The University of Manchester

Higher Education Academy, Engineering Subject Centre

Education for Sustainable Development in Engineering

Report of a Delphi Consultation

October 2007

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1. Introduction

This report is of a study, funded by the Higher Education Academy's Engineering Subject Centre, whose primary aim was to produce guidance for Engineering schools in designing modules or threads to embed sustainable development within the curriculum. A secondary aim was to investigate the use of Delphi[i] techniques in curriculum design[ii].

This work stems partly from a belief that issues of sustainable development are best tackled on a broad front and not in a single-discipline fashion[iii]. The underlying philosophy of the team towards education for sustainable development was one of encouraging collaboration, both between the various branches of engineering and also between engineers and other professions, to help towards the remediation of challenges that generally fall under the category of 'wicked problems'[iv]. This has underpinned many of the ideas and much of the work that we have initiated in this area. The pilot project[v] that we have been undertaking in the University of Manchester, sponsored by the Royal Academy of Engineering, proved a useful step along the road, but it is only a first step. A brief report on this project is appended at Appendix C. We saw synergy between the RAEng project and this project; in particular, we used the experience we gained on the pilot module in order to shape the issues to be tested in the Delphi process. This was a very cost-effective way of achieving something that we believe to be of great value across the subject area and also, potentially, for other disciplines in UK universities.

2. Setting up the consultation

The project undertook a modified 'Delphi' study to bring convergence of the views of experts from a range of engineering disciplines. This focused on a small number of related questions – for example *'What is a working definition of 'Sustainable Development' in the context of engineering education?',* within an overarching one of '*How may students in a Faculty of Engineering be assisted to develop a set of competences which will enable them to contribute to S D related aspects in their professional practice*? '

The final list of questions is given in Appendix A.

The initial step was to identify a team of experts to participate in the consultation. From our project for the Royal Academy of Engineering, we had already built a small core of contacts and we invited some of these to suggest others, in order to build a comprehensive list. We contacted all of those on this initial list to see if they were willing to participate and this reduced the number to thirty. The consultation was then conducted in four phases:

- In Round I we circulated a suggested list of questions and asked participants both to comment on the questions and also to suggest others if they wished.
- In Round II the consultation invited open ended suggestions in relation to the overarching question and the wider list of considerations.
- In Round III the consultation invited participants to review the summary of suggestions from Round II, ranking them and adding further suggestions.
- Round IV reported back to the participants on the outcomes of the consultation. These could then play a central role at an in depth discussion among those interested in the further development of education in sustainable development in the field of Engineering.

Participants were not required to participate in every round or to complete every question in that round: each was able to contribute to the extent that he or she wished. This meant that we had different numbers of responses for the different rounds and, indeed, different respondents. We had made provision for an additional consultation round – between III and IV – if necessary, but we felt that we had already achieved a fair degree of convergence of responses by the end of Round III.

3. Results of the consultation

The full results of the consultation are given in Appendix B.

3.1. Definition

The first point of note was the widespread acceptance of the definition (originally that used in our RAEng project) of Education for Sustainable Development, in the context of Engineering, as *"Education for Sustainable Development aims to enable the professional engineer to participate* with a leading contribution *in decisions about the way we do things individually and collectively, both locally and globally, to meet the needs and aspirations of the present generation without compromising the ability of future generations to meet their own needs and aspirations.*"

3.2. Sustainable development challenges for engineers

The main challenges in this area were generally seen to be social and political, rather than technical - being socially and politically skilled as well as technically so. Also identified was a need to confront conservative ideas and reluctance to change.

3.3. Sustainable development responsibilities for engineers

Awareness raising and communication came out as key responsibilities for newly graduated professional engineers, with technical skills only in second place.

3.4. Sustainable development tasks for engineers

In terms of tasks, the prime concerns were in evaluating complex problems (essentially the wicked problems that we had identified in earlier work) and in systems modelling to try to cope with this complexity. Individual engineering disciplines identified specific tools and techniques that might be expected to be employed (though the number of respondents was too small to otherwise make distinctions) but another major task was seen as that of participating in change management.

