

Royal Academy of Engineering

**Visiting Professors in Engineering Design
for Sustainable Development**

2005 Annual Workshop

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Royal Academy of Engineering Sustainable Design Workshop

Chairman: You might find this an interesting unstructured session this afternoon. Having talked to the syndicate chairmen, I think the best way to play this part is to take the aggregates of the headings rather than the 11 techniques, and talk about the personal, reconnecting to reality and holistic thinking, and I will do them in that order. I would like to ask the syndicate chairmen each to say a couple of words about the process they used, the mood of the discussion, et cetera, so we can get the tone before we wade into some of the detail. For the purposes of everyone, I would like to identify the key people in the room. If the syndicate chairmen could raise their hands so people can see: George, Dick, Alan and Matthew. For those of you who were not present this morning, there was a presentation by Gerald, who is sitting at the front, probably because he is going to be a little in the firing line, suitably protected by me. We also have Simon Steiner from the Engineering Subject Centre at Loughborough, and I might be going to any of these people out of apparent order because their views will be quite interesting. Could I ask George to say a word or two about the way the discussion went in the syndicate, without going into too much detail, so we can get the flavour.

George Drahun (Aston): In the first session we had an ice breaker. There were people from five universities and we each described the type of teaching we do, be it lectures, coursework, project work, role play, et cetera. In the second session we had this list of teaching techniques and we were going through this, and the question came up is this really pedagogy. We felt it is not really what we thought it was going to be about. We thought we were sharing good practice and how we teach the material to students, what is the best way students can learn. We used these headings as a guide rather than looking at them in detail, and shared the practice and experiences we have both as visiting professors and as academics who teach this. Many of the comments that will come out of Group A will certainly be along those lines rather than a detailed analysis of the points in the document.

Dick Fenner (Cambridge): We were told to start with the process would not involve the use of flipcharts, so the principle of sustainable development being to challenge perceived wisdom, we have brought our flipchart with us, which I will not bore you with at the moment. We did something very similar to Group A. We started by brainstorming the teaching methods we used in the various institutions represented, and then we came back after Gerald's presentation and briefly discussed the 11 approaches he had presented and agreed that we would try and map those on to our list of teaching

methods we had already identified. We tried to go through those individually one by one and judge each against the set of four criteria. We tried to look at the implications of using those different teaching methods against the resource implications, against how they were assessed, because there is sometimes difficulty within the university context of them, some of those exercises being perceived as slightly soft and fuzzy. What the outcomes were of different teaching approaches in terms of the student learning experience and level of stimulation it created in students, and then we rather bravely tried to put some kind of value on each activity, with an attempt, hopefully by the end of the session, to come up with a hierarchy of what was most valuable and what was least valuable. We went through that process. We ended up with our top scored activities as four star, and they came out to be role plays, field work and –

Chairman: Too much detail now.

Dick Fenner: What we agreed, having gone through that process of producing a hierarchy, was that we did not reject any method. We found they were all valuable in their own way, and a mix of teaching styles, one perhaps underpinning the other, was the way forward.

Alan Strong (Ulster): In the pursuit of brevity, all of the above from my two colleagues take as read. Just to add that in that evaluation of the approaches during the second session we read those to be aspirational goals to be achieved rather than learning and teaching techniques. However, in doing that we recognised some barriers, which people like Professor Alan Ervine and Jim Poole and others from the group will comment on later on when the discussion arrives, but perhaps we came to this conclusion. We believe there are three parallel kinds of activity going on in engineering departments if they are good departments, and that is that the essential teaching of fundamentals for engineering can never be ignored and must be deep learning and must be well grounded. Secondly, in parallel there is the experiential learning applied teaching which has a good shelf life to get a job, to get going, but has a limited shelf life. Thirdly, the whole issue of learning to learn is fundamental to the lifelong learning of the student, and that is the critical thing that sustainable development can deliver. We saw those three parallel strands as being essential in addressing the learning and teaching outcomes that we can comment on at a later time.

Matthew Simon (Sheffield Hallam): In our group there was a general slight divergence of opinion between the industrial point of view, which tended to home in particularly on the aspect of reconnecting to reality and the fact that the complexity of real world situations was core to the whole issue, and some academics who were more

inclined to accept the diversity of possible pedagogical approaches listed here and were happy to embrace all of them as potential aspects to the learning process. However, there is no doubt that number five was by far the most important to us.

Chairman: Gerald, would you like to comment on how you sit regarding the questioning of some of your list?

Gerald Dawe: It is fair enough to question the list. All I have been attempting to do today is facilitate discussion and put forward some proposals. I was not in the least concerned that some of them have been removed or you thought it better to look at them alongside other traits. This is the start of a process, or we are at the early stage of a process that has been going on for may be ten years. The key thing is to try and preserve some of the diversity in people's conclusions that are coming out at the moment and not try and suppress any of the conclusions that are coming out. Philosophically, I am in favour of trying to preserve diversity rather than attempt to say one approach is better than another. With the HEA work we found there is a tremendous diversity of opinion over all these techniques. Some people said they would use them and other people said they would not, and other people said they would rather substitute something else for those 11 things we proposed. My role is primarily as a facilitator in the spirit of participative decision-making which, as many will know, is at the heart of sustainability. I welcome all these different views being expressed.

Chairman: We will not be able to contain all the discussion within the aggregated headings, but I would like to move along and cover the discussion in three sections, firstly the personal, secondly reconnecting to reality and thirdly holistic thinking, and see where we get to. If I could ask each of the syndicate chairmen to contribute to a discussion on the personal, the techniques listed were educators as role models, learners as teachers, teachers as learners and lifelong learning. You may wish to call in people who were in your syndicate to make a fuller discussion. Of course anyone else can put their hand up and join in but we need to wait for the microphone to arrive. If I could take it to George first.

