

VISITING PROFESSORS IN PRINCIPLES OF ENGINEERING DESIGN

Churchill College Workshop, 14th September 1999

Review of Proceedings

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Section 1: Overview

The key objectives of this workshop were:

- To review the first ten years of the Visiting Professor scheme with particular regard to promoting good practice and to identifying problem areas.
 - A review of the work of the scheme was prepared and given to the workshop by Dr. David Lindley OBE FREng, and is reported in Section 3
 - This report repeated the importance of interdisciplinary work, and made some radical proposals in teaching methods, such as the adoption of studio work.
 - The report reiterated the need for further reviews of the role of the professional engineering institutions in furthering and accrediting innovative teaching methods, including making full use of industrial professors and tutors.
- To bring together a wide cross-section of visiting professors and academics to promote networking and exchange of good practice.
 - Some 120 senior academic and industrial representatives attended, showing a high level of involvement and contribution to the development of design teaching to the undergraduate student.
 - Lively discussions during the presentation of the keynote papers and in the discussion sessions, and in the final plenary session demonstrated the concerns, interests and contributions of both academics and industrialists.
- To review possible options for introducing more “systems thinking” into undergraduate engineering courses.
 - The address by Professor Ken Hambleton FREng, on Systems Integration, is reviewed in Section 4
 - There is a clear need for systems thinking at all stages in engineering courses.
 - It should be emphasised that this was a pervasive methodology, and not a separate discipline – to be developed both at the undergraduate and post-graduate level.
 - Good case studies were particularly valuable in demonstrating the application and value of systems methodology in engineering practice.
- To review the issues related to Sustainable Development that have relevance to the content and style of delivery of undergraduate engineering courses.
 - The key note address by Dr. David Fisk CB FREng, is reviewed in Section 5
 - The latest developments in using a series of ‘indicators’ helped to establish the range of important issues to be considered by the engineering professions
 - Sustainability should be a pervasive factor in all areas of the MEng course subjects
 - The lack of quantifiable evidence in Sustainability courses does not imply a lack of rigour in the subject
 - Concern for sustainable issues can improve economic performance.
 - Contemporary supportive attitudes among young people for sustainability should be recognised and suitable restructuring of courses should be made.

Section 2: Opening Session

After a welcome on behalf of The Royal Academy of Engineering from Sir David Davies CBE FREng, the workshop began with a keynote lecture by **Dr James Armstrong OBE FREng** on Principles of Engineering Design. This was previously distributed to all delegates, and the full text can be viewed on The Academy's web site. He made the following key points:

- The teaching of design should have an integral place in the formation of all engineers.
- There are principles of design common to all branches of engineering, and these should inform and underlie the means by which design is introduced to students.
- The three key principles of engineering design are:
 - All design begins with a clearly defined need.
 - All designs arise from a creative response to a need.
 - All designs result in a system, product or project, which meets the need.
- Design principles are best illustrated by example. Five examples were presented which illustrate something of the range of engineering:
 - An intelligent prosthesis (Blatchford & Sons)
 - The Tsing Ma Bridge (Mott Macdonald)
 - An asthma inhaler (Norton Healthcare)
 - Psion 'organiser' - personal digital assistant
 - Rolls-Royce Trent aeroengine.
- RAEng Visiting Professors play a vital role in bringing design thinking and case studies into the university environment.

At the Dinner following the introductory session, **David Brown FREng**, chairman of Motorola UK gave a talk entitled "Which Came First – The Customer or the Engineer?" This has been published in full in The Academy's journal *Ingenia*, and can also be accessed on The Academy's web site.

Section 3: First keynote address

The first keynote address of the workshop, given by **Dr David Lindley OBE FREng**, was entitled:

Good Practice in Teaching of Engineering Design (with Industrial Support)

The slides for this presentation are in Appendix 2. The following key points were made:

- Since 1989 the RAEng has supported some 140 Visiting Professors in 44 UK universities.
- During this time a number of lessons have been learnt and some characteristics of good practice have been identified:
 - VPs should be of high regard in their field and be fully supported by their firms to ensure sufficient time is devoted to the work.
 - VPs can stimulate staff and students alike through their active engagement in promoting and encouraging design-based project work.
 - VPs are most effective when they are active in a strategic capacity rather than day-to-day teaching.
 - VPs, especially when established in a local university, can promote university / industrial relationships and networks which go far beyond teaching and can lead to close collaboration on research, development and live projects. This can be a valuable catalyst for helping students to find good employers.
- Several universities have demonstrated the benefits of having several VPs in different departments, working together to promote engineering design and collaboration between departments.