3.5. Sustainable development skills for engineers

Reflecting the weighting given to systems modelling, the dominant generic or transferable skill identified was that of dealing with complexity, but also being able to think 'outside the box'. Other skills felt to be important were those of communicating and networking – particularly across disciplines.

3.6. Designing education for sustainable development

In terms of curriculum, the strength of feeling was that sustainable development should be embedded throughout and that student-centred learning methods, in particular role play and case studies, were most appropriate. Because of the nature of our question, it was not easy to reach a consensus about what percentage of the curriculum this should occupy, but a figure of about 10% seemed to be the median. This is compounded by the view of embedding: for some this suggests that sustainable development then inevitably becomes 100% of the curriculum, at least in terms of underlying philosophy. A significant number of respondents felt that sustainable development should form a compulsory element of the curriculum and others felt that making it compulsory was the only way to get students to take on board issues of sustainable development.

3.7. Evaluating education for sustainable development

In terms of evaluation, many favoured the final year project as the way to demonstrate that the lessons of sustainability literacy had been taken on board, but with recognition of the wider perspectives, not just the narrow technical ones.

3.8. Embedding education for sustainable development

There was a strong feeling that the engineering bodies should be solidly behind the idea if it was to achieve recognition by all academics in engineering. Also, it was felt that higher education institutions needed to embrace the ideal, preferably in their mission statements.

4. Delphi technique and curriculum development

This was a stimulating if, at times, difficult exercise in using the Delphi technique. Perhaps the biggest constraint was the relatively poor response rate. The number of respondents was appropriate to this technique and in other circumstances the response rate would be regarded as good. However, many of those who agreed to participate did not contribute at all or contributed only marginally. Those who did take part produced some interesting, and often challenging, responses that made us feel that the exercise had been worthwhile. The key is getting the initial set of questions right and so it was vital for us to treat the first round as a consultation on what questions should be asked, rather than on what responses we sought. This approach should be readily transferable to other curriculum questions, eg in the teaching of ethics to engineers. We formulated four rounds but stood ready to increase this number if we had not obtained reasonable convergence by the end of the fourth round. This, inevitably, has to be a *post hoc* judgement in the light of responses received.

5. Conclusions

The Delphi consultation has brought to light some consensus about the design of curricula for sustainable development within engineering courses. Much, but not all, of this accords with our expectations at the outset. We hope that this will form a useful basis for engineering departments to explore their sustainable development curricula.

The process of using the Delphi consultation was an interesting and challenging one. We considered using online methods but found that none of them ideally suited our approach. This meant that the majority of responses were received by email and analysed manually. As many of the answers were complex, this meant that the collation of responses was equally, if not more, complex. We feel that the use of open-ended questions enabled us to gain deeper insights but at the expense of more efficient methods of analysis. We approached ninety experts in the field, of whom only thirty agreed to participate. This is still a reasonable number for this type of exercise but does point to the need to have a wide field on which to draw. We believe that the exercise was a successful one and that the approach could readily be applied to other areas of curriculum design.

Acknowledgements

The intellectual stimulus for this project, and much of the hard work, came from Professor Charles Engel, ably supported by Bland Tomkinson, the University Adviser on Pedagogic Development. My own role in this has been much more one of coordination. Our project assistant, Alvin Lawson, undertook much of the correspondence with participants and collation of the data and Anna Christie provided considerable administrative and clerical support to the whole team. I am grateful for the support of the Engineering Subject Centre for the project, especially the personal support given by Dr Simon Steiner.

