enhancement. This is an example of a well developed and exploited niche within engineering education, although benefiting enormously from the limited competition from other universities.



⁶⁸ www.sbeg.co.uk/

⁶⁹ <http://bcim.lsbu.ac.uk/resources/BCIM/files/enterprise/KTP/KTP%20Business%20Brochure%20Brochure.pdf>

Active involvement with professional institutions

The ten core staff associated with Building Services Engineering at LSBU all come from industrial backgrounds and actively maintain a very high profile relationship with industry and the key professional institutions (CIBSE, the IMechE and the Energy Institute). LSBU considers this to be very useful in terms of understanding how people are developing their professional careers and, in turn, informs it about the marketplace for its courses and how they could be developed further.

The relationships between the University's academics and students, the ILP and their professional institutions are almost familial and are strengthened by encouraging the students to join CIBSE while still undergraduates and to attend popular and vibrant monthly meetings.

Engagement with statutory bodies

The staff are all involved in high level practical research linking the University and professional institutions with statutory bodies. Examples include working with the Greater London Authority to review the Mayor's London Plan policies and writing a new technical memorandum for ground source heat pumps and developing the associated policy aspect.

There is a strong desire to predict the future skills and graduate demands in major engineering developments and to consider how best to work towards satisfying those demands. The Visiting Professor is involved in negotiations with relevant groups and these discussions are attempting to map out the skills demographics for these projects and how LSBU can be involved in the delivery of programmes that will generate the technical, leadership and management competencies required.

Perceived benefits

- The close relationship with students, and beyond to their employers, leads to a high level of employer engagement which, in turn, provides continual feedback on the state of the industry.
- The highly active and multi-directional interplay between academics, the ILP and their professional institutions results in LSBU being highly responsive to industrial needs. The continuous link with the professional institutions is two-way: raising the profile of LSBU and enabling academic staff to influence what the professional institutions demand from HE.
- The interactions with statutory bodies on current topics makes students feel that they are entering a dynamic learning environment where policy is being developed rather than imposed from above.

Future developments and ideas

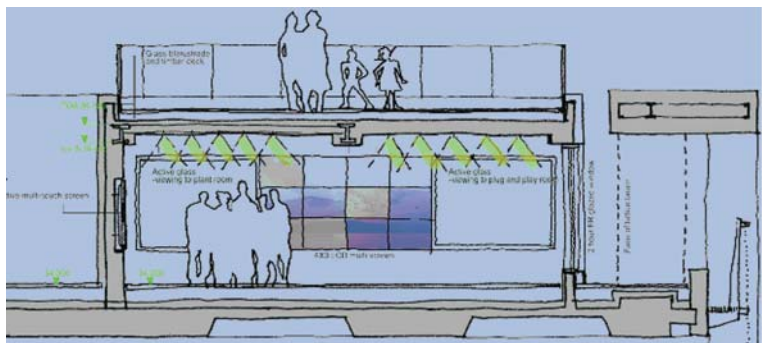
There is a view that the alumni could have even more involvement with the discipline at LSBU. While the ILP is considered to work extremely well, there is a huge untapped resource of other alumni that could be utilised. A Business Development Manager has recently been employed by the Engineering Systems Department to enhance the interaction with alumni, develop new ways of linking with industry and to capture new business that will also link with course development.

Effective practice exemplar 11: CEREB at LSBU

The Centre for Efficient and Renewable Energy in Buildings (CEREB) is a unique resource for the teaching, research and demonstration of low carbon energy technologies in the built environment. CEREB is currently under construction and has been designed as a roof level adjunct to the new Keyworth II building at LSBU. This building has been designed to have a number of features to reduce carbon emissions, including thermal massing, solar shading, solar thermal and ground source heating and cooling.

The creation of CEREB will mean that the new building will function not only as a building but also as an engineering teaching tool from May 2010. CEREB has been designed as a

demonstration facility with an associated teaching (50 person) and research (30 person) space. CEREB's direct access to the 'state of the art building energy management system will enable students and researchers to study the building and its energy use' (CEREB brochure).



CEREB will provide hands-on learning experiences for Building Services Engineering students involving the very latest technologies. Data held within the CEREB unit will also be made available online. Tony Day, Research Professor and Director of CEREB considers that CEREB is “a small physical space but a big virtual space.” This will facilitate online data



sharing and the potential for major collaborations with international academic and industrial partners.

In terms of the courses that will be run in CEREB, parts of course units on the Building Services Engineering courses at all levels will benefit, mainly Engineering Systems, Energy Systems, Energy Management and Energy Resources. Partner universities will use the facility for mechanical engineers, energy managers, planners and surveyors. New short courses on renewable energy technologies, leadership and management for the construction sector industry and continuous

commissioning (the ongoing energy management of buildings) are being developed. Some of these courses will commence before CEREB is actually operational and others are partnerships with industry to deliver courses to industry in CEREB.

Commitments to carry out research and to collaborate with industry were two of the prerequisites for obtaining some of the initial funding for CEREB. There was also a requirement imposed by HEFCE that the educational benefit would be shared with two other universities in the area, namely City University and Kingston University, and these will be involved in using CEREB for their own students and industrial partners. The unit will need to become self-sustainable and the three institutions are currently developing a business model for achieving this. The steering group for CEREB has strong input at Pro-Vice-Chancellor level from all three partner institutions and it will oversee the route to sustainability and the equitable and maximised use of the facilities.

Perceived benefits

The key benefit of this experience-led activity is that students will have the opportunity to learn about and work in real time on the complex energy requirements of buildings from within a major modern University development. Students will gain simulated work experience of state of the art technologies in a ‘live’ teaching facility.

Challenges

- CEREB has been piggy-backed onto an existing building design, which has resulted in delays and penalties. It would have been better to be involved right from the design stage
- Conditions imposed by funding sources
- The costing of courses for industry within CEREB.



Future developments and ideas

Negotiations are in progress on developing a similar educational facility within the Elephant and Castle redevelopment associated with a planned 17 megawatt biomass CHP station. CEREB has indicated its willingness to run such an education centre: “so CEREB could actually extend out into the community even more and have a sort of research and education centre on top of a power station. Now how many students get a chance to crawl over one of those?” (Tony Day, Research Professor and Director of CEREB). The estimated cost of developing such a facility would be in the region of £50 million.

4.6. Loughborough University, Faculty of Engineering

Background

Loughborough University is proud of its reputation for excellence in teaching and research, supported by strong and often longstanding links with business and industry. In the Times HE's Student Experience Survey of 2008, Loughborough was the highest scoring institution in the 'good industry connections' category and was the top-ranked institution overall for the third consecutive year⁷⁰.

The Faculty of Engineering comprises five departments: Aeronautical and Automotive Engineering; Chemical Engineering; Civil and Building Engineering; Electronic and Electrical Engineering; and Mechanical and Manufacturing Engineering. The Faculty hosts both the national Engineering Subject Centre and the University's Engineering Centre for Excellence in Teaching and Learning (engCETL).

At undergraduate level, the usual patterns of study are three year BEng and four year MEng degrees, with the option to take a sandwich year in industry leading to the additional award of the Diploma in Industrial Studies (DIS). At MSc level, availability of part-time and, increasingly, distance learning provision is intended to facilitate study for students working in business and industry. In the *Times Good University Guide 2010*, all of Loughborough's engineering departments have top ten rankings, including Building in first place⁷¹. In 2009, four out of five departments also held top ten rankings in the NSS. In the Research Assessment Exercise 2008 almost 20% of research in the Faculty was rated 'world leading'⁷².



Within six months of graduating, 90% of E&T graduates are employed or in further study, almost two-thirds have entered directly into engineering related careers while less than one-fifth have embarked upon careers classified outside E&T.

Overview of industry related components within the undergraduate engineering programmes

There is a well-established ethos within engineering at Loughborough that degree programmes should incorporate experience-led components and there are many examples of such components. Such commitment to industry ensures regular feedback to support the development of industry-ready graduates. *"The Chemical Engineering programmes are all taught at the leading edge and the course contents are fully up-to-date and address the needs of industry, providing graduate engineers with the appropriate educational training"* (External Examiner, Chemical Engineering, 2006).

Understanding the needs of industry

Interactions with industry occur at various levels. Formal interactions include the departmental Industrial Advisory Committees, which can help influence programme development.

Industrial participation in teaching and research provides further opportunities, both formal and informal, to gain further feedback and to help develop aspects of taught programmes. Loughborough staff are confident that this combination of formal and informal interactions works well to understand and then meet the needs of industry.

Effective practice exemplar 12: Diploma in Industrial Studies at Loughborough

The Diploma in Industrial Studies (DIS) is an additional qualification awarded for completion of a placement year in industry (minimum 45 weeks duration, UK or overseas) during the undergraduate degree programme. For 2006/07, uptake varied from 44% in the Department of Aeronautical and Automotive Engineering to 74% in the Department of Civil and Building Engineering. The placement usually takes place between the second and third undergraduate years.

Departments typically promote and support their placement schemes using an academic director and a placement administrator. Most departments also run placement fairs. Support from the Careers Service is used to help students gain the additional skills they need for placement. Students on placement are visited by a nominated academic from their department two or three times during the year, with day-to-day management provided by their manager in the

⁷⁰ THE Magazine, No. 1879, 15th-21st January 2009
www.timeshighereducation.co.uk/story.asp?storycode=404989

⁷¹ http://extras.timesonline.co.uk/tol_gug/gooduniversityguide.php?AC_sub=Building&sub=10&x=37&y=14

⁷² www.lboro.ac.uk/research/rae/index.html



company. Students keep a log book of their activities and prepare a dissertation related to their work. Assessment is made by both the visiting academic and company staff. With very few exceptions, DIS placements are salaried and placement students can expect to earn somewhere in the range of £12.5K to £20K.

Perceived benefits

Staff at Loughborough believe that placement students return with greater motivation which in turn leads to improved final year marks. Placements also appear to aid retention within the engineering sector. An engineering placement student is much more likely to embark upon an engineering and technology

related career than a non-placement student. From the 2006/07 graduate cohort, the first career destination data 6 months after graduating revealed that retention within the sector was over 85% for students who had been on a placement, compared with just over 60% for other students. For companies, placements are often regarded as an extended assessment process for graduate recruitment purposes.

The student's log book can contribute towards the achievement of Chartered Engineer (CEng) status. For Mechanical and Manufacturing Engineering, this recognition happens automatically through the IMechE, whose Professional Development Standards Committee views the DIS scheme as: "*an exemplary university thick sandwich course which is admirably linked to the Monitored Professional Development Scheme process.*"

Challenges

Despite average uptake of 57%, the main challenge faced is to increase DIS enrolments. This problem is exacerbated by the introduction of fees so that some students prefer to finish their degree as quickly as possible and move into a permanent job. Other deterrents include issues with accommodation and personal relationships.

The departments have no desire to make placements compulsory. Emphasis is always placed on students convincing the employer to recruit them, so such a move could prove difficult to implement. In addition, students are occasionally made redundant while on placement although the University will seek alternative opportunities for them. Loughborough's preference is to convince students of the merits of the scheme.