George Drahun: On the personal side, we were looking to some extent point by point, so a little more meat on this, but a general point about all of these. We felt that all of us are using these within our teaching to one degree or another. On the role models, we were wondering whether this means that any of us who have SUVs whether we should sell them. The key points that came out is when we teach, whatever method we teach, key words are honesty and clarity, integrity and social responsibility. The second point on learners as teachers and teachers as learners, that is fine in small

groups. We can learn from the students' experience when the group is may be half-a-dozen, but if we are teaching groups of 200 that is very much harder. On lifelong learning, fine – David, do you want to say something on your distance learning?

David Hicks (Bath): We were struggling to connect with our experience with this one, but here at Bath we have an environmental management systems course in our final year, which we deliver using distance learning materials pinched from an MSc programme. The beauty of that is by studying using distance learning materials the students have to become self-directed learners, so that is a skill they develop in studying that module that they take with them. That was our example of something you can do in an undergraduate course that promotes lifelong learning.

George Drahun: I am not sure there is very much more we can add on the personal side, so I will transfer to the next group.

Dick Fenner: We did not explicitly address Gerald's issues per se, but we went through a list of activities and we could probably map those activities into the categories we are talking about. If we were to do that, probably the discussion would focus on the personal in terms of lectures, in self-reflective learning logs, web-based learning and peer learning. These were the activities that probably reflected personal development. We felt lectures were by far most of value where they involve the person or they drew on examples of the person developing a lecture, and the question was raised can you do without them because they are useful for introducing basic concepts and they are quite resource efficient. We had some discussion about the use of self-reflective learning logs, some of which people in our group had experience of and others did not. There was not very high value placed on that activity, partly because there was uncertainty as to exactly what it involved.

Web-based learning again is a facilitative mechanism that can be done at a personal level and it can be used to draw out individuals who may not feel comfortable participating in group activity but can contribute and can be monitored to contribute through engagement with web-based material. The fourth item we put in that category was peer learning. Again, a sharing of personal experiences between members of the group, probably through seminar discussions, but the ability to capture the experience of others at a personal level, so personal interaction with peers on the course we found to be of great value. Probably those are the activities that would fall under that personal heading.

Alan Strong: Group C, having looked at these 11 aspirational approaches or goals to achieve learning and teaching, merged them into six categories.

In this section of personal issues we felt the whole issue of educators being role models was not a deliverable we could fully achieve. It was a nice thing to do but when we asked the group to say yes, it is a definite runner, no, we must park that for a long time or may be it is possible, the vast majority of votes came on the may be side. We merged one and two, that is educators as role models and the learners as teachers and the teachers as learners, on the whole principle that it is fundamental to getting the sustainable development message across, seeing staff members as coaches and as mentors, students as people who have the freedom to react and to respond and to offer ideas and suggestions so they take ownership of their own education. And there is an example of engineering without frontiers that Dr Sally Heslop of Bristol will comment on in a moment.

Thirdly, the whole area of lifelong learning was not, as Gerald's statement seemed to suggest, about doing more of the same – I know it does not say that, but it seemed to be CPD for the sake of it, tick-box attending courses. We perceived lifelong learning as a much deeper issue about externalising your knowledge and understanding, and Dr Jim McQuaid is going to say a brief word on work of Professor Hills in this area. Could I ask Jim to do that, please.

Jim McQuaid (RAE): I mentioned the contributions that have been made by Sir Graham Hills and Professor Alastair McFarland in this subject area for several years. They contributed to the Engineering Professors Council meeting in Glasgow in 2001. I will summarise what Professor Hills had to say. Teaching in HEIs is too knowledge-based. That should be left to the internet. We should focus on putting knowledge into its context more in the style of courses in law and medicine. I add my own interpretation of that, that we should give great emphasis to the use of case studies to describe the different contexts. Professor McFarland – and remember both of these were vice chancellors of universities – spoke about learning. He said that learning in future will become web-based and self-paced. The universities' job would be to support it, not to provide the knowledge. That was in 2001, and since then Professor Hills has been working on a project for the Royal Society of Arts. He described initial ideas at the end of last year/ the beginning of this year, which very much underlines what he spoke about in 2001, so you can read it, it is in the public domain, a very interesting and thought-provoking article.

Sally Heslop (Bristol): I just brought up the example of engineers without borders, and I suspect several universities here are familiar with that. It is a movement that started in Canada and then came over to the UK, starting in Cambridge and has moved out. It is student-led and it is engaging the interests of students who want to go and work in developing countries, they are interested in developing countries, hence

sustainability. They set up the groups within the universities and then get the students engaged, and then the students come and talk to us and get us engaged, so it is a good example of a person starting with the students and moving outwards.

Matthew Simon: Our group had some interesting observations on the personal educators as role models. Karel Mulder had something to say about mainstream engineering, but as well as the concept of the lecturer or the educator as a personal example of diversity among engineers, it is also important to recognise that the role of visiting professors and speakers who are practising sustainable engineers can be very valuable. The items from this list of three personal techniques we were presented with could be supplemented by some other points. One was on the importance of reflective practice as a personal attribute and skill of students. The other was a mention of enjoyment and fun as being part of engineering, which again is something students can personally experience in these sorts of studies. Perhaps I could ask Karel to say something, and Jenneth also had a comment on students.

Karel Mulder: First of all, I agree with practice what you preach, but it is important for sustainable development to get some status in our engineering schools, not to preach to the students that they should move into a kind of subculture and the lecturer also should be a member of the subculture as well. We all know the prejudices about environmentalists. Therefore, the role model we should give them should be something like engage in discussions in the engineering community and try to give sustainable development a good place, but do not act like whatever you may call it – the typical prejudices.

Jenneth Parker: My comment was to do with the notion of students' relationship to knowledge that they are gaining. I mentioned that one of the selling points of the programme I am involved in is that we emphasise that it is a cutting area of developing knowledge and that a Masters dissertation will contribute something valuable and new to a very important exciting developing field. That is part of the way we should be marketing sustainable development in our courses, that it is an opportunity to make a contribution.