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September 2007

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i The Delphi process involves a series of structured conversations between leading experts with the aim of reaching a group consensus on issues, scenarios or solutions. See, for example, http://www.is.njit.edu/pubs/delphibook/ch1.html

ii See also: Reeves G, Jauch L R (1978)' Curriculum development through Delphi'. Research in Higher Education, 8(2), pp157-168.
McLeod P L, Steinert Y, Trudel J, Gottesman R. (2001) Curriculum for education. Delphi process to identify the curriculum. Medical Education, 38, pp548-556.

iii See, for example, Tomkinson B, Warner R and Engel C (2005). Interdisciplinary Education for Societal Responsibility - A Major Reform in University Education. Paper given to Education for Sustainable Development Conference, Bournemouth, September 2005 and, also, http://www.unimaas.nl/gandi

iv According to Rittel H and Webber M (1973) 'Dilemmas in a General Theory of Planning' Policy Sciences volume 4, a 'wicked' problem has many of the following characteristics: it has no definitive formulation; it has no clear end, no 'stopping rule'; it has a solution that is 'good or bad' rather than 'right or wrong'; it has no immediate or ultimate test of its resolution; it has consequences to every solution, so that there is no possibility of learning by 'trial and error'; it does not have a well-described set of potential solutions; it is essentially unique; is a symptom of another problem; has causes with no unique explanation; it brings expectations that its 'owner' will find the 'right' answer.

v See, for example, Tomkinson B, Engel C, Tomkinson R and Dobson H (2007) 'Introducing an interdisciplinary professional course on Sustainable Development into Engineering programmes.' In Aung W et al (eds) 'Innovations 2007', International Network for Engineering Education and Research.

Appendix A

Results of the Delphi Consultation

1. Please suggest what **you** would see as a useful working definition of Education for Sustainable Development, in Engineering.

The clear favourite was:
"Education for Sustainable Development aims to enable the professional engineer to participate with a leading contribution *in decisions about the way we do things individually and collectively, both locally and globally, to meet the needs and aspirations of the present generation without compromising the ability of future generations to meet their own needs and aspirations.*"

The second choice of definition was:
"Education for sustainable development promotes the responsible use of energy and resources at a rate, and in a manner, which does not compromise the integrity of the natural environment, or the ability of future generations to meet their needs. Some of the most challenging tasks for our current society lie in achieving environmental, social, and economic developments that are sustainable. We can only achieve this by changing our behaviour and enhancing our technological capacity. The role of engineering is crucial to this in advancing technologies that can help protect the environment while contributing to competitiveness and human development"

2. SD calls for wider, interdisciplinary collaboration, but what would **you** regard as *the main challenges of SD* that are most frequently encountered in **your** branch of engineering?

The strongest challenge came out as:

Social aspects
" .. *the engineer is not just a technician but a social and political agent."*
"..weak appreciation of what is meant by 'social', 'equality'.."

Other challenges were noted as:

Confronting Conservatism
"..reluctance to change established practice.."
" The assumption that the way business operates... is optimized. It isn't..."

3. What would **you** regard as the most important *responsibilities* of a recently graduated engineer in relation to the main challenges of SD?

The most important responsibility was given as:

Raising awareness
" .. put SD on the agenda – everyday, at all projects.."

Almost equal in second place were:

Possessing technical knowledge
".. use their … technological expertise.."
Appreciation of others' roles
" value multidisciplinary working"
Communicate understanding
" To be able to communicate this understanding.."
"..efficiency of communication"

4. What *tasks* would **you** expect a recently graduated engineer in your branch to be able to carry out in relation to these *responsibilities*?

The most important task was:

Modelling and evaluating SD performance

" Be able to undertake engineering evaluation and design in the light of a underpinning background in the S & SD area. If this is partial to the whole project the graduate should be able to "check" the whole project … and then accurately evaluate the partial for its S &SD and how well this fits with the whole project"

Almost equal behind this were:

Personal and organisational development

" .. influencing organisational change .."

" .. have sufficient knowledge to learn more about it .. "

Specific technical skills

"design calculations"

"mass balances energy flows"

"complex computational tools"

5. What *general or 'transferable' abilities and skills* would **you** regard to be important in the successful execution of these *tasks*?