Effective practice exemplar 13: the Teaching Contract Scheme at Loughborough

The Teaching Contract Scheme in Mechanical and Manufacturing Engineering is an example of collaboration with multiple companies to provide industry-based group design projects. Currently, 14 companies and over 200 students are involved in the scheme, which operates with second and fourth year students who complete projects set by the collaborating company in cooperation with the University. In the second year module, *Application of Engineering Design: Industry-Based Project*, all Mechanical Engineering students complete projects in teams of up to four. In the final year of both Mechanical and Product Design MEng programmes, students tackle bigger projects and are organised into multi-disciplinary teams. In addition, MEng finalists act as mentors to second year groups.

At the start of the scheme, students visit their company and projects are negotiated and defined. Companies tend to have open-ended problems that need a solution and negotiation is often required to establish reasonable parameters for the project. Accompanying lecture programmes give structure to the project work. The industrialists visit Loughborough at specific times during the year for progress reports on the projects and to take part in tutorials. The students submit a final report and give an oral presentation to the company engineers. For final year projects there is also a major exhibition of all the work to which the companies and external examiners are invited.

The scheme is directed by one member of academic staff, with the part-time support of one member of administrative staff. They receive the full backing of the Head of School. The companies pay a small fee to the University which funds the necessary industrial visits, hospitality, basic project costs and maintains a high report presentation standard.

Perceived benefits

- Students gain knowledge of specialist engineering topics, awareness of industrial and commercial realities and develop vital transferable skills
- Student employability is increased and companies see the projects as a cost-effective way of targeting potential placement students and graduate employees
- Companies are able to tackle speculative projects that they would not normally resource and many have reported the benefit of fresh minds developing novel conceptual solutions to longstanding problems. Measures of success are that the companies involved keep coming back and that the scheme is highly regarded by professional accreditation bodies.

Challenges

The scheme relies heavily on the enthusiasm of individuals who devote significant time and effort to nurture contacts and to ensure that projects run efficiently. Students sometimes have issues with group work. These difficulties have been overcome to a large extent by using WebPA, an online tool that facilitates peer assessment of group work.

Effective practice exemplar 14: sponsored degree programmes at Loughborough

The sponsored degree programmes at Loughborough are each supported by a consortium of companies. The consortia input into curriculum development, take a close interest in the students and also provide funding to both the University and students. The programmes have all been developed in direct response to requests from industry.

Department of Civil and Building Engineering

Civil and Building Engineering has three sponsored programmes, attracting between 60 and 100 students per year. Two BSc programmes started to run in the early 1990's and a third bespoke sponsored MEng programme started in 2001. A total of 26 industrial sponsors have been involved with the development of these programmes. Each student does a placement year with their sponsoring company and they are usually able to undertake vacation work as well. The companies also provide a number of undergraduate projects and have funded leadership, management and teamwork exercises for undergraduates.

Department of Electronic and Electrical Engineering

The Systems Engineering inter-disciplinary programme has been offered for the last 15 years and recruits between 25 and 40 students per year. It is led by the Electronic and Electrical Engineering department but involves input from six further departments. For MEng students this is an exceptionally flexible programme and individual modules can be picked up in the third and fourth years from all three faculties within the University. This is intended to equip graduates with the capability to tackle multi-disciplinary problems. Much of the programme is problem-based and the projects involved are typically complex. Students on these projects are taught and assessed as individuals within a team. There are three sponsoring companies which give students conditional offers of employment at the start of their final year with approximately 75% take up of these offers.

Mechanical and Manufacturing Engineering

The Innovative Manufacturing Engineering degree programme has been running for just over five years. This is a four year MEng degree developed in combination with a group of international companies in order to attract able students into careers in manufacturing engineering.

Companies participate in recruitment, curriculum development and the provision of industrial placements. The programme integrates significant periods of industrial experience, equivalent approximately to a five year programme, but is completed within four years. Students are initially sponsored by the consortium as a whole and work for a minimum of four weeks for one of the companies over the summer at the end of the first year. They return to industry at the end of their second year and remain there throughout the first semester of their third year, completing their major





individual research project with the company. At this point, they enter into an exclusive sponsorship agreement with one company.

Perceived benefits

The key benefit is close and active industrial involvement in the degree programmes, ensuring relevance and producing highly employable graduates. There are financial benefits for the departments and the students, with income to departments of around £400 per student and student bursaries of about £1,500 per year, as well as funding for projects and prizes. Students also attract a salary of around £15,000 while on placement. Some students receive conditional offers of employment at the start of their final year. Over 95% of students believe they have benefited

from their sponsored programme, beyond the financial assistance⁷³. Companies regard the programmes as a cost-effective method of recruiting high calibre graduates who will match their requirements.

Challenges

Building a committed sponsoring consortium is a huge undertaking. Changes in company fortunes, priorities, and key personnel can have major repercussions. Academic leadership is critically important and replacing a dedicated director could be challenging. Consortium expectations need careful management. Students graduating from sponsored programmes are in significant demand and can be tempted to take offers of employment from other companies. This can result in sponsoring companies becoming disillusioned and questioning the value of their consortium membership.

Effective practice exemplar 15: engCETL at Loughborough

The Faculty of Engineering at Loughborough first established dedicated engineering education support in 1997. In 2005, the Faculty's reputation for excellent industrial links and educational technology development resulted in the award of HEFCE funding to establish the Centre for Excellence in Teaching and Learning (engCETL) with £2.5M for running costs and £1.65M for capital build. Now with 12 full-time equivalent staff, its remit covers a range of engineering education activities, with particular emphasis on links with industry. The relationship with departments is promoted by academics seconded from each of the engineering and technology departments for a small percentage of their time to act as champions for the Centre.

The engCETL Advisory Board consists of a range of stakeholders, including academics, support staff, students, industrialists and representatives from engineering institutions.

It focuses on topics relevant to the provision of experience-led degrees, such as accrediting work based learning and placements, models of industry engagement and Bologna compatibility.



⁷³ Soltani-Tafreshi, F., Twigg, D.R., and Dickens, J.G. (2009) The Role of industrial involvement in education of engineering students. STEM PRM 2009, 30 June 2009, Loughborough, UK.

The relationships formed with industrialists have led to the recent establishment of a RAEng Visiting Teaching Fellow in the Faculty. The engCETL Panel presides over the competitive bidding process for engineering and technology staff that allocates the Centre's staff resources to teaching projects. In addition to the internal projects, staff routinely place bids for externally funded projects. One project is WebPA, developed to provide an online method of assessing individual contributions to group work. The Centre also works closely with the co-located Engineering Subject Centre.



HEFCE capital funding enabled relocation to new accommodation which combined office space and teaching rooms. The teaching space was designed specifically for group design projects following consultation with students, industry and academics.

Perceived benefits

The Centre is seen as being responsive to the needs of academics and supportive through the implementation phases of their teaching innovations. The seconded academic system has worked very effectively⁷⁴.



The engCETL staff, funded PhD students and the seconded academics constitute a substantial research group whose activity has raised the profile of the Centre, both nationally and internationally.

The teaching space that the new engCETL accommodation provides has drawn new academics and their students into the Centre. The 2008 institutional audit team reported that *"engCETL has been instrumental in the provision of newly developed design teaching space. Engineering students [...] were particularly enthusiastic about the facilities [...] Their collaborative project with industry was another benefit provided through engCETL's extensive industrial network."*

Challenges

At all stages, Centre staff have had to ensure that activities are driven by the needs of academic staff and their students. Strategically, the Centre must have the unequivocal support of senior staff within the Faculty and work to ensure strong support from the University's senior management team. Dependence on intermittent, external funding raises understandable concerns over job security. Both these factors bring challenges for recruitment and retention of skilled staff.

⁷⁴ Tolley H. (2006) engCETL: the experiences thus far of its seconded academics, evaluation report. www.engcetl.ac.uk/downloads/research/evaluation/engcetl_seconded_academics_report.doc

5. Experience-led components of engineering degrees

The case studies described in Section 4 clearly demonstrate that the successful delivery of experience-led components within engineering degrees depends on a strong tripartite relationship between staff, students and industry (see Figure 2). The three way interactions impact directly on both teaching and curriculum development.

These relationships work in unique ways within each university and the case studies reveal resulting variations in the scale and impact of the experience-led activities on offer. Experience-led activities identified as occurring at some or all of the case study universities are summarised in Table 2: The table lists the components in order of effectiveness and hence priority, as judged by the Oversight Group on the basis of the available evidence. The benefits to the student learning experience are also given, based on the findings of the case studies and additional evidence in published literature.

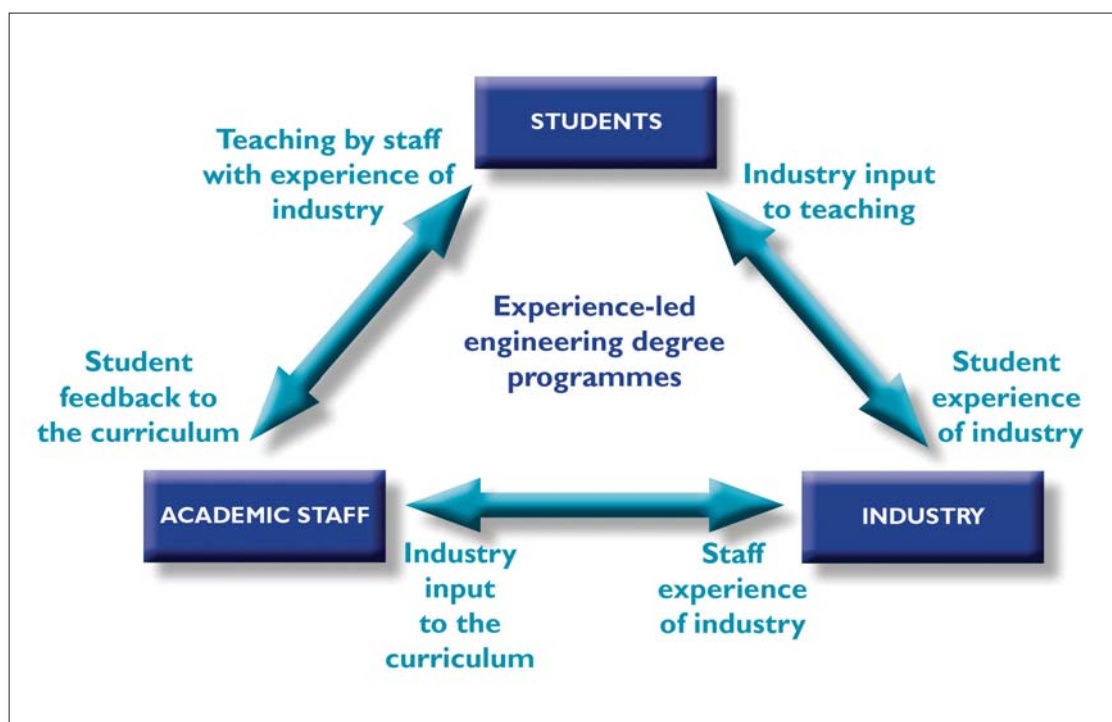


Figure 2: Relationships between academic staff, students and industry for experience-led engineering degree programmes