Simon Steiner (ESC): It is interesting to hear the discussion backward and forward on the personal perspective. My comment is may be a presupposition of the background and experiences of the teaching staff. It perhaps assumes that all experiences they have had are good and are worth communicating and transmitting to students. It may make the case that we put a great deal of effort and time into the

background profile we give to members of academic staff in supporting them in developing the role model.

Chairman: Are there any more comments or questions people from the floor would like to make on the area of the personal?

Roger Venables: Dick, forgive me if you said this and I missed it, but we had a discussion about the fact that the personal experiences definitely do not have to be all good. This is now me speaking. It seems to me it requires a certain confidence in one's own understanding of the underlying issues to be able to stand up in front of a bunch of students and admit to the fact that it is really difficult to get these things right and to acknowledge that some of the things one does are not right. Getting self-conscious about it, I am really beginning to fret about CO₂ out of the back of aeroplanes right now, because I have been travelling more than perhaps I ought to do. That was one point I wanted to make. The other one, in case you have not read it yet, Principle 12 in the new guide is one of the most challenging things we have written down, which is under Practice What You Preach but it is what we say underneath that is really interesting. If we can find a way of getting this across to the students we will be doing a service to society, because it says: "One's own everyday practices should not be at variance with what is being asked of others. You must not expect more of others than you do of yourself. Be prepared to be accountable for your design and engineering and uphold by example the beliefs it reflects. Change yourself before you seek to change others."

It was interesting there was a question at the Academy meeting last week on why don't we hear about bad experiences, why do we only hear about good experiences. Roland Clift, who is speaking later today from the panel, said it is okay to do a bad experience as long as you can put a good experience alongside it, which is a good point. However, there are also lawyers hanging around in the background on some of this, so one has to be cautious!

Chairman: For the benefit of the people at the summer school, the document Roger was referring to is this, and I will bring a copy for everybody at the beginning of Roland Clift's lecture. It is a recent Academy publication. Picking up on that point of Roger's, there is a strong feature of the American subculture, which is that you will be forgiven for any sin as long as you confess it openly and ask for forgiveness! There are some very good examples of that.

Steve Hurst (Cambridge): This was not specifically about the personal but it can tag on to that. This is from the perspective of an outsider looking in, not a sustainable engineer. It seems obvious to me that what you have to do to look after

issues of sustainability is to widen the scope, to look at things like the social issues, the economic issues, the issues to do with geography, et cetera. However, it is essential to remember that everybody is still an engineer, and you analyse whether something is sustainable quantitatively. As the old dictum said, if you cannot measure it you do not understand it. It is really important that engineering disciplines: counting, analysing, modelling, are still very high up in the toolkit of a sustainable engineer. When I look at the 11 criteria we were given, I do not get that picture. Putting it on a personal level, each engineer has to have the tools at his or her fingertips.

Chairman: Any other comments on this grouping? May be I could ask Gerald to sum up his view of what he has heard.

Gerald Dawe: Some very good viewpoints were given there. By and large we found when we were dealing with the HEA project and dealing with engineers, they were very much concerned with process efficiency and economic efficiency of the sort of engineering they were concerned with, and that is absolutely fair viewpoint. Just to take up one or two of the other issues I have heard about this afternoon, the business of not having ideal environmental performance can offer a very good way to deal with students, deal with the personal. You might admit to owning an SUV or travelling around the world by air, but at least if the students are comparing that sort of lifestyle and critiquing it with their own, some very useful discussion can come out of it. No way was this intended to be: you have to be totally sustainable before you undertake this exercise. In fact, many tutors are already carrying out work in this area. Quantitative work, which should appeal to engineers from what I heard this morning, from Karel at least, using ecological footprint methodology to calculate your own environmental impact, and there are very ready resources on the web to do that. Quite a few tutors find that a very useful way of quantifying personal impact and comparing impact between students and tutors. That is very useful. That is all I want to say about the personal.

Chairman: Thank you everyone for comments there. Can we move on to the next grouping, reconnecting to reality? There were a number of approaches here: relationships to the local community, real life problems and experiences, reconnecting people to people and nature, developing capacity for enacting non-prescribed change, links with university/EMS/SMS. Again, if we can follow the same procedure, starting with George, please.

George Drahun: This group of points struck a cord with Group A in that we do this. Many of our case studies across universities are real life. The now famous example is the Byker study started at Newcastle University, and perhaps Geoff might

want to say a few words about that in a moment, which has also been taken up by other universities as well. Most, if not all, the visiting professors are currently in industry or have retired after many years of industry, so they can bring to bear their industrial experience. We also raised the point here that came up a few moments ago, that the case studies we have do not have to be sustainable. We could bring in unsustainable case studies and say, what went wrong with this. At this point we came to the point of what is pedagogy, and if I can go slightly aside to what we understood by this. We decided the best way may be to start with lectures and introduction and then move on to areas where other students participate, be it through role playing, assignments, coursework, web-based projects or whatever. That came out of Group A as to how we present the material. I understand Geoff has left. That was Group A's contribution.

Question: What is Byker?

George Drahun: In the absence of Geoff, it is an incinerator in Byker in Newcastle which was going to burn domestic waste – it did successfully produce fuel. They deposited the ash from it on allotments and footpaths and they found all the vegetables on the allotments were heavily contaminated with heavy metals, dioxins and nasty things. The council had to take away all the ash they deposited and Byker was shut, and it is still shut, so they cannot burn their domestic waste.