Discussion

Following the keynote address, the delegates split into Syndicate Groups to discuss six issues. The proceedings and conclusions of these discussions were summarised and presented as follows by rapporteur Dr Graham Green.

A. How best can VPs / industrial lecturers present their design and decision making experience to motivate, enthuse and excite students and staff – and to stress the fundamental importance of creativity and design life, and the key role that all engineers have?

- By promoting a thinking process.
- Starting early in the undergraduate course.
- Using projects and working in small-group tutorials.
- Encouraging regular presentations by students.
- Tackling real problems (perhaps, even in real time).
- Integrate the views of more than one VP.
- Involve students in defining the need (developing the brief).
- Design is a life skill.
- Design provides an output for knowledge input.
- Undertake teaching within a clear strategy.
- The context of the problem must come through.

B. Should 'training' be provided to VPs in communicating with students?

- This has a low priority. It was felt that people of the calibre to be selected as a VP would be sufficiently competent in communication skills.
- Most important is to help VPs gain a better understanding of students' capabilities.
- One means of achieving this would be to help VPs know and understand students' qualifications from schools (e.g. CDT - Craft, Design and Technology at GCSE and A-level).
- It is important to give VPs a good introduction to, and understanding of their new (University) environment.
- It was widely agreed that VPs should not be used for core teaching.
- Use VPs to encourage / nurture young staff.

C. Is there a need for radical reforms in both curriculum and teaching methods? (could engineering teaching benefit from studio-based methods similar to those of architectural schools?)

- It was widely agreed that radical reform is required.
- The education process should aim to enable learning rather than to teach.
- Studios and studio teaching would be desirable, but would place a large burden on scarce resources.
- Would depend on the nature of the studio-based team.
- Design should permeate the entire course.
- More emphasis on integration of design with manufacturing issues.
- A hybrid design studio / problem-centred approach might be more desirable.
- It might be practical to develop such approaches during an additional year beyond an MEng.
- It is important to maintain a balance between analytical and creative components of courses.
- It is important to encourage communication between students.

D. Can the extent of inter-disciplinary teaching or project work be increased to include interests of architects, surveyors, planners, economists, lawyers (etc.) as well as complementary engineering skills?

- There is a need to appreciate and work with other disciplines.
- A year working in industry should be part of the course.
- A diverse range of courses is needed to meet the diverse needs of industry.
- The pressure to train rather than educate should be resisted.
- A case-study approach is (generally) better.
- Interdisciplinary skills are not available within departments.
- Interdisciplinary work can be increased and would be beneficial.

E. What role can design competitions play in stimulating enthusiasm and motivating students and staff?

- The most critical issues were being able to match the time-scales and deadlines of a competition with those of highly structured courses.
- Internal competitions (against other individuals or teams in the same university/department) can be strongly motivating. External competitions are less motivating (being more remote).
- The Society of Automobile Engineers (SAE) competition was seen to be good.
- Some felt that preparing entries for competitions was time-consuming for students and resource-intensive for departments. It was important that the reward for winning a competition was commensurate with the effort put in to it.
- It is imperative to encourage creativity in competitions (and avoid formulaic and textbook solutions).

F. What support could be provided by the Professional Engineering Institutions (PEI) in 'enabling' better collaborating with industry so that projects are real and to the 'benefit' of industry, students, staff and the University?

- They could provide access to industry-wide networks
- Some PEIs provide financial support for educational initiatives.
- It was felt that PEIs must change and modernise, but there was no agreement as to how.