Table 2: Summary of experience-led activities

Category	Experience-led component	Benefits to the student
Direct student experience of industry	<ul style="list-style-type: none"> Industrial placement year (sandwich courses) Other industrial work opportunities Relevant employment for part-time students Relevant student-led activity 	<ul style="list-style-type: none"> Placements can have an impact beyond academic studies on students, helping them to make life-changing decisions and contributing to attainment of chartered status Placements can result in job offers, as companies use the placement as an extended interview process Work experience (including relevant student-led activity) offers an opportunity for students to gain real industrial experience, highly valued by employers Students often return from work experience having more self-confidence, enthusiasm, motivation and improved 'soft' skills Work experience has been seen to help students recognise the relevance of taught material and theory and be more successful in their final year The nature and scope of voluntary projects encourages and motivates students to look beyond formal academic requirements
Indirect student experience of industry	<ul style="list-style-type: none"> Industrial simulation (Constructionarium and pilot plants) Project-based learning and other forms of active learning Industrial group projects, design projects, multi-disciplinary projects Case studies from industry Influence of part-time and mature students on full-time students Site visits and field trips Entry to national and international competitions Student involvement with professional institutions 	<ul style="list-style-type: none"> All opportunities to gain industrial experience, including simulated experience, are seen as key in preparing graduates for engineering careers Students find these more realistic experiences motivating, particularly where they are combined with inputs from real practising engineers Students feel they learn more through simulated activities than in a traditional classroom environment Improvements in retention have been noted where students have had a more activity based experience, particularly early on in the course Active learning processes are more likely to produce adaptable, resourceful graduates Curriculum delivery which utilises group work, especially active learning, is seen as key to enhancing student engagement Realistic projects can teach more than just the application of theory and can also introduce consideration of a wider picture, including business and finance Group projects are seen as important in representing industrial practices and can develop important teamworking and communication skills, helping to promote employability Design projects help students link theory to application and projects with an industry partner provide real industrial relevance Part-time students can share their industrial experiences with full-time students, which helps to improve the full-time student's understanding of what it would be like to be an engineer National competitions like Formula Student help students with the development of 'soft' skills such as teamwork, leadership and time management

A single experience-led activity at a university often contains more than one of the listed experience-led components. For example, the delivery of industry-based group design projects might also involve visits to industry, industrial input into tutorials and training in 'soft' skills.

Companies providing industry-based group design projects through the Teaching Contract Scheme at Loughborough University have reported how they benefit from the unrestrained basic research carried out with fresh and open minds and how this often leads to novel and otherwise ignored conceptual solutions to longstanding problems.

It was frequently cited that the experience-led components allow students to acquire ‘soft’ skills at the same time as, not at the expense of, the technical skills and this was seen as important. High priority given to group work in the curriculum is apparent at every case study university, although this has also resulted in a need for universities to ensure that assessment methods are appropriate for the increased use of group work. Both employers and students frequently refer to the benefits of work experience and it is considered more should be done to encourage wider uptake of placements or other experience of industry.

"The experience I have gained is experience that I couldn't have gained in an academic setting and will be extremely beneficial for my future employability." (returning placement student, Aston University)

Table 3: How experience-led engineering degrees meet the graduate recruitment needs of industry

Exemplar	Attractive courses		Relevant, high quality curriculum				Graduates with experience of industry	
	Attracts applicants	Retention on programme	Better industrial linkage	Student engagement	Being proactive to accreditation	Retention within engineering	Student experience of industry	Preparing students to work internationally
Aston University								
Industrial placements	✓		✓	✓		✓	✓	✓
Foundation degrees in power engineering			✓			✓		
Coventry University								
Activity-led learning	✓	✓	✓	✓		✓	✓	
Imperial College London								
Industrial simulation (Constructionarium and chemical pilot plant)	✓		✓	✓		✓		
Large group projects				✓	✓	✓	✓	
Student led activities	✓		✓	✓		✓	✓	✓
University of Liverpool								
Active learning (adapted from CDIO)	✓	✓	✓	✓		✓	✓	
Visiting professors	✓		✓			✓	✓	
London South Bank University								
'Live' experimental laboratory (CEREB)	✓		✓	✓		✓		
Loughborough University								
Industrial placements (Diploma in Industrial Studies)	✓		✓	✓		✓	✓	✓
Industrial group projects (Teaching Contract Scheme)	✓		✓	✓	✓	✓	✓	
Sponsored degree programmes	✓	✓	✓	✓	✓	✓	✓	

As shown in Table 3, experience-led engineering degrees help to meet the graduate recruitment needs of industry (as identified in Section 3.1) by providing attractive courses, relevant high quality curricula and student experience of industry. Opportunities for more widespread adoption of experience-led components in degree programmes exist in all universities and accreditation is a powerful vehicle that could be used to ensure further take up of experience-led activities. The Accreditation Standard gives universities freedom to plan and resource programmes, provided they achieve the required outcomes and values design as a means to integrate knowledge and understanding.

6. Case study analysis

The six case studies present detailed information regarding experience-led components within engineering degrees. Together they demonstrate excellence within current practice and a clear desire within proactive universities to develop engineering degrees whose graduates are attractive to industry.

The analysis of the case studies, together with additional evidence from published literature, offers clear messages about how to enhance a sustainable HE engineering sector that meets the graduate recruitment needs of industry. Eight themes were identified from the analysis and are now discussed in turn.

6.1. Institutional profile

Every university is different and has to apply a different approach to developing experience-led components of engineering degrees: *one size doesn't fit all*.

The six universities examined in this study differ in many ways. Relevant factors include geographical location, research or teaching led, vocational or academic focus, nature of the student cohort and the history of/mission for industrial engagement.

Each university has its own identity, recruiting students from a range of backgrounds (in terms of qualifications, age, part-time/full-time, work-based, socio-economic background) and producing engineering graduates with different skill sets and knowledge. This diversity in the HE system helps to cater for an ever-wider range of student and business needs (as discussed in *Stronger Together*) and produce engineers who can compete on the world stage in different ways.

Examples of different approaches include:

- Developing a recognised identity or 'graduate product', both to attract future applicants and encourage alumni interaction
- Having a specific focus such as meeting local needs or new/niche markets
- Focusing on a particular type of graduate.

Some universities position themselves to respond rapidly to, or even predict, emerging skills need requirements, quickly developing relevant programmes that enhance recruitment. Others develop programmes in response to a particular industry need but over a much longer timescale.

"So if we're not responding to the way the industry is working, we're either not going to get the part-time students in particular in the first place, or they're not going to be very employable at the end of it, or both." (Rob Best, Deputy Dean, LSBU)

Examples such as the development of vocationally-based Foundation degrees demonstrate how universities are already responding to the government's demand in *Higher Ambitions* for greater diversity in models of learning.

The power engineering Foundation degrees at Aston University are designed to meet specific needs within industry and are essentially employer driven. These programmes were developed specifically to address a perceived skills shortage *"based on a rationale that at the technician level within industry there is a huge, huge problem."* (Malcolm Booth, Director, Foundation Degree Centre, Aston University)

6.2. Student experience of industry

Students who undertake relevant work experience during their degree are more motivated on return to their course and more employable on graduation: *experience counts*.

Employers highly value graduates who have combined their academic study with relevant activities above and beyond the assessed components of degrees, recognising in particular the experience gained and the dedication demonstrated by these students.

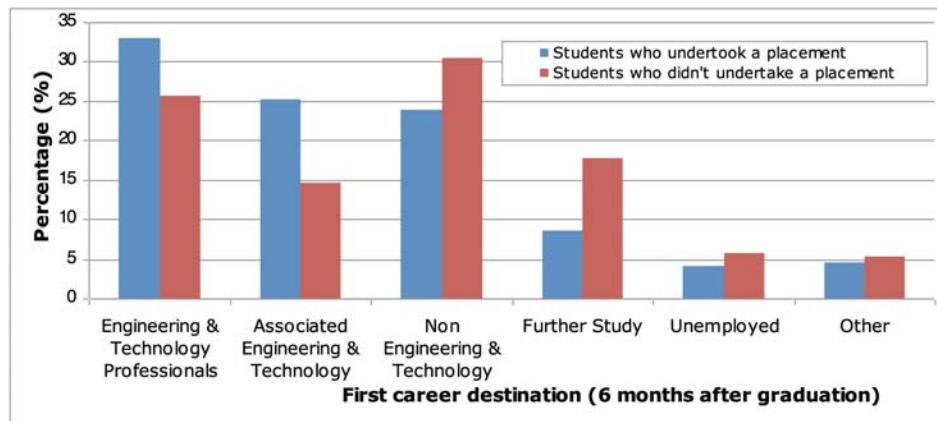


Figure 3: First career destinations for placement and non-placement students for UK/EU-domiciled full-time E&T graduates 2006/07

Students who have undertaken relevant work experience (paid or unpaid) during their course are clearer about their future career options and are more likely to find employment in engineering and technology related jobs on graduation⁷⁵. This is reflected in the HE Statistics Agency data for 2006/07 in Figure 3 which shows that 58% of students who undertook a placement went into engineering and technology careers against 40% who didn't do a placement. Although there is no clear evidence of a direct link between placements and improved degree classification, post-placement students are more motivated for the remainder of their course and are more confident, mature and professional⁷⁶. Employers report in Stronger Together that graduates who have had worthwhile work experience have acquired a higher level of employability, and the case studies agree with this and show that placement students have improved management, teamwork and communication skills.

"I finished Year 2 with 58.6%, I have just found out that I have finished my bachelors degree with a 1st. I can honestly say that I would not have achieved this had I not completed a [placement] year which set my priorities straight." (recent graduate, Loughborough University)

Some universities have considered making the placement year a creditable element in the degree programme but this has proved difficult to achieve, mainly due to issues related to assessment. However, one exemplar demonstrated how a placement scheme is sometimes able to formally contribute towards the professional development scheme of a chartered institution.

All of the case study universities encourage students to engage in engineering related activities above and beyond the assessed components of their degree. For example, each university enters a team into the Formula Student competition which involves a high level of participation and can be entirely voluntary, especially in early years of degrees (although it can also be assessed, for example, as final year projects). Involvement in such extra-curricular activities demonstrates key attributes to potential employers, including enthusiasm. One university uses an innovative method of encouraging involvement of students in extra-curricular activity by offering an open module which allows final year students to gain credit for the engagement with, and preparation of submissions to, national and international student engineering competitions, including Formula Student.

The Imperial College London student project leader of the 2008/09 trip to El Salvador to undertake construction projects commented: *"Well worthwhile experiences at the end of the day I reckon and I'm not going to regret paying for it at the end."*

At universities where the first year intake is dominated by full-time school leavers, the benefits of work experience are very significant. Less benefit accrues where intake is dominated by mature part-time students who already have employment in an engineering company. Again, one size doesn't fit all.

⁷⁵ Unleashing Aspiration: The Final Report of the Panel on Fair Access to the Professions, Cabinet Office 2009

⁷⁶ Lock et al (2009) Exploring the industrial placement experience for mechanical engineering undergraduates, Engineering Education 4.1

6.3. Student engagement

Student engagement, motivation and satisfaction are highlighted by many of the exemplars as benefits of the provision of industrially relevant curriculum content: *relevance motivates*.

Surveys such as the NSS⁷⁷ and the Times HE Student Experience Survey provide evidence about students' attitudes towards their experience at university. The case studies show that universities increasingly take such surveys seriously and that lower rankings are one of the main drivers for change.

Industrially relevant course content helps students to link theory to practice, enhancing student engagement and improving retention. In particular, active learning approaches are seen to enhance student engagement.