Dick Fenner: Again, the basis of our discussion was to focus on methods of delivery, and under this heading we would probably group the following techniques, which when we did our rating exercise we rated most highly and most valuable, and those were case studies, role play and field work. All of those are means of reconnecting to people and reconnecting to reality, and because we rated those activities the most highly perhaps this is the most valuable of the three areas we would have perceived from our group. If I can say a little about some of the issues we discussed in relation to those three things. We had a discussion about the value of case studies and whether we were talking about case histories or case studies, case histories perhaps being more of a backward analysis of something that existed, learning lessons of what went wrong or what went right. Whereas case studies were perhaps more open-ended problems posed for student-centred solutions. We agreed that although it would be nice to pool and share a library of this kind of material, it was sometimes very difficult to present it if you had not had personal involvement in it, and that need for personal ownership of a case study was seen to be particularly valuable. We felt this was a very good area for instilling critical thinking into students, but perhaps was an area that was problematic in some of the assessment issues, perhaps difficult to integrate into conventional assessment patterns,

may be because it is seen by other parts of universities as being rather soft and not falling in line with other assessment patterns.

We looked at role play. We had an interesting discussion about how to approach role play, whether students were set a basic scenario and allowed to define their own roles, or whether students were given predetermined roles that took them outside their comfort zone, so they had an emotional experience perhaps by asking them to take opposing views to those they might normally take, and that they would be expected to operate with incomplete information. That again is something students do not quite understand of the real world, that often decisions are made in the absence of the perfect. These were found to be extremely useful, but it was also important to debrief from that kind of activity to capture the learning outcomes that had been achieved.

Fieldwork was also felt to be extremely valuable, mostly in encouraging student interaction and its social value in bonding a group together, but it was recognised that it came with quite a cost burden and was therefore an activity that could not always be supported. We also talked about the use of visiting lecturers to get a window on reality, but were aware that sometimes that activity could be given a particular slant or pitch by the people coming in from outside, and that perhaps that was best done in an interrogation format rather than a straight lecture format.

David Foxley: The point Dick raised about the transferability of case studies is a fairly significant one and we ought to come back to it, because if the transferability is low the shelf life and value of them might be far less than we thought.

Chairman: We will come back to that; it is on my list of personal questions.

Alan Strong: To summarise on behalf of Group C, we saw the first three approaches by Gerald as being issues to do with the personal performance of the staff member. We saw the next group to do with reconnecting to reality as being the applied engineering skills, and there were five of them, and we saw that at the heart of what we were doing. The third group to do with holistic thinking was almost the awareness-gathering, the ethical issues. Dealing with approaches 4 to 8, once again we did some grouping on the following basis. The relationships to the local community, number 4, and links with university systems, number 8, seemed to fall neatly into the whole area of community connections, dealing with those who lived in the immediate catchment of the university. We need to be able to understand those and encourage our students to appreciate those to be able to measure them. Things like ecological footprint, a heavy tool but a very valuable one, looking at the impact of the university within the catchment,

using indicators, therefore data analysis and the opportunity to apply the engineering skills that have been developed in the fundamental teaching we referred to earlier. Then having the students aware of the key stakeholders within the community, those who make decisions on legal, planning and regeneration issues, et cetera. This one sat very neatly on the whole social and economic issues. I want to cite some work we have done with Forum for the Future looking at the five capitals of human, social, natural, manufactured and financial capital. That asks 12 feature questions, and this community connections falls very readily into the first two of human and social capitals.

I want to raise a general issue now because it is an appropriate time to do it, and it was raised by Alan Ervine in particular, and I know he will add to it if that is necessary. There is a great issue over the capability of engineering staff within current UK engineering departments to be able to deliver this particular section, on the issue that some staff have come on board because of their research capability, because of their deep learning, because of their lack of industrial knowledge in delivering design skills and tools, which are very important to this general section. Therefore, there remains a question who does this. Clearly the Royal Academy of Engineering has identified the role of visiting professors, and we see that as very important. Nevertheless, there has to be an in-house capability as well.

We then grouped categories 5 to 7, which were to do with reconnecting to reality in terms of real life problems, and we called this section real life issues, and it is really to do with problem-solving. Once again analytical engineering skills being involved and the issue of using things like design studio work, open-ended mini case studies that challenge thinking, require evidence-based material, being able to come up with judgments that are optimal, therefore learning from failures, and all those issues that have been mentioned earlier. It is critical to the engineering mind and the engineering psyche that give them lifelong learning skills.

We kept number 6 on its own, which is to do with connecting people to people in nature, and we called that respecting the natural environment. We were not talking about biodiversity issues but rather to do with transport, climate change and waste management, and things that engineers are doing to impose themselves on the natural environment and perhaps do not fully understand it. They are the techniques we might use. A number could be used but the whole issue of industrial placements, students work in industry making reflective learning and reflecting on what has been going on. Jim Poole is one who cited a number of issues in the whole area of delivering informal lecturing to challenge the thinking of the students, and once again this is an area in which respecting the natural environment can be addressed.

Matthew Simon: I don't think there was anybody in Group D who was not enthusiastic about the concept of allowing students to reconnect to real life complex problems and benefit from the experiences of others in studying case studies and trying to develop solutions. However, there were a number of different interpretations of exactly what this might mean in practice. One of the discussions we had was to contrast a more limited approach to dealing with a sustainable development problem as a real life problem that was very heavily constrained so that the possibility of solutions was more difficult, and those generally might be based on problems that had happened in the past and were based on historical case studies. And an alternative approach, which was to look forward to possible future case studies that allowed increased opportunity for students to develop radical solutions because they were going beyond the normal constraints of engineering practice nowadays. So there are different interpretations of what real life could mean.

Everybody felt it was in the business of engineers to be involved in the design, make and test cycle. Patrick Palmer from Brighton was emphasising this as being core to engineering, and David Bartholomew might want to say something about this in a moment because he also had strong views about this issue. We did not have very much to say about reconnecting people to nature or university management systems – there was not a great deal of experience in that. In terms of relating students to the local community, Karel Mulder mentioned the example of the Delft science shops that had run in the past, where students provided a science resource to the local community, as a good example of that. Perhaps I could ask David Bartholomew to make a comment, and also David Raffo had something to say about his experience.