Section 4: Second keynote address

The second keynote address of the workshop, given by **Professor Ken Hambleton FREng**, University College London, was entitled:

Systems Integration – the Challenges for Higher Education

The slides for this presentation are in Appendix 3. The following key points were made:

- The classic definition of system thinking (von Bertalanffy) is:
“A certain objective is given; to find ways and means for its realisation requires the system specialist (or team of specialists) to consider alternative solutions and to choose those offering optimisation at maximum efficiency and minimum cost in a tremendously complex network of interactions.”
- A systems approach to projects can be illustrated using the Boehm ‘waterfall diagram’ (slide 4), linking user requirements through performance specification, systems design to detail design, manufacture integration and acceptance by the user.
- The systems approach can also be illustrated using the ‘V-diagram’ (slide 5), which shows the initial divergence or partitioning of activities, followed by convergence or integration of the parts into a whole which delivers the users requirements.
- A system is characterised by a *purpose*, a system *boundary*, a *structure* within the boundary and a *synergy* by which the whole is greater than the sum of its parts.
- One man’s sub-system is another man’s system and, hence, they will have different perspectives and priorities.
- A systems engineering approach has been demonstrated to be fundamental to the successful delivery of complex engineering products, especially in aerospace, defence and automotive industries.
- The delivery of systems engineering courses has been particularly successful at post-graduate level, both as full time MScs and short courses. Generally speaking it is not the theme of specialist undergraduate courses, although several do include the phrase in course descriptions.

Discussion

Following the keynote address, the delegates split into Syndicate Groups to discuss six issues. The proceedings and conclusions of these discussions were summarised and presented as follows by rapporteur Dr Rod Edwards.

Each discussion group raised the same general issues:

- It was questioned whether systems integration was genuinely a new discipline. Many suspected it might be a case of ‘badge engineering’.
- Everyone agreed there is a need for systems engineering thinking in engineering curricula.
- However, most delegates questioned whether it was needed as a separate discipline. Some felt it was more appropriate to the needs of large firms engaged on complex projects.

- Many felt the case for a separate discipline came more from supplier (academic) push rather than consumer (industry) demand.

A. *When should systems engineering be taught during the formation of engineers?*

- It was agreed that systems engineering thinking should start early and be established as a core value, and an integral part of all good engineering practice.
- There was some agreement that during years 1 and 2 of an MEng the language and tools of systems engineering, and its scope (boundaries) could be introduced. These could be developed and put to use during years 3 and 4.

B. *What should be taught about systems engineering?*

- Its role in embracing the whole life cycle of a project such as the design and delivery of large and complex products, including the recycling of their component elements and materials.
- The ‘waterfall chart’ and the ‘V-chart’ are essential to introduce the subject. The bottom of the V-chart is more important at MEng level; the top tends to become more relevant later on.
- It is important to incorporate the organisation of the whole delivery chain and consider the three key elements: people, function and physical issues.
- It is especially important to address the client or user, especially end-user reliability.

C. *How should systems engineering be taught?*

- It must be introduced as an integral part of other subjects and modules. It should *not* be introduced as a discreet, stand-alone module.
- Good case studies should form a key role in its delivery. These should include full product life-cycle analysis.
- A specialist course would be valuable at post-graduate level.

D. *Who should teach systems engineering?*

- It is essential it be presented by practitioners not theoreticians.
- As an approach to engineering, systems engineering and integration should be pervasive throughout all courses delivered by all lecturers.

E. *How should the accreditation of systems engineering teaching be addressed?*

- The accreditation of engineering degrees by the PEIs is essential if students are to progress to membership and professional status. It was felt, therefore, that the universities and existing PEIs would satisfactorily address accreditation issues.
- All PEIs should be encouraged to include clear mention of Systems Engineering in their curricula guidance.

F. *How should systems engineering learning be topped up after formal education?*

- In the same manner as all other engineering disciplines, via short courses, in-house training and self-study.

Section 5: Third keynote address

The third keynote address of the workshop, given by **Dr David Fisk CB FREng**, Chief Scientist, Department of the Environment, Transport and the Regions, was entitled:

The Sustainable Development Indicators: Setting the Agenda for Industry and Education

The following key points were made:

- The DETR has had far greater success in discussing and achieving consensus about what is meant by *sustainable development* by focusing on indicators rather than attempting to find a single, acceptable definition.
- The UK government uses 14 indicators grouped under five headings:
 - *Economy*:
GDP; investment as a percentage of GDP
 - *Life*:
life expectancy; percentage of 19-year olds with 5 or more GCSEs; percentage of people of working age in employment;
 - *Local*:
proportion of housing unfit for occupancy; air pollution; crime;
 - *Resources*:
proportion of houses built on brownfield sites; vehicle miles travelled; waste production/disposal;
 - *Wider environment*:
bird species / numbers; river quality; CO₂ produced.
- The roles of both engineers and Western governments will be vital, but may be dominated by larger forces. Some figures are simply staggering:
 - The wealth of the richest 200 people in the world exceeds that of the poorest 200 million;
 - Populations in the new democracies will soon vastly outnumber the old democracies;
 - Monsanto's research budget of £1.26 billion p/a exceeds that of the whole UK government funding of research;
 - Tesco's investment exceeds the value of the entire Russian stock market.
 - The UK agricultural and rural economy is likely to be influenced more by land prices in Poland (for example) than by the UK government.
- If the world as a whole is to approach the ideals of sustainable development, the future will have to be different from the past – we will need to go back to a Victorian vision of problems and opportunities, but do so on the world stage.

Discussion

Following the keynote address, the delegates split into Syndicate Groups to discuss six issues. The proceedings and conclusions of these discussions were summarised and presented as follows by rapporteur Dr Richard Darton.

The feedback was prefaced with a reminder of the Brundtland definition of sustainable development and that the richest 20% of the world's 6 billion population account for 83% of wealth, while the poorest 20% own just 1.2% of its wealth. It is clear that the whole world cannot live at the same standard as the 200 million population of the USA.

- A. *How can the issues of Sustainable Development (SD) be incorporated into the mainstream engineering undergraduate syllabus***
- It should be an essential part of all MEng degrees.
 - There must be a pervasive awareness of sustainability throughout all parts of the curriculum.
 - As in other fields, principles should be introduced first, followed by applications.
- B. *Is the inclusion of Sustainable Development, as a main stream topic in the undergraduate syllabus, commensurate with maintaining and developing academic rigour in engineering development?***
- It was questioned whether SD is, or should be, a ‘main stream’ topic. The majority felt it was not (in an engineering degree).
 - The academic rigour depends on the approach used in the teaching. Because it was less easy to quantify some of the issues, this did not imply that Sustainable Development was a non-rigorous or ‘soft’ option.
- C. *Is the UK industry receptive to graduates with interest in, and knowledge of, Sustainable Development?***
- On the whole, yes, though some scepticism was likely to be encountered.
 - It was noted that the issue was not only a UK issue.
 - It was felt that firms would need to become more aware of the new knowledge (esp. of SD) that their new graduates bring with them.
- D. *What are the benefits to UK industry of graduates with an understanding of the issues relating to sustainable development?***
- There are clearly major economic benefits to be gained if waste can be turned into wealth.
 - A growing number of industries see SD as important to their commercial success.
- E. *Would the association of engineering with Sustainable Development have any impact on the quantity, quality and interests of applicants to engineering courses?***
- There was no consensus on this question.
 - It was felt likely to depend a lot on the awareness of the public and the awareness instilled in school pupils.
 - One group (comprising 100% men) felt that the association of engineering with SD would appeal to female students, however, the rest of the groups did not share this.
- F. *Is the high profile of Sustainable Development just a passing fad in educational and government circles? Would schooling in it best be left to life experience rather than the formal education phase of formation?***
- It was not agreed that SD is a fad outside certain parts of the Government and in a few sectors of the population.
 - It was agreed that this situation would change as more legislation related to SD was introduced.

Section 6: Plenary Discussion

Following the three keynote addresses, delegates conducted a plenary discussion under the chairmanship of **Dr John Forrest FREng**. A report of this discussion is given in Appendix 1. The following is a summary of the key points raised, which might lead to actions:

- The syllabuses, methods, and structure of engineering courses need to be given a radical shake-up:
 - They should focus on design throughout
 - They should make more use of new teaching technologies (e.g. CD-ROMs)
 - The learning environment should be more project-based
 - A systems-engineering approach should be introduced throughout courses
 - Broader and 'softer' (non-quantitative) issues must be introduced throughout the courses.
- It was felt the RAEng should use its influence to change recent changes in universities' value systems which reward (mainly) more bums on seats, and more published academic papers.
- It was felt that Sustainability was of immense importance, not just to engineers, but that engineers might have a particular responsibility for leading the way in introducing it at universities because they (engineers) are the ones who have been, and will continue to be, centrally involved in delivering Sustainability and, more specifically, safe supplies of energy.