"The key to a meaningful 'reformation' of our engineering degree programmes is to give the student engineer a more 'active' experience and we therefore embed active learning experiences into all our courses." (Gareth Padfield FEng, Head of Department, University of Liverpool)

Part-time students are often already employed in industry and highly motivated, understanding the benefits that their qualification will bring. These students can also influence their full-time peers.

Engineering at Coventry University has a high proportion of part-time students, employed by engineering companies. It is believed that a host of informal learning is absorbed by the full-time students from the industrial experience of the part-time students. A formal mechanism, run since 2007/08, has now been developed for part-time students to obtain credits for sharing their industrial experiences with their full-time student colleagues.

In some cases, students take responsibility for their own learning, providing a student voice which can impact on curriculum development, for example by sitting on liaison boards and staff-student committees.

6.4. Industry links

Engagement between universities and industry is crucial to the development and delivery of experience-led components of engineering degrees: *responsibility must be shared*.

Some of the most successful examples of experience-led activity have been developed not just in consultation but in genuine partnership with industry.

Engagement with industry

All of the case study universities currently engage with industry in a range of ways as detailed in Table 4. Advisory input to the curriculum, either formally or informally, can result in the development of new or enhanced experience-led components. Input to teaching by engineers from industry at all stages in their career (including recent graduates) delivers up-to-date relevant content directly to the students.

Table 4: Summary of industrial components

Category	Industrial component
Industry input to teaching	Industrial visiting professors Bought-in lecturers Guest lectures / seminars from engineers in industry Other industrial teaching: training, mentoring, tutoring Sponsored programmes
Industry input to the curriculum	Industrial liaison boards Input resulting from research based links Industry-sponsored student prizes Informal industrial input

As well as input to the curriculum and teaching, the engagement can bring further benefits: loans or gifts of experimental equipment and software, funding, sponsorship, placements, site visits and so on. Many of these are crucial to the successful delivery of experience-led components. Responsibility must be shared between universities and industry for the delivery of experience-led degrees.

⁷⁷ www.thestudentsurvey.com/

More generally, all relevant bodies (government, professional institutions, industry and universities) need to maintain a forward-looking dialogue to address the evolving needs of society.

Moving from engagement to genuine effective partnership

Constructionarium and sponsored programmes are two examples of very successful experience-led activity which have been developed not just in consultation but in genuine partnership with industry. The CBI/UUK report Future Fit also suggests that employers and universities need to develop successful partnerships if tomorrow's graduates are to contribute quickly and effectively to their employer's success. New initiatives do arise from strong links between individuals but collaborations between multiple universities and industries deliver more sustainable outcomes.

The sponsored programmes exemplar at Loughborough University involves a consortium of companies working with the University to provide an industry relevant degree programme. Students are formally connected to industry from day one through sponsorship and 'buy into' engineering – often through vacation work as well as placements. They remain motivated, have improved understanding of the professional role and are more likely to stay within engineering.

Constructionarium is a hands-on six day Civil Engineering construction experience, developed at Imperial College London but now undertaken by 17 UK universities. Groups of students take control of a construction site in association with an industrial consulting engineer and a contractor and build scaled down (typically 1:10) engineering projects. *"This is a new form of teaching, innovative in the way it embeds industry in an academic context with students in charge."* (Alison Ahearn, Civil Engineering and EnVision, Imperial College London)

6.5. Staff capacity and capability

Introducing experience-led teaching requires different staff capabilities and often increased staff capacity. It is crucial that academic staff have either prior experience of industry or access to opportunities to gain insight into industry (which could be through interaction with industry during the experience-led teaching activity itself).

Dedicated champions, often responsible for both developing and implementing change, play a pivotal role and must be recognised, supported and rewarded. The number of such champions needs to increase and this can be partially achieved through adequate resourcing of discipline-specific staff development and support: *change needs champions.*

Capacity

Introducing a new, experience-led teaching methodology generally requires a lower student:staff ratio. This can mean recruiting additional staff but other measures to address this issue have been successfully implemented, including use of industrialists in teaching, employment of visiting professors and the development of innovative job roles.

At Coventry, a new staff category, 'Graduate Intern', has been developed to help facilitate group work, mentoring and additional aspects of student support: *"The Dean's ambition [...] is that every academic will have one of these teaching assistants allocated to them. They each deliver something like 500 hours of support per year over two years part-time, [...] which is not inconsiderable."* (Ian Dunn, Associate Dean, Faculty of Engineering and Computing, Coventry University)

Capability

The case studies show the importance of recognising and encouraging individual champions and small committed teams as they drive the implementation of change. Successful examples include teaching awards, project grants and recognition of engineering education research.

EnVision is a dedicated engineering education centre at Imperial College London, working with the Faculty of Engineering in four key areas: direct departmental support; development of the educational ethos to ensure that excellence in engineering education is rewarded, supported and celebrated; development of the public areas and learning spaces; and funding of projects. *"EnVision is [...] actually about stirring the pot, allowing good practice to be disseminated but then also trying some new things and supporting them"* (Anthony Bull, Academic Director, EnVision)

Staff who may have limited experience of proposed new pedagogies need properly resourced (both time and money) opportunities for staff development, including the sharing and transfer of effective practice between engineering departments. Examples from the case studies include dedicated discipline-support units or teams, internal international fact-finding missions to bring in ideas and form links with other practitioners (both in the UK and internationally), involvement with the CDIO international network and the use of external organisations such as the Engineering Subject Centre.

The RAEng Visiting Professors' Scheme increases capability as well as capacity. The professors are amongst the UK's most senior and experienced engineers, possibly recently retired, and the success of this scheme is highlighted within the case studies. The scheme does not necessarily provide direct engagement with industry; the focus is on interaction on a one-to-one basis between department and visiting professor.

The Liverpool case study describes three RAEng Visiting Professors with quite different roles – the first has revitalised the industrial liaison committee and has a role to engage industry at a senior level; the second has helped to integrate innovation input into modules and the third brings relevance from developing industries (nuclear engineering) into final year projects.

Industrial experience of academic staff

It is widely recognised throughout the case studies that academics with industrial experience help to create, implement and sustain experience-led engineering degrees. However, several incentives in the current funding models of universities act against this. For example, research-led universities tend to favour staff with profiles likely to be highly rated in the research assessment exercise⁷⁸.

The situation at UK universities is in contrast to German universities of applied science, where staff are usually only recruited if they can demonstrate at least five years' practical experience in industry⁷⁹.

Staff without prior experience of industry when they join a university can gain insight through formal schemes such as the RAEng Industrial Secondment Scheme or informally through collaborative research or their involvement in experience-led teaching components such as placement visits and group design projects.

6.6. Implementing change

The ability to change is heavily dependent on senior management support and can be either incremental or radical: *management leads change.*

The case study universities have implemented either incremental or radical changes to enhance their engineering degrees, depending on institutional ethos with regard to industry. Radical change is often triggered when a department or faculty has 'stood still' for a while. Incremental change tends to be part of an ongoing process in cases where a continuous response to industry engagement is embedded into institutional ethos. Sometimes, however, ongoing incremental change becomes insufficient and more wide-scale change is planned.

"If single modules are addressed and 'tweaked' then these may well engender enthusiasm among the students but there is the likelihood that this could divert interest away from aspects of the programme that may have remained unchanged because they were considered crucial". (Richard Simons, Professor of Fluid Mechanics and Coastal Engineering, University College London)

Radical change can bring large scale benefits, such as coherence across programmes, opportunities for efficiency gains and good use of capital spend. Incremental change can mean a faster response to changing needs, keeping ahead of the game and taking advantage of opportunities as they arise ('managed serendipity'). These different types of change result in hugely different costs, levels of risk, timescales and staff development needs. The more radical the change, the harder it can be to bring staff along with that change. Both types of change depend heavily on the support of senior management.

⁷⁸ The research assessment exercise will be replaced by the Research Excellence Framework (REF) in 2013.

⁷⁹ Maillardet, F. 2007, "The German experience of Academe-Industry links", Engage Project, www.engsc.ac.uk/engage/

Examples of radical change include the introduction of new pedagogic approaches such as activity based learning, sponsored programmes or the adoption of educational frameworks such as CDIO, which aim to create an environment that motivates and engages students.

To enhance the student experience, 'active learning experiences' aligned to the CDIO philosophy, have been incorporated throughout all the undergraduate programmes in the Department of Engineering at the University of Liverpool: "We want our engineers when they graduate and they leave us to be industry ready. So they have hands-on learning, they take the theory from their classes and their laboratories and they make things and they test things." (quote from online video by Professor Ieuan Owen, Dean of Engineering)

Incremental change includes the development or enhancement of experience-led components such as large group projects, student led activities, visiting professors, innovative teaching facilities and industrial group projects.

The Chemical Engineering Department at Imperial College London run final year design projects with teams of ten students, emulating the working environment that graduates will experience in industry.

6.7. Learning spaces and technology

Space is an over-arching issue; enhanced teaching techniques often demand different learning and teaching spaces to the traditional lecture theatre and laboratory. Space issues can create logistical and financial issues that can be a real barrier to change: *resources matter*.

Space is an over-arching issue; enhanced teaching techniques often demand different learning and teaching spaces. Even relatively new, purpose-built buildings may not have learning spaces that are flexible enough to support project-based learning, for example. Both new build and refurbishment of existing space cause logistical and financial issues that can be real barriers to change.

Most of the case study universities have recently built new learning spaces or redesigned existing ones, informed by pedagogy and often to meet a need for increased group work which demands flexible, flat space for use by groups both formally and informally. The new spaces mimic the industrial environment, engage both students and academics, encourage active learning and enhance the student experience.



The University of Liverpool has undertaken a total refurbishment of the Department of Engineering at a cost of £36M, with renewed research laboratories and purpose-built flexible learning spaces such as 250-place active learning laboratories, meetings.

Coventry University are currently constructing a new engineering building specifically designed for activity led programmes at a cost of £60M. The new building will have laboratory/computer aided simulation space, classrooms, and student bookable spaces – all designed for group learning. The 'living' building will have strong environmental credentials and students will have online access to data from these features (solar heating, rainwater harvesting etc) for teaching purposes.

Secondly, the desire for more hands-on industrially relevant experiences drives the development towards highly specific internal or external spaces. Examples include:

- Hands on discipline-specific pilot plant
- The outdoor learning space of Constructionarium
- A new build which incorporates a 'live' experimental laboratory, offering real data and monitoring facilities.

In the second and third examples, the facilities are shared between universities and it is felt that this represents good practice that could be increased.

The Centre for Efficient and Renewable Energy in Buildings at LSBU is an experimental laboratory created within a new build, used for the teaching, research and demonstration of the low carbon energy technologies within the building. Use of technology and virtual learning enables the data to also be made available online.

New technologies for teaching-related purposes are often introduced at the same time as new/updated learning spaces, funded through similar means. A question arises about the lifespan of all of these spaces, especially spaces which are highly technology driven.

Two of the case studies reveal very recent or planned development of space that are directly linked to internal engineering education units.



The engineering education support unit at Loughborough, engCETL, has used capital funding associated with the CETL award to undertake a new build designed specifically for group design projects and self study. The space is equipped with appropriate technology and consists of a large design studio and four breakout rooms, plus office space and a foyer for informal group meetings.