David Bartholomew (De Montfort): I think what I am being asked to comment on is the particular value, as I see it, in case studies that are based on analysis of things that have already happened in the real world, whether they have turned out well or not well. The reason I feel that is so particularly valuable is that many of the obstacles – and it seems to me, in the field in which I have had most experience, which is the built environment – many of the obstacles to progress in sustainability are not technical ones, they are not fundamentally problems of lack of engineering knowledge or even, in many cases, lack of engineering will. They are problems that arise in the translation of concepts into solid concrete bricks, mortar, whatever, and then in the subsequent operation of buildings by occupants whose ideas about how they are best operated to serve their purposes may be entirely different from those of the designers.

An example I quoted was from Hampshire, which a number of years ago built a string of low-energy schools, which were state-of-the-art at the time and would still be quite good. Unusually, after completion these were re-examined to see how well they

were performing and what was going on, and there were real difficulties in some of them. In one of them there was something that particularly stuck in my mind. The designers had incorporated into the concept ideas of controlled natural ventilation that would provide low-energy consumption while maintaining internal comfort conditions, and in order to achieve that they made assumptions about what people would do with the windows. They said, logically when it is cold outside in the winter they will shut the windows, but when they went back they found that the teachers were opening the windows. The teachers said, 'It's all very well, it may save energy, but I want to open the windows because a blast of cold air wakes the children up.' That exemplifies exactly the kind of way in which the efforts of engineers can be stymied if they fail to understand the non-engineering realities that surround their products in the real world. They are only going to become aware of that sort of thing through looking at real experience from the past, because by definition the reason the problem was there was that nobody had anticipated it. If one were doing case studies in which one simply said to a bunch of students, 'Go out and design a lower energy school', no one would have thought of that.

David Raffo (Leeds): From those 11 approaches or principles this morning, one jumped out for me, and that was number 5, which was the experienced learning based on real and messy problems. Against our proposal to the Royal Academy we had gone back to them and said we do not want to use historical case studies, we want to create the case studies in what we do with the projects we have. This seemed to tie in with that conversation, real and messy problems that are out there, with the fact that the knowledge base engineers have to learn is growing hugely, so you cannot teach them everything. How can you go about teaching engineering if you cannot possibly teach them everything in the time, so why don't we set them problems to solve and they can go and find the knowledge they need to resolve these problems. I also harp back to what Karel said this morning, which was that it is important to enhance the ability to develop solutions, not in the detailed content of those solutions. All these things fitted together and seemed to lock round number 5, the experiential learning.

The thing for me, coming from a product design and development background, is that we always talk about problem-solving. I try never to do that because I always think what we are trying to find is opportunities to do things differently, and we are not trying to solve problems. To do that I start all my first lectures in the first years with the Honda advert and it pulls together everything we want to do. I don't know if you have seen this advert on the television but this Honda factory makes okays and it is very happy making okays. Then the guy making them sneezes and sees the keyboard and sees he has a lot of other things to play with, and he types in "What if?". The first thing we get our students

to do is to say suppose we change the rules, what if the world was different, what would our solutions look like then. That is how we want to deal with the case studies; we want to look at them as opportunities and not problems to be solved.

Jim McQuaid: A further word about Byker. My recollection is that Byker started as a good case study that progressed to being a bad case study. When it was first put in place everything seemed to be right. It was only late on that the problems with the ash arose. [*Disagreement expressed*] This is my recollection.

The second comment I would make is that there is a connection to reality that I would like to add. The techniques for embedding education for sustainable development should include the rather more subtle approach of not trying to embed sustainable development. The reality is – and we have heard this umpteen times – that the opposition to embedding sustainable development is such that it is going to be an enormous uphill task. We saw this with the HEFCE consultation document earlier this year and the emotions that aroused. One could achieve the same eventual outcome by focusing on the embedding of approaches that can be used and applied to sustainable development and are inextricably linked to sustainable development, like communicating complex subjects, in ways other than just the written word. This document is a prime example of poor communication. There is no diagram in it from beginning to end, it is all words and some of it is very difficult to follow – at least I found it. Other approaches would be how to handle uncertainty because uncertainty surrounds all sustainable development issues, how to make decisions and so on. You do those things in sustainable development capability drops out as a natural consequence.

Matthew Simon: Particularly for the benefit of the summer school delegates who have just arrived, I wonder if I might be allowed to give an example of a case study we piloted this summer as part of our scheme with a group of final year mechanical engineering students. This concerns the decommissioning of the number one pile at Sellafield, and we had the benefit of the experience of our visiting professor and an ex-colleague of his to act as expert participants in the case study itself. This particular case study gives students a very good picture of not only what can go wrong in engineering but also what engineers can do to be part of the solution, so it forms a particularly rich case study.

The case study started with a keynote lecture about the history of nuclear power and plutonium manufacture in Britain, and mention of the fact that the Windscale piles were built to provide a British nuclear deterrent in the immediate post-war period, so politics and ethics come into this straight away. Then the result of a major disaster at the

pile in 1957 was the need for a cleanup, so it brings in the engineering reasons for the failure and the fire in the first place. As a result, the radiological restrictions on the engineering solutions mean the students have to be able to design remote equipment for removing some of the contaminated material from the inside of this pile chimney. They had to use standard engineering equipment in an imaginative way and at the same time be aware of the risks of failure, because if any piece of equipment failed it had to be also removed remotely from the reactor for repair, so they were dealing with risk assessment as well. We took them on a visit to Sellafield and the visitor centre, and that is always a very good educational experience, so they could immediately see what they were dealing with, because the size of it in real life is impressive, and the scale of the problem. The engineering solutions they proposed were then criticised and we had a feedback session with the visiting professor and the engineers on what happened in real life.