The most highly regarded skill, by far, was:

Dealing with complexity

"Ability to make a decision related to complex issues"

"Criticality, analysis, problem-solving and creativity"

Almost equal second, but much further down the list, were:

Communication skills

".. construct coherent arguments"

Networking

" .. develop and maintain co-operative networks .."

" appreciation of other people's points of view"

Lateral thinking

" .. ability to think outside the box .."

6. In **your** opinion how could the students be helped to develop the general *abilities and skills*?

The strongest support came for:

Case studies and role play

" .. case studies based on real life"

" .. role plays and simulations .. "

Other suggestions included:

Interdisciplinary learning

" .. collaborative learning, particularly across disciplines.."

" .. cross-disciplinary processes .."

7. **(i)** How could such educational *activities* be organized within the students' curriculum?

There was very strong support for:

Embed in the entire curriculum

" .. embedded in the whole professional educational curriculum.."

"Do not have a separate SD module. Do integrate SD considerations .."

A second, though much weaker, thread was:

Introductory/short courses

" .. short courses on sustainability literacy"

" .. optional strands .."

(ii) How much curriculum time would need to be assigned to your suggestion in (i) above? This proved difficult to assess from the answers, but the mean was around 10% with a significant number of respondents opting for 20% or more.

8. What evidence would satisfy **you** that the education in relation to SD had been effective?

Almost equal in favour as the two types of evidence were:

Demonstration of a wider perspective

" .. understanding that sustainability is about process, not about technology and products .."

Project work

" final year project"

" .. through project and design work.."

9. What incentives might be offered to persuade students in your branch of engineering to participate in SD education?

The favoured incentive was;

Make it compulsory

" .. sensibly incorporated in the core curriculum."

There was also strong support for:

Evidence of enhanced employability

" .. better prospects for the future .."

" .. accreditation by Institutes .."

10. How might academics be persuaded to develop SD courses or components or to include SD in their existing courses?

A very clear message came about the development of courses, with strong support for:

Support from professional bodies

" I suspect the professional institutions are the best placed .."

" .. clear requirements from the accrediting institutions .."

Also highly regarded, though very much a second thread, was:

Institutional vision and leadership

" .. part of mission statement .."

" .. leadership style and culture .. "

Appendix B

Participating experts

Charles Ainger	University of Cambridge
Mustafa Akay	University of Ulster
Gordon Baker	Heriot Watt University
David Bartholomew	De Montfort University
David Book	University of Birmingham
Stefan Boron	Heriot Watt University
Jack Bradley	University of Bradford
Roland Clift	University of Surrey
Richard Darton	University of Oxford
George Drahun	Aston University
Alan Emery	University of Bath
Roger Falconer	Cardiff University
Jacqueline Glass	Loughborough University
David Grierson	University of Strathclyde
Sue Haile	University of Newcastle
Sandy Halliday	University of Strathclyde
Rex Harris	University of Birmingham
Sally Heslop	University of Bristol
David Hicks	University of Bath
George Howarth	Bournemouth University
Jeff Hulse	University of Newcastle
John Hughes	University of Sheffield
Jamal Khatib	University of Wolverhampton
Paola Lettieri	University College London
Andrew Lloyd	University of Brighton
Alison McKay	University of Leeds
Roger Penlington	University of Northumbria
Shahin Rahimifard	University of Loughborough
Ed Stentiford	University of Leeds
Alan Strong	University of Ulster

Appendix C

Education for Sustainable Development – the RAEng pilot module

1 Introduction

Members of the project team have challenged higher education for some while (see Engel and Tomkinson, 2006) about its response to complex, 'wicked', global problems, initially from the standpoint of interdisciplinarity with societal responsibility. We have also looked at the universities' role with regard to sustainable development and also (Tomkinson, Engel and Tomkinson, 2006) at the nature of these wicked worldwide problems: Gro Brundtland (1987) identified a number of such issues, including:

- The burden of debt in the developing world, inequitable commercial regulations and a growing number of the world's population living at or below subsistence level;
- Overuse of non renewable resources, growing competition for limited water supplies and threaten armed conflict over access to water;
- Reduction of biodiversity and continuing desertification;
- Pollution of air, water and soil with detrimental influences on the global environment and climate change;
- Continuing growth of the world's population, coupled with additional economic pressures caused by increased life expectancy;
- Increasing nationalistic, political and religious extremism, terrorism, armed conflict, mass migration and social disruption.