6.8. Funding

Delivering more experience-led components in engineering degrees will require focused and prioritised funding both to set up and maintain. Even without such enhancements, engineering teaching in the six case study universities now operates with a shortfall: achieving *financial sustainability* is a significant challenge.

Cost of a sustainable engineering degree

A dedicated study was commissioned to establish the cost of a sustainable engineering degree. For the six universities covered by this study, the best available data on the costs of teaching engineering (from TRAC) shows that in most cases their costs incurred in 2008-09 are higher than the HEFCE unit of resource (grant plus variable fee) but that their surplus/deficit on a historic cost basis has improved since a comparable study was done for the Engineering Training Board in 2007. This improvement is owing to the introduction of variable student fees, with a progressive impact from 2006-07, and to the additional capital funding made available to universities in the middle of the decade.

However, historic costs tend to reflect the level of funding available to universities at the time rather than what they need to spend for sustainable operation. There is evidence from the six universities that, even when conservative adjustments are made for sustainability, all six are in deficit on a sustainable cost basis, with a mean shortfall of 15% across the sector. Other known threats to sustainability such as pension scheme deficits have not been included in this analysis.

The impact of these 'cost pressures' is seen, for example, in increased student:staff ratios and a resulting deterioration in the opportunities for individual tailored support to students – this area (feedback) is consistently rated poorly by students in the NSS. While most of these universities have made or planned major investments in buildings and capital

equipment with consequent benefits for engineering teaching, there are serious pressures on more routine expenditure on lower-level equipment, maintenance, non-academic staff (for example, technicians) and generally on non-pay budgets in academic departments. Exacerbated by the current economic climate, the impact of all these cost pressures is potentially damaging to the quality, relevance, reputation and sustainability of UK engineering education.

Exemplar costing

Introducing or enhancing experience-led components almost always incurs additional costs as shown in Table 5 and Table 6. Set up costs can be significant if they include capital costs and funding for these is usually found from external or university level sources. It should be noted that although recurrent costs of experience-led components vary considerably, all the exemplars demonstrate that industry or other sources are often willing to put money into supporting them. They also demonstrate the potential for greater efficiency through more imaginative and intensive use and sharing of facilities between universities, industry, colleges and public bodies.

Whilst the promise set out in *Higher Ambitions* of “enhanced support for the ‘STEM’ subjects” is welcomed, further consideration should be given to the funding mechanisms needed to encourage and enable the development of more experience-led degrees. If new funding cannot be made available, then, in the view of the Oversight Group, existing funding should be prioritised towards the further development and provision of experience-led degrees in a manner that is ring-fenced to encourage and support universities to move in this direction. An approach of this nature might result in a reduction in the total number of universities that can offer engineering degrees and an expansion of student numbers in those offering experience-led degrees.

Table 5: Set up costs of exemplars

University	Exemplar	Capital £M	Other £M	Total £M	Notes
Coventry University	1. Activity led learning	55.00	4.11	59.11	The capital cost will provide a new engineering building. Other costs include refurbishment of the Built Environment department and significant staff time to undertake this faculty wide pedagogical change to activity led learning, including international fact-finding visits and staff development.
Imperial College London	4. Chemical pilot plant	0.60		0.60	£0.6M is the cost for renewing the pilot plant. The total cost for completely renewing the pilot plant, control rooms, teaching and research areas is £8.5M. However, it should be noted that Imperial's location in central London is a significant factor in these costs.
	5. EnVision		0.34	0.34	EnVision started out as a project to support engineering education, primed by internal funding, but is now an established centre.
University of Liverpool	8. Active learning	18.30	0.50	18.80	The capital spend has provided new active learning labs and other teaching facilities. Other costs are mainly staff input over a five year development period including exploratory visits, plus some publicity costs.
	9. Visiting professors		0.02	0.02	Staff time to develop proposal, meet with interested parties etc.
London South Bank University	11. CEREB	2.97	0.05	3.02	The capital funds were raised from a number of sources including HEFCE and have resulted in CEREB having two other universities as partners. Other costs are mainly staffing costs to project manage the development.
Loughborough University	15. engCETL	1.65		1.65	engCETL was set up following an award from HEFCE. The capital money enabled provision of new teaching space comprising a design studio, four breakout rooms, informal meeting space and staff office.

Table 6: Recurrent costs of exemplars

Exemplar	Staff £k/yr	Space £k/yr	Other £k/yr	Total £k/yr	Cost per participating student £	Notes
Aston University						
1. Industrial placements	41		45	86	£2,150	Costs for 40 mechanical engineering placement students only, includes central service costs. Placement students obtain an average salary of £15k; industry pays a fee of £500/student not included.
Coventry University						
3. Activity led learning	2008	1450	1261	4719	£1,888	Costs are for UK-based students only and include central service costs plus depreciation costs of the new building. Other significant costs include the additional staff required for the new teaching approach and costs of materials.
Imperial College London						
4a. Constructionarium	18		40	58	£327	Used by civil engineering students. Total costs are net and show direct costs to the university only (staff and technician time, travel and accommodation, materials, equipment hire). Central services costs are included at a reduced value as activity is off-site. Income that offsets these costs includes ~£250 from students towards accommodation, ~£7,000 raised by students. An annual CPD budget saving of £1,800 for technician training is costed. The civil engineering contractor supplies staff, plant, equipment, materials and know-how, worth ~£20,000. The consultancy firm provides a design brief, worth ~£9,000. Constructionarium Ltd has raised £3.5million since 2003, worth ~£30,000 annual in-kind benefit (site, portacabins, staff on site etc).
4b. Chemical Engineering pilot plant	18	60		78	£648	Used by first and second year chemical engineering students. Costs include depreciation for the plant equipment but not the whole building, nor running costs or central service costs. They also include the cost of a process engineer for the plant.
5. EnVision	212		421	633	£211	Costs for FTE students and include central service costs. The centre runs with a core of academic and administrative staff plus consultants seconded from engineering departments. £244,000 is set aside annually to fund internal projects, awards and lectures. Industry provides £53,000 in-kind support for projects.
7. Student-led activities: El Salvador	1		1	1	£88	Cost to the university is time given to support, mentor and encourage the students who are going. Students pay £400 themselves and then raise the outstanding amount through sponsorship etc to cover the cost of materials, travel, food, accommodation etc.
University of Liverpool						
8. Active learning	360	425	815	1600	£1,600	Costs for FTE students and include central service costs plus depreciation costs of the new building and equipment. Other significant costs include the additional staff required for the new teaching approach plus direct costs of incorporating design-build activities.
9. Visiting professors	200		200	400	£400	Cost for FTE students of 10 visiting professors working two days/week including central service costs but not space costs. Funding can be gained for visiting professors from the RAEng. It is estimated that these 10 posts bring in-kind contributions (visitors etc) worth ~£50,000, this income is not included.

Exemplar	Staff £k/yr	Space £k/yr	Other £k/yr	Total £k/yr	Cost per participating student £	Notes
London South Bank University						
10. Understanding stakeholder needs	74		78	152	£210	Costs for FTE engineering systems students. Staff costs for involvement in or support of industrial liaison panels, foundation degrees, KTPs, work with professional bodies excluding accreditation. This work is assumed to benefit all students in the Department of Engineering Systems.
11. CEREB	316	65	366	747	£996	Costs for FTE students including direct costs to the university (staff, centre manager, technical support, publicity, materials, central services). The student number includes use by LSBU students and partner institutions. The cost/student could also be realistically reduced to ~£538, due to the facilities being used for income-generating activities as well as by students.
Loughborough University						
12. Industrial placements	190		380	570	£1,250	Costs for 456 placement students, including central service costs. Administration and visits to students on placements (two or three times/year) are a significant factor. Students obtain an average salary of £15,000 on placement and industry pays a fee of £500 per student which is not included in the costing.
13. Teaching Contract Scheme	23		27	50	£215	These are costs above the normal teaching costs for FTE students, including central services and are net of industry fees. Most of the costs relate to additional staffing and administration costs. Other significant costs include project materials, travel, hospitality and publicity. Industry pays a fee to join the scheme.
14. Sponsored degree programmes	47		48	95	£100-£300	The four different programmes all run with very different costing models. Costs given relate to the FTE students and are the impact of the sponsorship - not to the total costs of the degree programme and include the cost of central services but are net of income from industry. Additional costs relate to recruiting, visiting and retaining companies, student interaction, materials and administration. Industry input can include a payment per student (£400 in one dept), materials for projects, bursaries (~£1,500), salaries on placement (~£15,000).
15. engCETL				711	£237 per FTE student	Full costs, including senior academic and academic staff time, technician and other non-teaching staff plus premises charge. This is funded through the HEFCE CETL stream and internally by the university. Other income generated by externally sponsored project work, often not directly associated with students is excluded here. Many other students throughout the university use systems developed and supported by the engCETL so the cost per student could be considered slightly inflated.

6.9. Summary of research findings

The results of the analysis of the case studies are summarised in Figure 4. The main finding is that the case studies provide substantial evidence that experience-led engineering degrees help to meet the graduate recruitment needs of industry through providing attractive courses, relevant high quality curricula and student experience of industry. One very specific issue that needs to be addressed is the apparent decline in the number of placements available to students⁸⁰.



Figure 4: Findings from the case study analysis

The case studies mainly focus on the benefits to students and universities, but engagement with academia can also provide real benefits for industry⁸¹ which need to be disseminated more widely to encourage greater industrial involvement. A few examples from the case studies include:

- Placements acting as a cost effective recruitment tool for industry
- Employers of work-based students adopting technologies that their employees learn in the course of their studies
- Industry-sponsored prizes acting as a marketing tool for industry
- Professional development opportunities, particularly for junior engineers
- Industry-focused projects solving real problems for industry
- Universities helping industry to address skills shortages.

A significant barrier from the industrial perspective in engaging with academia is the cost involved (particularly staff time). It has been suggested that a scheme similar to the R&D Tax Credits⁸² could be possibly help alleviate this issue. A report on the feasibility of this idea is provided in Appendix 4.

⁸⁰ Higher Ambitions states that the number of students on sandwich courses has fallen by 4% since the middle of the last decade during a period when overall student numbers have increased by around 32%.

⁸¹ More examples can be found in the guide Involving industrialists in teaching, www.engcetl.ac.uk/iit/ produced by Loughborough University

⁸² www.hmrc.gov.uk/randd/. Note: the R&D Tax Credit system has been applied widely by other major countries in Europe

From the universities' perspective, establishing sustainable, effective working relationships between industry and academia is not without its problems. Developing a shared understanding is critical and requires overcoming differences in culture and language, taking time, effort and commitment⁸³. Communication needs to be two-way and not only do universities need to understand the priorities and drivers of industry, but industry needs to adapt to strategic and operational drivers of academia and have an appreciation of the needs of the new graduates that they recruit. It can be easier to establish engagement with large companies than smaller ones.