One of the aspects of this case study we felt was particularly useful was that it was not a didactic one. We were not giving them a ram-down-their-throat lesson in what sustainable development is. In fact, by doing the work themselves they could not help but come to realise the ramifications and the issues involved and the social aspects, so you do not need to lecture them on that because it becomes immediately apparent as they are doing the work.

Jim Poole (Cardiff): All this stuff about real life. If we are talking about preparing engineers for real life, it seems to me we are in danger of trying to create super-humans, super-engineers, people who can do all these things in these 12 boxes. Reality is that you do not have to do it all yourself; in fact, you must not do it all yourself, you have to adopt some sort of team approach. Therefore, if we are talking about skills versus knowledge, it is time we built some proper team skills into the courses we do. Engineers tend to end up with leadership roles in the projects they are involved with, so it is very important they develop skills and are aware of skills for facilitating input from other people, how do they identify other stakeholders might be involved in a project, and how can they interpret technical issues for non-technical people. These are the skills they will be faced with in real life.

Roger Venables: Two disconnected points but related to case studies. The first is – I am not trying to put my editor's hat on – we need to be very careful to make a distinction between a good and a bad case study on the one hand and a case study about good and bad practice on the other. It is very easy to fall into the trap of saying a bad case study is one about bad practice. Secondly, to pick up on Steve Hurst's point, I think you said if you cannot measure something you cannot understand it. Is that what you said? [Yes] I am not sure I agree with that but what I would say is that one of the

things I feel very strongly about, that fits in with a number of comments other people have made about giving people the ability to approach a problem they are facing, is that you have to help them to understand something to the best of their ability, even though there are many aspects of it they cannot measure. If we focus on the idea that it is all too difficult if we cannot measure it – and I am not saying that is what you said, but there are people who do say that: if you cannot measure it you cannot manage it idea – there are loads of stuff we will never attempt to manage. We have to equip people with the ability, even more than we do already, to deal with lack of knowledge, uncertainty and the quality of that knowledge. [*Apply judgment.*] What a brilliant idea. Get engineers to apply judgment, that would be really good!

Chairman: I would like to linger on case studies a moment. Jim has spent many years chasing all of us visiting professors to deliver case studies to make them available, including me. Case studies are a tough option in many ways because the question I would pose is, how useful are case studies as a delivery tool to someone who has not been involved in developing that case study. In my case, where I do a case study on laundry detergents tablets, I get pretty good response from the students, and I can do it quickly or I can do it over a week or so, it can be done in different ways. However, it was not until I started delivering it that I realised a great deal of my own personal knowledge was being used in how I sifted the questions, how I put in bits of information and took them back because they were confidential. It is quite a tough task to hand that over to someone, and no one is beating a path to my door to say, give us information on this case study.

When I was asked to put something into the principles document it looked fairly bland at first reading. You might think it is bland when you read it through, but when I look at it now, there are some good messages there, particularly when you line up the principles we have identified against the particular case study I was involved in. You think, that is not a bad story and that could go to someone who has not been involved in the subject, if they wish to pick it up, but it is rather more bland than the content I can deliver to students. An issue we are having to deal with is, there is role playing, there are case studies, there is total immersion on a barge, there are all sorts of ways one can teach, and case study has to be looked at in the context of everything else, not least of which is the time available. There is a question – and I don't know whether there is an answer to the question – have we been pushing case studies a little too much in relation to what the Academy visiting professors should be delivering.

George Howarth (Bournemouth): On the case studies I would argue that what we have is case studies in specific engineering areas, like the build

environment, civil engineering. What I suspect we have not done very well is get those groups that are interested in the built environment talking about their various case studies and using them. One of the things I would be asking RAE is for various groups within the visiting professors to get together more and use it in their particular field.

Chairman: The chemical engineers have done this already: Newcastle, Birmingham, Aston.

George Howarth: I think the other engineers have not, and there is an opportunity there.

David Bartholomew: This is a hobby horse. I am absolutely convinced the Academy was right in setting up an initiative whose purpose was to develop high quality case studies, and also right in having the ambition that these would collectively form a resource that would have wider value around higher education. It seems to me that, as evidence for this, we should be prepared to learn from others, and in particular to look at the teaching of business-related issues in business schools. And note that not only is case-based teaching very widespread, and indeed one of the normal practices within business schools, by virtue of, as I certainly believe, its unique ability to grapple with the complexities that arise equally in management and in sustainable engineering, but also in the business school world case studies are not only used in other institutions, they are tradable commodities. Harvard Business School has a healthy business in selling its cases to other business schools. One of the things I think should be done is to try to involve in the next stage of this process – and I am putting in a strong plea that there should be a next stage – people from a business school background who have a much longer experience of using cases in teaching.

That brings me to the second point, which is that one of our experiences at De Montfort is that many university teachers have no experience of using cases in teaching, and they simply do not know what to do with them. Case studies need to be accompanied, not necessarily one-to-one, by some sort of set of examples, of hints, of material to teach the teachers how to use case study material.

Chairman: I agree with what you are saying. If you look at the web page of the Natural Edge in Australia they have some case studies and they have some notes with those case studies. I would make the point do not underestimate how good the teachers at business schools are. I have been to Harvard and sat through ten case studies. The guys that deliver these are absolutely top-notch, they are the best. The skill required to deliver a case study takes an enormous amount of work. It may only be a couple of

hours of student time, may be two hours reading, but it requires a skill level that is quite difficult to transfer from one person to another.

David Bartholomew: Absolutely. I am conscious of that. I can only say I was mildly horrified that you should seek to set them up as an unattainable ideal. It seems to me it is an ideal to which good teachers of engineering should aspire.

Chairman: I do not want to linger on the point too long, but people pay to go to business schools to receive those case studies, and we are fighting against departments who do not wish to give us space in order to put sustainable development on the agenda. That is the difference we have.