In describing such problems as 'wicked', we have drawn upon Horst Rittel and Melvin Webber (1973). But, politicians have a notoriously short-term view of these complex issues and it falls to the professions to 'carry the torch' for their amelioration and resolution.

2 The challenge for educating professional engineers

The challenge for the future education of professional engineers is both to higher education and to the profession itself. In the US, the National Academy of Engineering (2005) suggested that '[the] future engineering curriculum should be built around developing skills and not around teaching knowledge… We must teach future engineers to be creative and flexible, to be curious and imaginative.' In the UK, the Engineering Council produced new standards of engineering competence (2005) that explicitly included sustainable development. The standards document states that: '[Engineers have a] crucial part to play in minimising risk to the environment, and in bringing about sustainable development, not only in the UK but throughout the world.' Also in 2005, the University of Manchester invited the Royal Academy of Engineering to sponsor a pilot project for an interdisciplinary stream on sustainable development in undergraduate engineering and physical sciences programmes. This interdisciplinary, problem-based, pilot course started in January 2007.

3 Curriculum design

The key to the design of the curriculum was a detailed, step by step process, involving the use of four advisory groups (see Tomkinson, Engel, Tomkinson and Dobson: 2007) the essential nature of which was:

- Defining a working definition of 'Sustainable Development'.

- Identifying abilities and skills that ought to begin to be developed in the pilot module in the context of realistic case studies. Eighteen case studies were identified initially and five were developed for use in the pilot module.
- Identifying how the learning outcomes of this module might be assessed and how successful participation by the students might be recognized.
- Monitoring and evaluating the process of implementing the pilot module, and how commitment to a new approach to teaching and learning might be recognized.

The advisory groups were drawn mostly from senior academic staff and were set up with a limited time commitment for any one individual.

The key was the design of the exercises and the learning taking place in small student groups. So, one of the pivotal roles was that of the facilitators, who were recruited from amongst post-doctoral research staff. These were trained specifically for this key task and their induction training was also used to identify those among the many volunteers most likely to be comfortable in this unusual role. The role involves acting as friend and adviser to students, in how to benefit from the unfamiliar opportunity of being responsible for their self-directed learning, rather than traditional teaching. Cynthia Mitchell and others (2004) suggest that learning how to learn is the single most important goal for sustainable development and that Problem-based learning (PBL) naturally lends itself to this situation. However, '[a] shift to PBL may be challenging. Part of this challenge arises from the adjustment required in educators and learners mind-sets… the locus of responsibility for learning rests much more firmly with the student… This represents a challenging shift for teachers of science and engineering, who may be skilled at and derive great satisfaction from the more accustomed practice of delivering "objective" knowledge.'

Each of the five student exercises extended over three weeks, with one small group session in each week. Each group comprised two students from each of the four disciplines. They elected a *secretary* who liaised with the Project Team. For each exercise, the group recruited one of its members to act as *scribe* - to note the group's progress in its discussions:

- Session **one** focussed on identifying the nature and challenges in the task presented in a *scenario*, ending with agreement on the allocation of questions to be followed up through private study, in preparation for the next session.
- Session **two** started with the exchange of what had been learned in answer to the questions and a brief formative assessment, followed by a discussion of suggested 'model answers', for early feedback. The second half of the session led to a discussion to plan how the task was to be undertaken by the Group.
- Session **three** began with a discussion of the appraisal of the group's report by an expert. The session ended with a period of reflection where all students were encouraged to summarise how they had learned and how they had helped the group.