In particular, the exemplars highlight the benefits gained from innovative, sustained partnerships between universities and industry. These relationships not only result in some truly innovative experience-led components but also often formally embed the industrial interaction into the curriculum (for example, through sponsored programmes), which can help to sustain engagement and also provide industrial funding. Collaborative activities and facilities shared between universities or with industry make efficient use of resources. Good use of alumni and existing national schemes help the development of such partnerships **but both industry and the universities must commit to championing enhancements to experience-led engineering degrees.**

Universities' ability to change is heavily dependent on having the right **senior management support** and **developing teaching champions**, in particular, **staff with experience of industry**, who play a vital role in driving forward change within engineering degrees. Discipline-based support in learning and teaching that helps staff develop, deliver and share new methods of teaching is valued at both an institutional and national level. When universities share facilities and good practice, or collaborate on pedagogic research then more can be achieved.

The exemplar costing reveals that experience-led components are an additional cost. **Focused ring-fenced funding** could provide greater incentives for universities to make change including provision of **appropriate learning spaces, equipment and supporting technologies**. One size doesn't fit all however, and **universities must be able to take its own approach to developing and embedding experience-led components.**

Student-related issues that need to be overcome include those related to the introduction of student fees, the provision of effective student feedback and the unwillingness of students to take up available opportunities (including placements). More research needs to be carried out on how to help students understand the potential benefits of any optional activity at an early stage. Activities such as placements could be made compulsory, as is sometimes the case in business schools, but this wouldn't be without its difficulties, particularly in the current economic climate, and would not be appropriate in every university.

In conclusion, industrially relevant course content and opportunities for students to gain work experience should be integral within every undergraduate engineering course and therefore **more widespread adoption of experience-led engineering must be achieved.**

⁸³ Engage Project Report 2008, www.engsc.ac.uk/engage

7. Recommendations

Sustainable world-class experience-led HE engineering degree programmes which attract the best students are an essential element to meet the graduate recruitment needs of industry. To achieve this will require input from academia, industry, professional bodies and the government.

Eight key research findings have been identified from this study:

- One size doesn't fit all
- Experience counts
- Relevance motivates
- Change needs champions
- Responsibility must be shared
- Management leads change
- Resources matter
- Financial sustainability.

Three recommendations arise from these research findings. The RAEng and Higher Education Academy Engineering Subject Centre are committed to supporting industry, professional bodies, university engineering departments and government in implementing the recommendations and to disseminating the effective practice highlighted in this report.

Recommendation 1

Experience counts and relevance motivates. Experience-led components must be embedded into every engineering degree, using the effective practice outlined in these case studies as inspiration. Experience-led engineering degrees benefit students and industry alike, supporting economic recovery and future prosperity.

Outcomes	Mechanism	Actioned by
Leadership and commitment to deliver graduates with the required skills	Incorporate proposed changes into business plans including learning space design, equipment, technologies and finances	Universities
The right staff with the right vision and attitude	Provide discipline-based support for learning and teaching and reward for excellent teaching	
More staff with up-to-date experience of industry	Develop, support and encourage use of mechanisms that enable academics to gain insights into industry	University engineering departments
Enhancement of the student experience	Increase opportunities for academics and their students to gain experience of industry	Industry
Universities have the capacity to develop flexible approaches to experience-led degrees	Provide funding mechanisms that enable universities to use available funds more effectively and to focus on the delivery of experience-led engineering degree programmes	Government / the Funding Councils
Active dissemination of effective practice and professional support to implement change	Continue to fund the Higher Education Academy Engineering Subject Centre	
Wider adoption of experience-led engineering degrees by HE	Ensure that degree accreditation requires experience-led components	Professional bodies

Recommendation 2

Preferential ring-fenced investment in experience-led HE engineering is required to deliver the higher skills needed. Innovative mechanisms are needed to focus and prioritise the investment required, in the context of a difficult fiscal period and an existing shortfall in the funding of engineering degree programmes necessary for financial sustainability.

Outcomes	Mechanism	Actioned by
Greater efficiencies and students benefit from a wider experience	Require universities and industry to share knowledge, facilities and equipment	University engineering departments and industry
Less reliance on public funding	Increase income from a wider range of external sources	Universities
Industry takes a more active role in engineering education	Increase financial and in-kind support to universities and students, inspired by the exemplars	Industry
Removal of perceived obstacles related to the development of innovative mechanisms	Further research into how universities and industry can be best encouraged and supported to share knowledge, facilities and equipment – overcoming issues related to access, health and safety, staff resistance and other restrictions on use	Government / the Funding Councils
A focus on the provision of experience-led degrees	Targeted funding for experience-led engineering degree programmes that demonstrate industrial support and greater efficiency	

Recommendation 3

Significant time and energy should be directed towards building, enhancing and sustaining university/industry partnerships. Effective partnerships are a key feature of the most successful exemplars.

Outcomes	Mechanism	Actioned by
Innovative solutions that may involve multiple stakeholders, academic, industrial and professional	Develop effective partnerships and innovative approaches to sustaining relationships	University engineering departments, professional bodies and industry
More experience-led components and work opportunities that enhance the student experience	Increase engagement with industry, including use of alumni and existing national schemes where available	University engineering departments
More industrial input into degree programmes and more work opportunities for students (including high quality industry placements)	Increase engagement with universities, using staff at all levels as appropriate and existing national schemes where available	Industry
Increased industrial relevance within degree programmes	Utilise fiscal incentives for industry to get more involved with enhancing engineering education	Government
Greater interaction and collaboration between industry and academia	Exploit potential of both academic and industrial representation amongst membership through cross-profession working structures	Professional bodies

APPENDIX 1: Terms of reference and membership of the study

Terms of reference

Aim

The principal objective of the study is to identify the options for encouraging and enabling universities to develop engineering courses that better meet the needs of industry and to identify the opportunities, barriers and costs involved, thereby implementing Recommendation 7.17 of Lord Sainsbury's Review of Government's Science and Innovation Policies (*The Race to the Top*, October 2007).

Scope

1. To review current approaches to experience-led engineering degree courses.
2. To identify effective practice within current and developing experience-led engineering degrees that meet the needs of industry.
3. To make recommendations on how these outcomes can be implemented to enhance future engineering degrees.

Conduct of the project

The project will be directed by an Oversight Group which will provide strategic advice and input to the project, agree the Terms of Reference and the Work Plan and approve the final report. This will be executed by a Project Management Group which will undertake the day-to-day workings of the project and report back as agreed to the Oversight Group.

Membership of the Oversight Group

Chair – **Lord Browne of Madingley FREng FRS**: President - Royal Academy of Engineering (until November 2009⁸⁴)

Professor Sir William Wakeham FREng: (from November 2009) Chair of the Project Management Group, Vice President and Hon Secretary for International Activities of the RAEng, former Vice Chancellor of Southampton University

Professor Helen Atkinson FREng: Leicester University

Dr Stephen Axford: Department for Business, Innovation and Skills

John Baxter FREng: Director of Engineering - BP plc

Professor Barry Clarke: Engineering Professors' Council

Professor Ed Crawley FREng: Massachusetts Institute of Technology, USA

Professor Bob Cryan: Chairman – Engineering Accreditation Board

Professor John Dickens: Director - Engineering Subject Centre and engCETL, Loughborough University

Professor Peter Goodhew FREng: Liverpool University (Head UK CDIO Regional Centre)

Iain Gray FREng: Chief Executive - Technology Strategy Board, former Managing Director and General Manager, UK Airbus Ltd

Alun Griffiths: Executive HR Director - WS Atkins

Keith Herrmann: Deputy Chief Executive – Council for Industry and Higher Education

Professor Dame Julia Higgins DBE FREng FRS: Imperial College London

Dr Michael Howse OBE FREng: Consultant – Rolls-Royce plc

Professor Michael Kelly FREng FRS: Chief Scientific Adviser - DCLG

Professor Julia King CBE FREng: Vice Chancellor - Aston University (until November 2009⁸⁴)

Dr Tim Leverton FREng: Group Engineering Director - JCB

Professor Robert Mair CBE FREng FRS: Cambridge University

Professor Sa'ad Medhat: Chief Executive – New Engineering Foundation

⁸⁴ Lord Browne and Professor King were members of the Oversight Group during the data collection phases of the study but withdrew prior to the completion of this report following their appointment, as Chairman and member respectively, to the BIS Independent Review of Higher Education Funding and Student Finance.

Professor David Nethercot OBE FREng: Head of Civil and Environmental Engineering - Imperial College London

Richard Olver FREng: Chairman – BAE Systems

Vaughan Pomeroy: Lloyds Register

Andrew Ramsay: CEO – Engineering Council

Colin Smith FREng: Director of Engineering & Technology - Rolls-Royce plc

David Waboso FREng: Director of Engineering - London Underground

Professor John Wood CBE FREng: International Relations Advisor - Imperial College London

Membership of the Project Management Group

Chair - **Professor Sir William Wakeham FREng:** Vice President and Hon Secretary for International Activities of the RAEng, former Vice Chancellor of Southampton University

Carol Arlett: Assistant Director - Engineering Subject Centre

Professor Robert Berry: Executive Dean – Engineering and Applied Sciences, Aston University

Professor Rao Bhamidimarri: Executive Dean – London South Bank University

Professor Barry Clarke: Engineering Professors' Council

Dr Adam Crawford: Manager - engCETL, Loughborough University

Dr Richard Dales: Research Fellow - Engineering Subject Centre (seconded from Coventry University)

Professor John Dickens: Director - Engineering Subject Centre and engCETL, Loughborough University

Professor Richard Dodds FREng: Deputy Chairman of the Project Management Group, Chair - RAEng Visiting Professors' Management Group

Ian Dunn: Associate Dean of Engineering and Computing - Coventry University

Professor Peter Goodhew FREng: Liverpool University (Head UK CDIO Regional Centre)

Anne Grikitis: Science and Society Unit, Department for Business, Innovation and Skills

Martin Harris: Science and Society Unit, Department for Business, Innovation and Skills

Professor Paul Ivey: Dean of Engineering and Computing – Coventry University

Fiona Lamb: Project Director - Engineering Subject Centre (seconded from engCETL, Loughborough University)

Professor David Nethercot OBE FREng: Head of Civil and Environmental Engineering - Imperial College London

Professor Steve Rothberg: Dean of Engineering - Loughborough University

Richard Shearman: Director of Formation – Engineering Council

Secretariat

Dr Bob Ditchfield: Director of Education Affairs – RAEng

Beverley Parkin: Director Policy & Public Affairs - RAEng

Membership of the Study Team

Carol Arlett: Assistant Director - Engineering Subject Centre

Dr Richard Dales: Research Fellow - Engineering Subject Centre (seconded from Coventry University)

Dr Emma Hurdle: Project Officer - Engineering Subject Centre

Fiona Lamb: Project Director - Engineering Subject Centre (seconded from engCETL, Loughborough University)

with contributions from other Engineering Subject Centre staff and support from Iain Nixon of The KSA Partnership

APPENDIX 2: Participating universities

Case studies

Aston University	School of Engineering and Applied Science
Coventry University	Faculty of Engineering and Computing
Imperial College London	Faculty of Engineering
University of Liverpool	Department of Engineering
London South Bank University	Faculty of Engineering, Science and the Built Environment
Loughborough University	Faculty of Engineering

Mini case study

University College London	Department of Civil, Environmental and Geomatic Engineering
---------------------------	---

Symposium contributions

University of Birmingham	School of Mechanical Engineering
Coventry University	Faculty of Engineering and Computing
Cranfield University	School of Applied Sciences
University of Leeds	School of Mechanical Engineering
London South Bank University	Faculty of Engineering, Science and the Built Environment
Loughborough University	Faculty of Engineering
University of Queensland, Australia	School of Engineering
University of Southampton	School of Engineering Sciences
University of Ulster	School of Engineering
University College London	Department of Civil, Environmental and Geomatic Engineering

APPENDIX 3: Report on costing of engineering degrees

JM Consulting (JMC) LLP, November 2009

1. Introduction

- 1.1. We, J M Consulting (JMC) LLP, have been acting as an adviser to the Royal Academy of Engineering (RAE) on the costs of engineering education in connection with the Engineers for Enterprise study.
- 1.2. This report draws upon work carried out in 2009 by Nigel Brown Associates, using data provided by six case study universities used in the Engineers for Enterprise study (Aston, Coventry, Imperial College, Liverpool, London South Bank, Loughborough).
- 1.3. We have also drawn upon other relevant studies and reports, chiefly a study of the costs of engineering provision which we did in 2007 for the Engineering and Technology Board (ETB)⁸⁵, and the report on “The Sustainability of Teaching and Learning in English Higher Education” published in December 2008 by the Financial Sustainability Strategy Group (FSSG)⁸⁶.
- 1.4. The main focus of this short report is to draw upon the best available information and to make an assessment of the costs associated with this provision in terms of:
- 1.5. The baseline historic costs of engineering teaching, which can be derived using TRAC data (Transparent Approach to Costing);
- 1.6. The sustainable (long-run) costs of engineering teaching (which requires making some adjustments in areas where historic expenditure may be inadequate for sustainable provision).