David Bartholomew: Without going off into too many side issues, it would seem to me that cases are not valuable only in teaching the aspects of engineering that we would label as sustainability. They are a way of teaching good engineering practice in the larger sense.

Chairman: I do agree with the point.

David Bartholomew: The final thing I wanted to suggest – and this is the plea – is that having invested as much as it has in the development of all these case studies, the Academy should now consider following up with a final act that is in effect an exercise in marketing and training, conscious activities that are specifically aimed at bringing these things into more prominence and helping people on a not necessarily one-to-one but definitely a more personal basis than simply to a website. Helping people to understand what the possibilities are and to find matches between cases and potential users based on their salients –

Chairman: Is that something we could progress with the gentleman sitting next to you on the Engineering Subject Centre?

Simon Steiner: It certainly is. What we have been talking about in reconnecting to reality is about learning and teaching styles. Case examples, case histories, whatever we are going to call them, albeit they are slightly different, are very often mechanisms in how we can be imaginative in engaging with the students. We have talked over a number of different techniques as well as case examples. This reconnecting to reality and engaging with the students is where we have to move to in the future with students, not assume that we can rely on didactically delivering a lecture to a student group or expecting the student group to use a degree of initiative, that we presume is there, for them to take case study material further forward. I very much

support David's point of what we need to do when we have a case study, that there needs to be case material to go with it in order to embellish that case study.

David Bartholomew: A final word as far as the Academy is concerned is that for the expenditure of another ten per cent the impact of the scheme could potentially be a figure out of the air doubled, because the distribution and the multiple use of these things is the key to that.

Chairman: We will be back on that, David. It is a point well made. I do not want to linger too long on this area because I want to finish at around four. David, are you wanting to make a point there?

David Foxley: It is not an infra dig point, and David has been one of the best examples of making case study material well available with backup notes and everything. There are still far too many establishments involved in the scheme who have their case studies in a box with a lock on it and they have not yet given us the key. Please bring out your case studies, because until they are out in the public domain nobody can share them.

Chairman: I would like to make a couple of points. Universities are now often one of the largest employers in a city, so if you look at Manchester University or Liverpool University, the associated administration of the university, the infrastructure, the students, they have a massive impact. We cannot ignore this role of universities and their social responsibility as part of what we are doing, and I am surprised it did not come through a little more in discussions, because they are big businesses. A vice chancellor of a university is the same as the chief exec of a very large company, massive numbers.

I am fascinated by role playing, and I wonder whether it is possible to do role playing in a very short period of time. Is it possible to take a group of students and do role playing in an hour or two hours, or does it need a day? And if I wanted to do something in a short space of time, where would I look for guidance to do that, because I don't think I have the confidence of sitting in front of 50 students or 200 students and saying, now switch into role playing mode? Is there anywhere to look, is there anywhere to find out how to do this?

Jim Poole: I adopt role play for all my case studies and as part of the process students are asked to reflect on the process of undergoing the role play. They are asked to reflect on how they got their points across, how others got their points across, and how productive the overall process was. That is a transferable approach between case studies. When I asked the students for their feedback they compared their experience with role play very favourably with having to do a presentation, for example.

They said it was far easier to get their points across in that more informal atmosphere than if they had to stand up on their hind legs and do it. Some students are better at it than others, but some people can get into the skins of the stakeholder they are meant to be representing and come up with some quite surprising stuff.

Speaker: This is a practical suggestion. You buy yourself a box of murder mystery for a party at home, take out the stuff and rewrite it, because that takes the same amount of time. You hand out cards to people a week before they come to the party and it takes two hours to go through it. If you just take an example from somewhere else, it would be possible to do it.

Roger Booth (Oxford): In answer to how long can it take, in our coursework module we do one role play that is a full day. It is based on the Byker project, so they have a long period of studying in depth and then about two hours to do presentation. In other cases we do role play where the whole exercise takes about an hour. They are asked to imagine, for example, they are the board of a small oil company and they have to put forward their strategy for how to survive in a carbon-constrained world, and they get quite a lot of joy out of doing that. It can be quite short, it can be quite long.

George Howarth: To support Roger there, on the website we have some ideas, problems and views of the stakeholder, so we define the stakeholder for the student and we ask what are the issues that are important to him. When they come and do their presentation and their work, they have some basic information as to what that stakeholder is concerned about, so they have something to build on.

Heather Cruickshank (Cambridge): Just another example. We have had experience of doing very quick role plays, we also do some very long ones with stakeholder dialogue and in depth. However, we have done it within an hour. It requires a great deal of very good planning for your murder mystery game preparation style. However, we did it one year where we sprung it completely on a group of about 45 undergraduate students, and as they walked in the door we gave them their characters, their background and their briefing, and they did the whole thing in an hour. Preparation beforehand takes a great deal of time and effort and needs to be quite thorough, and debriefing afterwards. We did a debrief and discussion of it the next week and drew out the issues from it, and that is very important as well, but it can be done.

Chairman: Thank you for those comments. Can we now move on to the last grouping of holistic thinking? These were interdisciplinarity and critical thinking,

systems thinking, respect/sensitivity for all subject areas. Could I switch to George, please?

George Drahun: Group A interpreted this group as interdisciplinary work with different sorts of engineers. We raised the point that perhaps students ought to be thinking outside the box because that is what companies do. Companies that succeed very often succeed because they have thought outside the box. We wondered, without necessarily producing an answer, how do we teach this teaching outside the box. We came to the conclusion that what would be very important to teach is a range that comes from communication, negotiating and selling skills, because if an engineer has a good idea, they have to persuade people within the company initially, within the government and the public, that it is a good idea. How do we teach those communication, negotiating and selling skills? The good old favourite came up, how do we teach the teachers, but I will leave that to one side in terms of academics.