4. Assessment

Because of the student-centred and problem-based nature of the design, the development of assessment was fairly complex. We had to balance the need for assessment to support the way the project team wished to help students to develop new competences with the need to comply with institutional rules and regulations. To achieve some balance the team developed four different assessments:

- Modified essay questions (see Feletti and Engel 1980). The one-hour examination was designed to deliver two scenarios and to test individuals' knowledge and comprehension.

- Staff Observation. For the final scenario, groups were monitored by a facilitator from another group with a checklist of attributes of group collaboration to observe. A team of senior assessors based criterion referenced judgements on the recorded observations.
- Group Report. At the conclusion of the final scenario each group submitted a written report marked on the basis of application of the knowledge and understanding gained over the duration of the course.
- Peer Assessment. Each group member was given a checklist and asked to indicate the presence, or otherwise, of a number of contributions to the group process, from each of the other members of the group. These anonymous judgements were collated and used for the allocation of individual marks by the team of senior assessors (see Conway, Kember, Sivan and Wu, 1993).

The formative assessment largely mirrored the summative assessment. The reflective period towards the end of the second session for each of the first four exercises provided students with the opportunity to identify not only how they had arranged their learning, but also how they had collaborated within the group

5. Facilitators – selection, induction & support

We received a large number of applications to be considered as facilitators and we were keen to select post-doctoral researchers who were: good listeners, encouraging regarding creative ideas, sensitive to students' concerns and confident enough to travel an unfamiliar path with us. Clear communication skills were also important, especially as so many of our students come from all over the world.

Induction of the facilitators was conducted in four sessions: the sequence started with a general discussion of the process of PBL, particularly for the development of abilities and skills in relation to sustainable development in engineering. In the second session they looked at the activities which they would set out to support in the three sessions which are assigned to each scenario. They also began to take it in turns to role play what the facilitator would do during the first session of a new Exercise. The third session set out to reinforce what had been discussed in the previous session and to provide opportunities for further role play. The final session examined the content and related challenges of the first Exercise for the student groups.

Support for the facilitators was primarily their participation in the regular, informal 'post session debriefing session', where they meet with members of the Project Team to exchange impressions and experiences, as well as observations relating to the members of their group. This exchange represented a significant opportunity for support and learning from each other.

6 Student exercises

The design of the student exercises was no easy task. The need to find problem scenarios: that challenged students, without becoming over-facing; built knowledge cumulatively, without undue repetition; between them covered a range of topics in sustainable development, without focusing unduly on subject knowledge; allowed for interdisciplinary interplay, without becoming shallow and anodyne – was a complex one, and doubtless the authors will be criticised for not 'covering' someone's favourite topic or technique. The scenarios used, ultimately, in what was originally intended to be an Introductory Module, are described briefly in Table 1.

Title	Aspects	Task
Wheels	Sustainability definitions, tools and techniques; Corporate attitudes; Understanding stakeholders' perspectives.	Recommend sustainable development initiatives for the company. A consultant's letter provides a list of projects that students may decide to investigate and could choose to include in their plan.
Shelter	Impacts of natural disasters on communities; Stakeholder co-operation; Infrastructure and logistics; Cultural etc differences; Sustainable design.	Develop a strategy for transitional accommodation (housing, schools, clinics, etc) after a natural disaster. Analyse possible alternative approaches and propose a sound and sustainable strategy for their construction. Achieve a realistic and workable balance between international aid and local skills and manpower.
Rules	Implementing change via regulation; Impact of environmental regulation; Impact on supply chain: Minimising life cycle impacts.	Review the UK's implementation of specified EU directives, identifying weaknesses in minimising the negative life cycle impacts (environmental and social) of PCs etc, particularly as they affect small businesses.
Energy	Implementing change through new technology; Cost-benefit analysis; Barriers to new technology; Infrastructure support for new technologies.	Weigh up the social, financial and environmental impacts of devices such as wind-turbines, solar water heating, geothermal heat pump and photovoltaic cells, through an initial cost-benefit analysis. Understand the implications of introducing new technology to the marketplace.
Shops	Implementing change through company policy; Supply chain management; Assessing sustainability; Benchmarking.	Assess the current supply chain sustainability; evaluate the company against industry good practice in terms of the supply chain sustainability and recommend actions to ensure consistency with government requirements for "green procurement"?