2. Baseline costs and surplus/deficit

- 2.1. The J M Consulting study for the ETB (based on 2005-06 data) and Nigel Brown’s work (based on 2007-08 data) both analyse the baseline (historic) costs of teaching engineering to a HEFCE-fundable student, as recorded by TRAC (called Subject-FACTS)⁸⁷. (See reference for a brief description.)
- 2.2. As expected, both studies show that these costs vary significantly between universities and departments. The ETB study found a range of costs (in three universities) from £7,060 to £8,650. When these costs are compared with the public funding available in the relevant year (HEFCE grant plus tuition fees), all the institutions were recording financial deficits on their engineering provision. (Data from a fourth university was questionable: and it is worth noting that TRAC for Teaching was newly-introduced in 2005-06.)
- 2.3. The level of deficit observed in that study was in the range -15% to -40%, which suggested a significant issue about the levels of funding in relation to the costs of engineering provision.
- 2.4. Moving forward to the work done this year, we would expect to see an increase in both costs and income. The general level of indexation of university non-pay costs over the period 2005-06 to 2008-09 was 13%⁸⁸. In particular, there was a large increase in staff costs in universities over this period associated with the new pay framework (13%)⁸⁹ and pay modernisation reforms (8%)⁹⁰.
- 2.5. Since 2006-07, institutions have had the benefit of increased student fees (making a progressive contribution to income as each new cohort of engineering students start to pay fees). In 2008-09 the ‘top-up fee’ (variable fee less HEFCE’s assumed fee) comprised 22% of the total grant+fee income for eligible engineering students.
- 2.6. This significant increase in fee income was provided to make teaching provision more financially-viable. Some of the new income would have been spent on bursaries and improvements to the central university facilities and services for students, and some on the exceptional increases in staff pay.

⁸⁵ The costs of engineering degrees. Report for the Engineering and Technology Board and the Engineering Professors Council by J M Consulting. November 2007

⁸⁶ Report from the Financial Strategy and Sustainability Group issued in February 2009
www.hefce.ac.uk/finance/fundinghe/trac/fssg/FSSGreport.pdf

⁸⁷ A full description of TRAC is in the “Policy Overview” report distributed to all universities in 2009 and available at www.hefce.ac.uk/finance/fundinghe/trac/tdg/FSSGJuly2009.pdf

⁸⁸ HEPI July 2006-July 2008 non-pay expenditure 10%, plus 2.5% to the end of 2009

⁸⁹ 2006 Pay Agreement 2006-2008

⁹⁰ A review of the implementation of the Framework Agreement for the modernisation of pay structures in higher education. UCEA. September 2008. An addition of the median annual expenditure of surveyed institutions, for each of the first three years of implementation (to 2008/09)

- 2.7. There was also a significant increase in capital grants for teaching and learning over the middle of the decade, and we have added this in to the income figures. This adds something in the region of 1% to recurrent funding income⁹¹.
- 2.8. Due to both the increase in fee income and in capital funding, we would therefore expect to see some improvement in the position between 2005-06 and 2008-09.
- 2.9. Nigel Brown's data for 2007-08 shows a range of costs from £6,643 to £9,163. We updated Nigel's data to the latest academic year 2008-09, using national data reflecting the increases in the final years of the 2006 pay awards and the Framework Agreement, and reflecting indexation of non-pay costs. We also added in an estimate for each institution of bursary costs per student (which are not specific to engineering), and are now significantly higher in some institutions (funded through the new variable fees).
- 2.10. These adjustments give a revised and up-dated historic cost position for the six case study universities in 2008-09, of £7,383 to £10,257. When compared with the teaching unit of resource for engineering in 2008-09 of £8,715, the six institutions show a range of surplus/deficit positions from -17% to +15% (with two in surplus and four in deficit).

3. Interpreting the baseline costs

- 3.1. These figures would support a view that the financial position of engineering teaching has improved between 2007 and 2009. However, there is still reason for concern about the financial position.
- 3.2. A key factor is that universities seek to manage their finances prudently and to "live within their funding" so that in effect, a university's expenditure on any subject is limited by what it receives in its core HEFCE funding for teaching, even though there may be a need or a business case to spend more.
- 3.3. This picture is complicated, as spend on HEFCE-fundable students (represented by Subject-FACTS) is not only influenced by the notional grant+variable fee. Other equally important factors are:
- the resource allocation model (how much each department is given to spend out of the HEFCE block grant for Teaching);
 - the Research activity (income and expenditure, and potential deficit, in each department);
 - the volume of overseas students. This non-publicly funded activity generally contributes a surplus – so that a university with a large number of overseas engineering students will have more disposable income to spend on engineering teaching – benefiting all students – but will therefore show a larger deficit in TRAC. This means that overseas income is subsidising HEFCE-fundable teaching costs, and HEFCE income is covering a smaller part of total costs;
 - other income that the department may receive for example from endowments, and "Other" (the third TRAC primary activity) – e.g. income-generating activity such as consultancy;
 - the 4th year HEFCE-fundable students in engineering who, in 2008-09, are not yet paying the full variable fee.
- 3.4. These factors can all affect the level of spend on HEFCE-fundable Teaching, and therefore the costs represented by Subject-FACTS. Nevertheless, TRAC Subject-FACTS remain the best⁹², and the only consistently prepared, set of full cost figures in each subject area that are available. They are being used, for example, to inform the subject weights for HEFCE's Teaching Funding Method (and similarly in Scotland).
- 3.5. The fact that four institutions are recording deficits calculated on historical cost information is notable. Coupled with other information obtained in both the 2007 and 2009 studies there is a cause for concern about the sustainability of the provision at these levels of expenditure.
- 3.6. To understand this further, it is necessary to go beyond TRAC and Subject-FACTS, which are based on institutions' historical costs and do not show all the costs they should be spending for a long-term sustainable Teaching to the required levels of quality. This is discussed in the next section.

⁹¹ We took the aggregate of five years of capital grants – which each year amounted to some £500 per student – and amortised this over 40 years which is a normal depreciation lifetime for university capital assets. This calculation led to an estimate of the release of capital grant in 2008/09 (to match against the depreciation on the capital expenditure also shown in the accounts for that year) of less than £100 per student or 1% of the recurrent grant.

⁹² It is of note that five of the six institutions in this study stated to HEFCE that their Subject-FACTS figures were robust (in TRAC terms) at the level of academic department, even though this is going further than the minimum required to calculate and report Subject-FACTS.

4. Sustainable costs

- 4.1. Both studies found that the perception of many of those working in these engineering departments is that resources are very stretched, often to the point that sustainability and future quality of provision may be threatened. In many cases, the departments had been forced to make significant changes as a result of resource pressures.
- 4.2. There is an apparent paradox in that most of these university engineering departments are in deficit, but they are not under threat of closure. The reason is that these universities are doing a variety of things to manage the situation. These include: restructuring and rationalising provision; larger teaching group sizes; reducing the amount of practical hands-on experience with large equipment; making greater use of desk-top and IT laboratory experiences; rationalisation of estates; more intensive use of resources; and relying increasingly on growth in student numbers, and on subsidy from overseas students fees, and legacy income to balance their budgets.
- 4.3. It should of course be noted that these latter income growth strategies (additional home and overseas students) are no longer so available.
- 4.4. The FSSG report referenced in the introduction, above, identified a number of areas where the student learning experience is under pressure across most disciplines. These pressures are due to increased costs and demands (e.g. the increased complexity of the curriculum and assessment; the greater expectations of students and employers; external QA and accreditation regimes; demands of market competitiveness) at a time when levels of public funding fell significantly in real terms over the whole of the 1990s, and have only recovered slowly in the past few years. This report identified areas of particular pressure on resources and the “coping strategies” that universities are using to maintain the student experience.
- 4.5. Some of the coping strategies used in the six engineering departments studied in 2009 may be efficient and effective (such as innovations in teaching styles that reduce the demand for staff time, greater self-directed learning and greater use of IT and simulations). However, some of these strategies will eventually affect the quality of the student experience and hence the competitiveness of UK engineering education, and therefore can be said to be not sustainable in the long-term.
- 4.6. For example, it is a negative factor if (due to raised SSRs) students have less access to the time of permanent academic staff who are leading experts in their field, or if (due to reduced non-pay budgets) they are not able to experience working with “industry standard” facilities and equipment, or if opportunities for work-experience are curtailed.
- 4.7. There is strong evidence that SSRs have deteriorated over the past 15 years (although these are difficult to quote robustly over a period and between institutions). Over this period, academic staff have also seen a growth in the time spent on various accountability and regulatory requirements, quality assurance, and administration. These factors impinge directly on the quality and sustainability of the student learning experience as demonstrated by evidence from the NSS where students consistently give poor ratings to the quality and timeliness of feedback and accessibility of academic staff which is at the heart of the distinctive UK higher education experience. (Discussed in more detail in the FSSG report.)