We wondered who are the customers of this Royal Academy scheme. Is it the universities, is it industry or is it government, because industry wants well-rounded engineers who can be all-singing and all-dancing. In the old days industry taught the graduate engineers what they required, but with slimming-down of industry, they expect those well-rounded engineers to have all these skills. It is perhaps that which should be part of the teaching. We raised the point that sustainable development teaching is perhaps now where safety was 30 years ago, and what we should be aiming for is not to have loads of engineers who are SD experts. Have a few of those, but have a culture amongst all engineers that they know a certain amount about sustainable development for their work, just as safety is nowadays, and perhaps that is the way we ought to be moving.

Dick Fenner: This is an area we probably gave least attention to, so I am looking to my colleagues in Group B to add any comments. Roger and Adrian, if there is anything I miss because several members of our team have already left. We focused on the practical aspect of running interdisciplinary design groups. One of the constraints that was felt to be a barrier to that was a problem with timetabling across different subjects, even practical constraints like the sheer size of rooms to get people together. It was suggested that a great deal of that interdisciplinarity could be sparked by online group discussions that took the activity outside the timetable. It was also felt that face-to-face meetings and discussions were very important, and that those activities often focused around project-based material with an industry focus. We mentioned very briefly the use of simulations and simulation games where you can ask 'What if?' questions to see how

the system responds by changing various variables. We did not spend a great deal of time on that, it was just another supporting technique.

I come back to a point Karel made this morning about engineers and how many engineers have dual qualifications, and how good we are at talking across subject boundaries. If we honestly ask ourselves how good are we engaging with other disciplines, and therefore what position are we to take that holistic view, is a question I would pose. It is an observation I would make that several of our graduates, when they leave us, go on to take other degrees in things like economics and law, because they see what we are equipping them with is only part of the skill set they are going to need to be effective. Those are the observations I would make, and I would invite other members of the group to comment if I have missed anything.

Alan Strong: We looked at the holistic thinking trio of approaches under the heading of meta systems. We saw a sequence to this: developing an awareness of sustainable development, looking at multidiscipline issues. It was quite interesting in our group, some do, some don't. Those who did not were amazed that multidiscipline activity, even in awareness teaching, could happen. This brings me to a point I will make now, that the single-discipline engineering schemes within the Royal Academy in many ways are different to the built environment schemes within the Academy visiting professorship scheme, insofar as the built environment teams need to interact with many other professions, the single-theme engineering schemes do not need to do that. There was an issue made earlier that the built environment groups could do well to share a little better.

That awareness multidiscipline teaching goes on to the relationship systems approach, and relates back to the earlier point made about lifelong learning, about embedding the ability to learn and understand, so we are not depending on the shelf life of the knowledge but rather the ability to secure further knowledge. The awareness teaching is done in a variety of ways: large groups, small groups. We have some experience at Ulster in looking at online testing as a means of teaching and learning, and it has proved very beneficial. The whole issue of web chat rooms is another way of sharing information. The use of large case studies, some points were made by you, Richard, about certain reservations about those. After the workshop last year we went away and developed a suite of mini case studies, some from our large case study and some others. We found that very beneficial in design and workshop studios whereby you could tackle the whole issue of decision-making, appreciation of sustainable development issues, and a very short snap window of opportunity, and we had a great deal of benefit

out of that. It took away the whole issue of knowledge being retained by the author of the case study, which is a great danger.

Moving to problem-solving, the whole issue of looking at entrepreneurship, looking at things like interdisciplinary issues such as design, building business case studies. Those skills are around in our universities, may be not necessarily in our engineering or built environment departments, and we would do well to live off the fat of others' knowledge. That was some of the feedback from our group, but there is a sequence. This holistic thinking is central to the embedding of all the good fundamental knowledge.

Matthew Simon: Of these three techniques at the end, we did not spend a great deal of time on interdisciplinarity, although it was clear that those people who had tried to address the issue by putting together multidiscipline student groups to work on projects and case studies found in practice that was much more difficult in the university system than it should be. As far as holistic thinking and critical thinking went, the comment was made that there is some confusion about this and what holistic thinking means, and quite a need for staff development in these areas, in that although we recognise they are important, we do not quite know what they are or what they imply for the engineering pedagogical process. The Academy could give some thought to whether critical thinking should be taught specifically within engineering as a subject in its own right, as it is in some American universities. The systems thinking one was also recognised as important, and Alison McKay from Leeds had some comments about systems thinking that were quite relevant.

Alison McKay: The project I described and how it linked to systems thinking is that David and myself ran a project for a level 2 project design students last year, and we are running it again this year. The students started by researching in a broad area and, having done their research, they envisioned a future, and within that vision of the future they defined individual briefs and then designed products that would fit into this future, may be 10 or 15 years from now. One of the difficulties they had was articulating what this future might look like. This year for our level 3 students we have a module that includes soft systems thinking, so by the time the students graduate they will be able to use soft systems methodologies to write down the vision of the future into which their products and designs will fit.

Chairman: I am conscious of time. I would like to ask Gerald to come back and comment on these last two areas from his perspective.

Gerald Dawe: It has been fascinating to see the number of different approaches that have come out of these 11 prongs that prompted you to come up with

these solutions. There was a comment earlier about uncertainty in sustainable development, in other words what should it be, what should be taught. This is a big issue and therefore I reiterate what I said earlier. All of what could be regarded as contradictions we have heard this afternoon, for example people in favour of case studies, other people not using case studies for various personal reasons, all need to be preserved somehow at the moment, because this is the most powerful way to move forward in SD within the engineering profession. I would end with a simple plea to preserve all the discussion that has gone on this afternoon; it will be most fascinating to see it written up.

Chairman: Thank you very much. It is interesting. There has been some criticism of the list of 11 but it has prompted a pretty healthy discussion, and Gerald deserves a round of applause for the effort he has put in. [*Applause*]

[*Ends*]