Appendix 1: Plenary Discussion

Full (but not always verbatim) notes of comments made by delegates and the Chairman, Dr John Forrest.

C1 Paul Wesley, VP at the University of Brighton

In industry we often talk about systems and the capability of systems. It would be interesting to hear what the RAEng feels about the capability of the education system because it seems that the actual product is not coming through the process as we would wish it to. A few comments I have picked up from this workshop are:

- Teaching hours are now down.
- Students are now tending to choose those courses with lowest contact hours.
- Students don't understand the basic elements of machinery now. We have been talking here about rather esoteric issues, but if they don't understand the basics of machinery, then we have a real problem.
- Students are tending to come to university to seek the qualification. I think we're on a hiding to nothing if that is true and continues.
- Not all universities are producing 'real engineers'.
- Engineers are often seen as the 'delivery boys' and this is perhaps more so for mechanical and electrical engineers than for civil engineers, and this despite the Finniston Commission and other reports.
- If we are going to have a quality education system, and if the student is now the customer, then the contractual obligations of the student must be made clearer.
- While practical work is more costly, it is regarded as valuable. The aim should be to educate not to reduce the use of costly resources.
- If we are to include all the things we have been talking about, I conclude we do need longer courses. While I hear the usual objections, nobody is saying - here is where we are, here is where we want to get to, and this is what we need to do to achieve it. We cannot get a quart into a pint pot.

C2 Prof. Paul Jowitt, Heriot Watt University

- It is reassuring to find folk theorems about education proved in this workshop. One of them is that people only remember 20% of a lecture. For instance we heard consistently in the excellent lecture about sustainable development that it concerns much more than the environment, yet in the following discussion, that is all we heard about.
- In the syndicate discussion on systems engineering there was a great tendency for professional engineers (both VPs and ordinary Ps) to retreat into their techno-anorak mode, and to reject anything new outside their traditional disciplines.
- We heard that students of English and History are regularly assessed in a holistic way. If this is possible, surely we should be able to assess engineering students in the same holistic way.

C3 Dr Richard Darton, Oxford University

Concerning the length of courses, I think four years at university is long enough. If we can't get it into four years, we should question whether we need it at all. When looking at the formation of engineers we should always look at the 2 years (or more) training in industry required by most of the Institutions alongside the 4 years' academic part.

C4 Chairman

Responding on that point, Gordon Higginson reported some years ago that universities are not making the most of new teaching technologies. Could we perhaps put much of our courses onto CD-ROMs and break away from the talk and chalk methods that seem agreed not to be effective, and make more effective use of our academic staff in tutorials and project studies that we have been getting so enthusiastic about in our discussions? Can we make better use of the new technologies?

C5 Dr Richard Darton, Oxford University

I think quite a lot of courses have already broken away from talk and chalk. I know the Chemical Engineering course at Bradford University has very few lectures at all. Most of the teaching is by project work, which is not exactly what you mean by new technologies.

C6 Dr Adisa Azapagic, University of Surrey

Following the appointment of the VP we have got support to fund a research fellow who will be developing a multi-media learning and teaching package on CD-ROM with case studies related to sustainable development. This follows our previous experience in developing a similar package to teach environmental ethics to engineers.

C7 David Walters, VP at University of Sheffield

One way of helping 'get the quart into a pint pot' might be to modify the current IGDS scheme so that graduate engineers had to do four 1-week modules during their two-year training period in industry.

C8 Dr David Fisk, DETR

I should explain that everything I said is in addition to what you have been discussing, not trying to replace it. There are problems with the Brundtland definition of sustainability, which bring problems for this Government:

- it does not say who defines 'needs' and, more seriously for the Government,
- it depends what boundaries you take – the whole world? There are some American right-wingers who say just that – because the whole world has got richer, we are OK; if you happen to live in the Sahara Desert that's your problem and you can apply for an American passport.

The approach I offered was trying to give you the 14 indicators which are clear examples of needs we all experience. I was not trying to knock the green agenda. The trouble is it can so easily become a minority-interest subject, something you do on a Friday afternoon and be separated from the student's work during the rest of the week. I was trying to stretch it; I feel it is rather more fundamental than that, rather more Victorian, in my way of looking at it. The United Nations is currently working to devise a set of internationally recognised indicators, but we haven't got there yet. I introduced the UK set as something to be going on with – and we haven't really got engineering sorted out at home yet.