Table 1 Student exercises

7 Monitoring and evaluation

Monitoring is a means of gathering data in relation to the ongoing process of planning, designing, implementing and assessing the curriculum and also provides an opportunity for identifying what goes wrong and may be fixed *en passant*. This was done in a number of ways:

- First, the reflections of the project team have been captured as we have gone along.
- Second, there have been weekly debriefings of the facilitators, as a group, and the results of these deliberations and reflections are written up.
- Third, the students have completed three questionnaires, each no more than one side of A4, intended to measure changes in: self-perception of skills in, and attitudes towards, sustainable development; approaches to study, using a modified version of the SETLQ questionnaire (ETL Project 2005) and; readiness for interdisciplinary learning, using a modified version of the RIPL questionnaire (see Mattick and Bligh 2006).
- Fourth, the team obtained student and facilitator feedback through the nominal group technique (see, for example Mackay, 2003) to identify what the students and, separately, the facilitators found so good that it ought not to be changed and what was so weak that it ought to be changed in any rerun of the module.

The results of the student evaluation data were, to some extent, mixed. The scores given on the standard university module satisfaction questionnaire were exceedingly high on most attributes and those attributes that fared less well were inappropriate to this mode of

learning. The self-perception questionnaire showed a demonstrable improvement in perception of skills in relation to the learning, over the course of the module. The SETL questionnaire showed significant increases in deep learning, and commensurate decreases in surface learning, but the RIPL questionnaire showed no significant change. The last of these came as no surprise since the initial RIPL scores were very high, perhaps reflecting a large element of self selection.

From the nominal group results, we learned that there was unanimity, in the end-of-session administration, about the value of inter-disciplinary working, something only mentioned by half the groups in mid-semester. Groupwork featured in most of the responses in both mid-semester (where it had the highest incidence across the groups) and also at the end of the semester. The course content also featured in the top three positive aspects on both occasions, occurring in half of the groups. The variety and nature of assessment featured positively at the end of semester (coming in the top three of half of the groups) but had not featured at all in mid-semester, although both the learning approach and also the feedback received had merited mention. On the negative side, timetabling issues featured prominently on both occasions. These varied from difficulties of trying to get together students from different programmes to lack of enthusiasm for 9am starts! Timing also came under scrutiny in two other ways: timing of assessments (both formative and summative), particularly where this conflicted with major pieces of work for other modules, and also the structure of the weekly two-hour sessions. A concern for a lack of contact with other groups in mid-semester disappeared by end of semester, by which time the noise of other groups, working in nearby areas, had become an issue!

The results of the mid-semester nominal group process for the facilitators showed their key positive points to be the imaginative and varied tasks, the use of problem-based learning and the use of communication skills and group learning, though the facilitators also felt that it was a valuable learning exercise of their own. By the end of the semester the multidisciplinary nature of the module featured more prominently, together with the currency of the issues raised in the scenarios and the professional development aspects. The two key concerns at the mid-point were the narrow range of disciplines represented by the students and the roles of the two ‘reserve’ facilitators. The imprecise role of the ‘reserve’ facilitators was still prominent in the end-of-semester session but was joined by some unease with the modified essay questions and a suggestion for a broader range of topics.

8 Conclusions

In view of a number of obstacles, we would have liked rather more time for the process and more financial flexibility. Our original intention was to provide an introductory level course for first year undergraduates, but timetabling difficulties precluded this, and we had to focus on a third year option.