5. The sustainable costs of engineering teaching

- 5.1. The factors discussed above can be said to represent a “hidden cost” of the provision, which is not reported in accounts or in TRAC because they are really a “shortfall in necessary expenditure”, rather than an actual cost incurred. In this section we make an assessment of the level of resource that would be needed for a sustainable provision. This is not a costing question and cannot be determined in such an objective or auditable manner as historic costs can, but this does not reduce the importance for policy of reaching a reasonably evidence-based view on the level of resource required for sustainable engineering provision.
- 5.2. It should be noted that TRAC already includes a Return for Financing and Investment (RFI), which is a proxy for some of the costs not in the historic expenditure accounts, but this does not cover all the factors which were identified at the six case study universities. We have therefore made judgements in each case about the appropriate level of additional shortfall to be added, drawing on the data provided to Nigel Brown by the case study universities.
- 5.3. The areas of “sustainability deficit” where we have adjusted costs (and the relative scale of adjustments) were different in each institution, but the areas where we found it necessary to make cost adjustments to reflect unsustainable pressure on resources or current shortfalls in expenditure were as follows:

- **Academic staff costs:** the pressure on SSRs has already been noted and it was a common theme in most universities that there were severe pressures on academic staff (despite increased efficiency, larger class sizes, and greater use of teaching assistants and of other less-experienced staff). We made adjustments to cover issues including: staff vacancies, recently appointed posts not yet in TRAC, additional staff needed to deliver the curriculum and to ensure retention of students;
- **Other staff costs:** most of the universities had deficiencies in technician support, and/or problems about adequate numbers of other support staff and we made adjustments in this area.
- Adjustments for **non-pay costs** were also commonly required, reflecting inadequate resourcing of industrial liaison, routine equipment replacement, materials, student work experience. By contrast, major equipment purchases were adequately covered, either as part of building replacement or refurbishment, or from the new student fee income.
- **Estates costs.** five of the six case study universities had benefited from either very recent or currently planned major new building or refurbishment projects which would lead to major improvements in the quality and fitness for purpose of the space and facilities for teaching engineering. However, these costs were not all in TRAC (some too recent), and moreover, the initial capital cost of such improvements is only a part of the long-term sustainable costs which include the costs of maintaining and servicing such new assets, including the need for periodic refurbishment and reconfiguration to meet the needs of the changing curriculum and student expectations.

5.4. We made estimates of additional costs in all these areas, where appropriate. These were necessarily at a higher level, and therefore 'less robust' than the Subject-FACTS calculated through TRAC. We only included additional sustainability adjustments which we considered were not reasonably already covered by the RFI (we are involved in the review of the role and future of the RFI, currently being undertaken by the TRAC Development Group).

5.5. Throughout this process, we have chosen to err on the conservative side in making adjustments. For example, we have made no adjustment for pensions despite the fact that the sector's pension spend is now increasing above 2008/09 levels, and that many institutions are experiencing a further increase in staff costs arising from the Framework Agreement.

5.6. The adjusted level of sustainable costs of engineering at the six case study universities in 2008-09 range from £9,224 to £10,926. When compared with the grant+fee for 2008-09 (£8,715), all six universities are in deficit against these sustainable costs. The range of levels of deficit as a percentage of income is from -6% to -25%, with a mean of around -15%.

5.7. We believe this is a significant finding in relation to the financial sustainability challenge facing engineering departments in the current resourcing environment. It confirms that, even in the best-resourced universities, there are serious pressures on resources which are beginning to impact on the student experience (for example, by reduced time for feedback and contact with academic staff), and which also threaten investment for future quality and sustainability of the provision.

5.8. These findings are of greater concern because the methodology we have had to use probably leads to an understatement of the appropriate level of sustainability adjustment, and changes and pressures that are already in the system make it clear that the position will worsen rather than improve in the near future.

APPENDIX 4: Report on the suitability of an “R&D Tax Credit” style scheme to incentivise industry to increase involvement with teaching

Summary⁹³ of a report by David North ACA, Harrison North⁹⁴
17 August 2009

Brief outline of the current R&D tax credit scheme

The current R&D tax credit scheme (www.hmrc.gov.uk/randd/) seeks to incentivise companies to increase expenditure on areas which achieve an advance in science or technology. The value of the tax credit for small and medium sized companies is £24.50 for every £100 of qualifying expenditure. Preparing a claim for the R&D scheme does require specific work to be undertaken but the burden upon the company is small, particularly when considered in light of the potential rewards. One of the greatest barriers to the R&D scheme has been in informing qualifying companies of the criteria for a claim.

How this could be applied to a new scheme for teaching

The scheme could in theory be extended to cover any other area, simply by altering the definition of qualifying expenditure. There has been a precedent set for this already – the Vaccines Research Relief (VRR). Critically, the VRR scheme can be combined with R&D tax credits in areas which qualify for both. This would be essential for any new scheme.

Types of qualifying expenditure

Suggestions for types of qualifying expenditure include:

- Payroll expenditure on placement students.
- Staff time spent on university-related activities such as mentoring students, attending industrial liaison boards, lecturing or providing student projects.
- Donation of equipment.

Benefits of the scheme

The scheme could be expected to be highly effective at motivating industry to assist in those areas where the activity is seen to be mutually beneficial, for example industrial placements. Industry would benefit from the assistance of another member of staff employed at a reduced cost and potentially lower recruitment costs in the future. This might reduce current barriers where the cost is deemed too high.

For activities which offer less immediately obvious benefits to industry, such as activities which require staff time to be given (for example attending industrial liaison boards or student mentoring), then such a scheme could be exceedingly effective as the incentive offered would be directly proportional to the time provided.

Many engineering companies will already be familiar with the R&D scheme and the prospect of claiming under a similar scheme would likely be far less daunting. The strict requirements and frequent inspections, both characteristics of the R&D scheme, would persist and prevent the scheme from being open to abuse.

⁹³ Full report available from www.engsci.ac.uk/graduates-for-industry

⁹⁴ Harrison North (www.harrisonnorth.co.uk) is a firm of London based accountants established in 1994. With six years experience of compiling and submitting R&D tax claims, Harrison North has built up a reputation as one of the country's most accomplished firms operating in this area.

The Engineering Subject Centre

The Engineering Subject Centre is one of the 24 subject centres that form the subject network of the Higher Education Academy. As the national centre for all engineering academics in the UK, we deliver subject based support to promote quality learning and teaching.

Our mission is to work in partnership with the UK engineering community to provide the best possible higher education learning experience for all students and contribute to the long term health of the engineering profession.

This is achieved through our strategic aims:

- Sharing effective practice
- Facilitating departmental change
- Informing and influencing policy
- Promoting engineering education research
- Championing teaching.

The Royal Academy of Engineering

As Britain's national academy for engineering, we bring together the country's most eminent engineers from all disciplines to promote excellence in the science, art and practice of engineering. Our strategic priorities are to enhance the UK's engineering capabilities, to celebrate excellence and inspire the next generation, and to lead debate by guiding informed thinking and influencing public policy.



The Royal Academy of Engineering promotes excellence in the science, art and practice of engineering.

Registered charity number 293074

The Royal Academy of Engineering
3 Carlton House Terrace, London SW1Y 5DG

Tel: 020 7766 0600

Fax: 020 7930 1549

www.raeng.org.uk

APPENDIX 6: Report on the Suitability of an "R&D Tax Credit" Style Scheme

David North ACA, Harrison North¹, 17 August 2009

This report sets out my opinion on the feasibility of a scheme similar to the R&D Tax Credit scheme (www.hmrc.gov.uk/randd/) in meeting the objective of enhancing undergraduate engineering education. I also offer any further recommendations beyond this scheme which might be suited to these objectives.

How the Scheme Could be Structured to Maximise its Effect

Brief Outline of Current R&D Tax Credit Scheme

The current R&D tax scheme seeks to incentivise companies to increase expenditure on areas which achieve an advance in science or technology. For companies which are loss-making, a repayable tax credit is receivable, whilst for companies which are in a tax-paying situation a corresponding credit is applied against the tax liability. Once all the calculations have been applied, the value of the tax credit for small and medium sized companies is £24.50 for every £100 of qualifying expenditure. Preparing a claim for the R&D scheme does require specific work to be undertaken but the burden upon the company is small particularly when considered in light of the potential rewards.

Surprisingly one of the greatest barriers to the R&D scheme has been in informing qualifying companies of the criteria for a claim. There are many instances of companies who would qualify for this tax incentive but are unaware of their suitability.

How This Could Be Applied to a New Scheme

The incentive under the R&D scheme is generated via enhancing tax relief on expenditure. It could therefore in theory be extended to cover any other area, simply by altering the definition of qualifying expenditure. This would be done under a new scheme and there has been a precedent set for this already – the Vaccines Research Relief (VRR). This tax relief is almost identical to the R&D tax relief credit except in the type of qualifying expenditure. Expenditure does not have to be on areas which achieve an advance in science or technology (and therefore subject to the detailed requirements of R&D credits) but instead needs to be on the research and development into vaccine and medicines for the prevention and treatment of certain diseases. Before August 2008, contributions made to a charity, university or scientific research organisation would also qualify.

¹ Harrison North (www.harrisonnorth.co.uk) is a firm of London based accountants established in 1994. With six years experience of compiling and submitting R&D tax claims, Harrison North has built up a reputation as one of the country's most accomplished firms operating in this area.

Critically, the VRR scheme can be combined with R&D tax credits in areas which qualify for both. Any new scheme would be disadvantaged if it failed to offer this as companies would have a disincentive to integrate with universities in projects which currently qualify for R&D. Permitting the two schemes to be combined would have the benefit of encouraging companies to integrate the university with their most cutting-edge projects.

Types of Qualifying Expenditure

Determining what expenditure would qualify is of importance as many past schemes have resulted in companies "playing the system". It is always worth questioning whether in providing an incentive for expenditure in one area, whether a disincentive is being created elsewhere and what negative effect this could have.

In August 2009, I was made aware of a client of my firm who currently employ a seconded member of staff, already with the assistance of a government grant, but are unable to afford the cost of employing a second, despite a desire to. Payroll expenditure on secondment students would be necessary for inclusion in the scheme, presumably subject to an upper salary limit.

The commitment of staff time to mentoring students, attending Advisory Boards, teaching in lecture rooms or providing student projects, is one of the key issues that needs sufficient incentive to occur. From personal experience, companies which would be seen as desirable for cooperation with universities are very streamlined and have very little scope for activities beyond their core operation. This may not be the case in much larger organisations with much larger workforces. It is likely to remain one of the hardest challenges of the Engineers for Enterprise Study – how to incentivise companies to commit staff time. It therefore would be vitally important for companies to be able to claim for the time proportion of staff salary spent on university-related activities as a qualifying activity, in just the same way as they do for R&D activities.

One area where a new scheme could consider providing incentive concerns the donation of equipment. Where companies have machinery which would be welcomed by the Engineering department of a university, the scheme could, as one suggestion, consider the depreciated value of that machinery to meet the criteria of qualifying expenditure.

What Objectives Could the Scheme be Capable of Achieving

The scheme could be expected to be highly effective at motivating industry to assist in those areas where the activity is seen to be mutually beneficial and at no extra cost to the company. This would include activities such as industrial placements and staff secondments. Industry will benefit from the assistance of another member of staff employed at a reduced cost and potentially lower recruitment costs in the future as students are given more permanent placements upon finishing their degree. Currently barriers do exist which restrict the cooperation between

universities and industry in this area due to the costs being deemed too high.

Quite separately, there are those activities which will offer little immediate benefit to industry and for which the company would be correspondingly compensated. This would be activities which require staff time to be given, for example in providing student mentoring, attending advisory boards or creating student projects. A scheme such as that proposed could be expected to be far more effective in this area than previous attempts to incentivise companies. As opposed to grants, the incentive offered would be directly proportional to the time provided. Many engineering companies will already be familiar with the R&D scheme and the prospect of claiming under a similar scheme would likely be far less daunting. The strict requirements and frequent inspections, both characteristics of the R&D scheme, would persist and prevent the scheme from being open to abuse. For these reasons it is possible that such a scheme could be capable of achieving the greatest challenge – of motivating companies to commit valuable staff time to working alongside university students.