C9 Tom Smith, Royal Academy of Engineering

I would like to add to what Dr Fisk has said. To criticise what he said as a green approach was rather unkind. I reacted to what he said with horror – horror for two reasons – the awful future that lies ahead for the world, and, as someone who has been involved in sustainable development for some time, I had never opened my blinkers to see the real width of the problem that faces this world.

I hope that Dr Fisk will publish what he has said so that people like me who thought they knew what the problem was can have their eyes opened even more. There is a problem that exists that simply *must* be addressed. I got the feeling in my discussion group that we could perhaps just leave it; things would sort themselves out in the end. But it really is a problem and it must be addressed in the most serious tones.

C10 Chairman

I was imagining while you were talking one of Dr Fisk's predecessors in the year 1750 looking forward into the industrial revolution. We really are dealing with uncharted territory here and it calls for some revolutionary methods to deal with it.

C11 Graham Oates, VP at Birmingham University

As engineers we have, in fact, made enormous strides in dealing with these issues and that message needs to be made much more strongly to publicise the engineer's role. It is so much broader than just engineering and more than the UK. Often it is only by legislation that the right commercial climate can be created in which those engineers that are so minded can cause these things to happen.

From my own background in the nuclear industry, we heard arguments made by the Friends of the Earth, and we agreed with a lot of what they said, but the industry was constrained by being obliged to make a profit. But engineers do have a role in demonstrating that certain sustainable issues can be addressed to the advantage of the company, because that is the only way it will get done.

It seemed all rather parochial to be discussing sustainable development as a possible marketing device to get more students. It is a much more important issue than that, which needs government and international moves to create the opportunities for us engineers to make it happen.

C12 Chairman

Yet we heard coming out of the syndicate groups there was a bit of uncertainty whether this was mainstream or not. I wonder whether the worry is that if it is included in our engineering courses, even though we feel it is an important part of being an engineer, something will have to be pushed out to make way; I don't know.

C13 Edmund Booth, VP at Oxford University

It is debatable whether legislation can really be very effecting in achieving a sustainable engineering future. It is frightening to consider the aspirations of those in the developing world. That could destroy the lot of us. It is a problem to work out what the UK government should say to get itself elected at the next election.

I don't agree that it is parochial to consider using sustainability to attract more students. It is an important point to make that we can contribute so much as engineers. We need good engineers, and a major reason is the sustainability issue.

C14 Jonathon Wood, VP at Aston University

Concerning sustainability, should we not do more research and understand it better before we teach it? This lack of understanding of quantification extends into the political process where emotion and feeling guides decisions. Take energy for instance; we can look at the needs. Yet emotionally, people have rejected nuclear energy; but as engineers, I think everyone in this room realises that our grand children will need nuclear supplies of energy. As engineers we fail to put the facts in a proper numerate way to the political community that one of our high priorities during the next century will be the provision of safe nuclear power.

I have friends who say the Chinese shouldn't dam the Yangtse river but how can you provide the electricity for China without fully exploiting hydropower. Do you really want them to burn coal?

We have got to quantify and set these issues out in a much more numerate way to change the political debate from an emotional debate driven by people with very good hearts but very poor rationale, to one which faces up to this major problem and asks how do we deliver? I think that's going to focus our engineering duty to the community into a number of new and exciting areas and it is training the engineers who can deliver energy that's going to be important.

C15 Chairman

This has been coming out in some of our discussions about the need for better transferable skills in softer areas, rather than the traditional focus on technology, so that engineers might be more influential in these other fields.

C16 Dr Adisa Azapagic, University of Surrey

A comment was made earlier on that sustainable development would appeal to women. It's nice to see that it appeals to my male colleagues too.

I would like to ask Dr Fisk why those 14 indicators of sustainable development were chosen, and how they were prioritised from a much long list of possible indicators.