For the pilot course the team restricted the student numbers to six groups consisting of pairs from four discipline streams – Civil Engineering, Electrical Engineering, Mechanical Engineering and Earth and Environmental Sciences – a total of 48 students. This gave us an immediate problem, as the pilot unit was heavily oversubscribed and the project team had to find ways of sifting down to the required number. In the event, the university’s student record system and approach to third year options meant that some students did not turn up for the first session and lost their place. We had similar problems in recruiting post-doctoral research staff and had to turn away some very good candidates. After the first selection, the remaining candidates received their induction training and eight were chosen to act as facilitators. It did mean that the disciplines covered by facilitators were extended to include Chemical Engineering, Chemistry and Computer Science.

The pressure of other responsibilities, the limitation of three days per week for the project manager and the location of the Visiting Professor in London caused essential communication, particularly with the Steering Group and the four Advisory Groups, to be less frequent and personal than some of us would have wished. At the same time we need to acknowledge that ours is a difficult and complex task that calls for more time to overcome inevitable, vested interests in maintaining the *status quo* or in developing sustainable development in a narrow, single-discipline fashion.

REFERENCES

Brundtland, G.H., Our Common Future New York, United Nations, 1987

Conway, R., Kember,D., Sivan, A. and Wu, M., 'Peer assessment of an individual's contribution to a group project'. Assessment and Evaluation, Vol 18 no1, (1993) pp 45-56.

Engel, C.E., Towards a European approach to an enhanced education of the health professions in the 21st Century. London, CAIPE, 2002. Available online at http://www.caipe.org.uk/pdf/CEReport.PDF (accessed 23 March 2006)

Engel, C.E. and Tomkinson, B., 'Changing higher education to face the global challenges of sustainability', in Hunt, L., Tomkinson, B. and Bromage, A. (eds). Realities of Educational Change in Higher Education. Routledge, Falmer, 2006.

Engineering Council UK, UK Standard for Professional Engineering Competence: Chartered Engineer and Incorporated Engineer Standards. London , Engineering Council, 2005.

ETL Project, Shortened Experiences of Teaching and Learning Questionnaire. 2005. Available online at: http://www.tla.ed.ac.uk/etl/docs/SETLQ.pdf (accessed 13 February 2007)

Feletti, G.I. and Engel, C.E., 'The modified essay question for testing problem-solving skills'. The Medical Journal of Australia Vol 1 no 2, Jan 1980 pp79-80.

Mackay S., 'Problem-based Learning in Radiographer Education: Testing the Water before Taking the Plunge'. Case Study 8 in Smith B. and Tomkinson B. (eds), 'Critical Encounters: scholarly approaches to teaching and learning', York, LTSN Generic Centre, 2003. Available online at https://www.heacademy.ac.uk/profdev/case_study8.pdf (accessed 13 February 2007)

Mattick, K. and Bligh, J. 'Getting the measure of inter-professional learning' Medical Education, 40, pp. 399 – 400, May 2006.

Mitchell, C.A., Carew, A.L. and Clift, R., 'The Role of the Professional Engineer and Scientist in Sustainable Development' in Azapagic, A., Perdan, S. and Clift, R. (eds) Sustainable Development in Practice: Case Studies for Engineers and Scientists. Chichester, Wiley, 2004.

Rittel, H. and Webber, M., 'Dilemmas in a General Theory of Planning' Policy Sciences vol 4. Amsterdam, Elsevier, 1973.

National Academy of Engineering, Educating the Engineer of 2020. Washington, National Academies Press, 2005.

Tomkinson, B., Engel, C.E. and Tomkinson, R., 'Extending our boundaries: higher education and new solutions for complex problems'. Paper given to the 31st Improving University Teaching Conference, Dunedin, New Zealand, July 2006.

Tomkinson, B., Engel, C.E., Tomkinson, R and Dobson H., 'Introducing an interdisciplinary professional course on Sustainable Development into Engineering programmes.' In Aung W., et al (eds), Innovations 2007: World Innovations in Engineering Education and Research. Redding CT, Begell House, 2007.