C17 Dr David Fisk

There were 50 or 60 indicators and it was agreed that that was too many. A shorter list was drawn up and put to about three hundred people and organisations in a national consultation process with the aim of reducing the list to 12. We finally managed to get it to 14 while still getting a consensus that these were what a government should be keeping its eyes on. We found it much easier to reach this consensus than trying to get a single definition of sustainable development. Next year there will be new lists, going into individual sectors in more detail e.g. in transport.

C18 Graham Oates, VP at University of Birmingham

I would just like to return to the point about nuclear energy being an inevitable source of power in the future. The Government's decision to reject it was certainly not due to the engineers' inability to put the case for nuclear option clearly. We put that argument so clearly there was no way it was misunderstood. It was simply that, given the way the government did its calculations, nuclear was not economic. Gas was too cheap and government time horizons too short. If the government had looked at the environmental impact and the true costs of the effects of non-nuclear methods of generation, the outcome might well have been different. The public was not aware of the full story and the environmental groups were never able to reconcile the idea that nuclear might be a preferable choice. The decision was made on emotional grounds.

C19 Roger Booth, VP at Oxford University

I think there is a link between two of today's topics - sustainable development and systems engineering. In 35 years of chemical engineering we always considered the impact on the local environment using a systems engineering approach.

The sustainable development idea has opened our eyes to how our industrial activity can be having an impact on a global level - the hole in the ozone layer, for example. I think the role of the VP is not to increase the core skills of young engineers. Rather we can use sustainable development and systems engineering to 'open the eyes of the next generation' so that they look at problems broadly. Engineering education has tended to focus down and down and reject anything that

couldn't be quantified. We must broaden the mental processes of the next generation of engineers to help them think on a global scale.

C20 Prof. Peter Hills, University of Newcastle

One idea that came out of our syndicate was the idea of VPs giving master-classes. This was something they could do that ordinary academic staff couldn't. They could engage with a small group of students and lead them through the design processes of a project, with a larger group looking on and listening.

C21 Ivan Yates, VP at University of Cambridge

I would like to return to the question of VPs perhaps being taken from too senior a level in firms. The advantage, of course, is that senior staff have experienced rather more than younger colleagues have.

Teamwork is essential in all aerospace and automotive engineering now. To be blunt, most universities are not producing engineers; they are producing people with a handle on engineering science. Most industrial post-graduate training is probably inadequate; and it would be interesting to gauge how we may have undermined the whole thing by destroying the stream of very good people who came through the apprenticeships. The whole process by which we produced good, rounded engineers who were able to run a company by their late twenties has been undermined.

Universities that are paid to put bums on places, and other measures which mean publish for God's sake, is really destroying the system.

We must really look at this very seriously and compare ourselves with other countries. I think this is one thing the Academy could do. The other message for the Academy is that it should not accept that there are limitations on funding, and should tell the Government how it is, what has to be spent, or trouble will follow. Otherwise if we go on for another decade we shall be producing technicians who are employed by lawyers and accountants. We must get back to our industry being run by engineers. If we don't do that we are not going to be able to solve any of the problems, including the environmental ones.

C22 Richard Batchelor, VP at University of Hull

I want to get back to the idea of design, and engineers being the deliverers. *Design* is the transformation of function into form. *A design* is an instruction to the supply chain and a contract with the supply chain. In universities we have got to accept that apprenticeships have gone and we have to find new ways, more numerate ways to communicate the designs down the supply chain. We must get back to delivery.

C23 Chairman

Let me conclude by just saying one or two words about what I have taken away from this workshop.

- Compared to two years ago, there is now a strong mood to change teaching methodologies and syllabus; change is necessary and its got to happen pretty quickly. And there is now a very strong feeling for the transferable skills, and not as bolt-ons, either. These have to be part of courses and teaching methodologies.
- Certainly there seems to be a strong enthusiasm for systems and systems engineering, and for it to be integrated into courses not as something separate. There might be specialist courses at postgraduate level, but it must be introduced much earlier.
- I think we've got quite a way to go on sustainability. No one denies these issues are important, but it is not yet clear how it could be introduced to engineers. In fact, from what Dr Fisk has said, it seems clear that the subject should be

introduced into *every* university course. Maybe it could be up to us as engineers to show the way.

- Finally there is the challenge of dealing with systems engineering and sustainable development which have so many common issues and overlapping concepts in our courses.

The important thing now is to bring the whole discussion together and move on to the next steps – actions.