Developing sustainable development

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Abstract

Ralf Brand and Andrew Karvonen (The ecosystem of expertise: complementary knowledges for sustainable development. *Sustainability: Science, Practice and Policy*, 3(1), pp 21–31, Spring 2007) suggest that sustainability poses challenges to the discourse of technical experts and that many existing models do not fit with traditional disciplinary boundaries. In this context, the education of engineers and scientists in sustainability literacy has to be regarded afresh. Brand and Karvonen argue for the development of 'meta-experts' who have '... a clear understanding of what specific disciplines can and cannot contribute to problems of sustainability.' Our own approach arose from a concern for developing graduates to tackle and ameliorate global issues, many of which might be deemed as problems of sustainability and all of which might be considered as 'wicked'. To that end, higher education has to be seen as inter-disciplinary, student-centred and problem-based. As part of the development of these ideas, we obtained funding from the Royal Academy of Engineering to design and run a pilot module on sustainable development for engineers and scientists.

This paper looks at the curriculum design process, the development of the case studies used, the mode of assessment (including the use of modified essay questions) and the way in which the programme was received by students and facilitators. The mode of delivery was essentially that of problem-based learning and small groups, drawn from across one science and three engineering programmes, were each facilitated by a post-doctoral researcher who was specially trained for the task. The students undertook a readiness for inter-professional learning questionnaire, a learning styles questionnaire and a self-evaluation questionnaire both in the initial stages and at the end of the pilot programme and these have formed part of the evaluation. The principal means of evaluation, however, has been through a nominal group process, both for students and for facilitators. The results of these evaluations form the final part of the paper.
Keywords: curriculum design, inter-disciplinarity, staff development, student development, sustainable development.

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1 The ultimate challenge

In a keynote speech to a University of Manchester symposium in 2002, Charles Engel presented what he described as the 'ultimate challenge' [3]. He made the point that the magnitude and complexity of the numerous problems facing the present century require nothing less than inter-professional and inter-sectoral collaboration across the world. Politicians have a notoriously short-term view and so it is incumbent upon the professions to 'carry the torch' for the resolution of these complex issues. One outcome of the symposium was that members of the project team, Charles Engel and Bland Tomkinson [2], have challenged the higher education community about its response to complex, some might say 'wicked', global problems. Initially this was from the standpoint of an approach to such problems that was inter-professional and inter-sectoral, with an emphasis on societal responsibility. Within this context we have also looked at the role of universities, particularly with regard to sustainable development. Three of us, Bland Tomkinson, Charles Engel and Rosemary Tomkinson [4], have looked at the nature of the major problems facing the world, based partly on the ideas of Gro Brundtland [5], who identified an array 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 these problems as 'wicked', we have drawn upon Horst Rittel and Melvin Webber's [6], view of a wicked problem as:

- Having no definitive formulation;
- Having no clear end, no 'stopping rule';
- Having a solution that is 'good or bad' rather than 'right or wrong';
- Having no immediate or ultimate test of its resolution;
- Having consequences to every solution, there is no possibility of learning by 'trial and error';
- Not having a well-described set of potential solutions;
- Being essentially unique;
- Being a symptom of another problem;
- Having causes with no unique explanation;
- Bringing expectations that its 'owner' will find the 'right' answer.

Clearly, not all of these have to be present for a problem to be 'wicked', but it is equally clear that many of the issues of sustainable development align with these determinants. Moreover, it can be seen that curriculum design in this area also possesses many of the attributes of 'wickedness'.

Ralf Brand and Andrew Karvonen [1] advocate an inter-disciplinary, perhaps a meta-disciplinary, approach as the only way forward in issues of sustainability: 'influential exemplars of sustainability scholarship … are conceptual hybrids that do not fit with traditional disciplinary boundaries.' They suggest that sustainability poses challenges to the discourse of technical experts and so, in this context, the education of engineers and scientists in sustainability literacy has to be regarded afresh. Brand and Karvonen argue for the development of 'meta-experts' who have '... a clear understanding of what specific disciplines can and cannot contribute to problems of sustainability.'

2 Curriculum design

An opportunity to put our ideas into practice arose when the UK Royal Academy of Engineering agreed to support a project to introduce a novel inter-disciplinary module in sustainable development in the University of Manchester. At the time that we approached the Royal Academy of Engineering, the National Academy of Engineering [7] in the US 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.' And, the Engineering Council [8] in the UK produced new standards of engineering competence that explicitly included sustainable development: '[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.'

Two key principles underlined our approach to curriculum design in this context. First, we believed that the only way to tackle the 'wicked' problems of sustainable development was though and inter-disciplinary, student-centred approach. Cynthia Mitchell and colleagues [9] suggest that learning how to learn is the single most important educational 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.' In our view, PBL enables students to:

- Practise a logical, analytical approach to unfamiliar situations;
- Activate their existing knowledge;
- Elaborate new knowledge;
- Learn in the context in which knowledge is to be used;
- Learn in an integrated fashion;
- Practise application of new knowledge;
- Practise critical reasoning;
- Practise critical appraisal;

- Practise self-directed learning;
- Practise different communication skills;
- Practise collaboration in a team;
- Practise reflective learning.

These opportunities need to be exploited quite deliberately by the students' small group facilitator.

Second, we saw a need to establish dialogue before attempting to deal with the, apparently simple, task of developing a curriculum. To achieve this, we developed four advisory groups to, respectively:

- Define a working definition of 'Sustainable Development'.
- Identify abilities and skills to be developed in the module, in the context of realistic case studies.
- Identify how the learning outcomes of this module might be assessed, formatively and summatively, and how successful participation by the students might be recognized.
- Monitor and evaluate the process of implementation and identifying how commitment to a new approach to teaching and learning might be recognized.

These groups were drawn mostly from senior academic staff and were designed to require only limited time commitment from any one individual. The intention was that these groups would help to ensure the credibility and encouragement of the educational approaches among their colleagues.

In this context, the definition arrived at by the first advisory group 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.'

3 Case studies

One unexpected, though minor, problem has been one of terminology. And, in some ways this reflects one of the issues of inter-disciplinary working - that of understanding one another's language. Our approach was a series of five 'triggers' that would prompt the student learning over the next two weeks. Some of these were designed by individuals brought in from other schools, faculties or universities. Traditionally these could be thought of as 'problems', but that could lead to a traditional problem-solving approach rather than a problem-based learning one. Some regarded them as case studies but, again, this can lead to a teacher-oriented approach rather than a student-centred one. In discussions with students and facilitators, we most often describe the triggers as 'scenarios' but for external purposes we more often describe them as case studies.

Forty-eight students, from four disciplines, were chosen to undertake the pilot module in inter-disciplinary teams of eight. Session were held for two hours every Wednesday morning and followed the pattern of: a one-hour introduction to the scenario (in some cases the designer would give the whole group a brief presentation) with the students discussing what they needed to do and allotting the tasks between them; for the whole of the session in the second week, the students reported back and discussed the issues and then allocated responsibilities for the report on the task, which had to be submitted the following weekend.; the first hour of the third week was then taken up with further discussion and feedback on their report, delivered by their facilitator, from the academic responsible for that case study, followed by a brief period of reflection on what had been learned from the scenario and how each student had collaborated with the group.

The design of the triggers was a complex process. The initial challenge was to provide triggers that covered the whole spectrum of sustainability issues, but we soon realised that this was an impossible task. By carefully selecting from the eighteen potential case studies, we came up with five that could be structured to cover a range of economic, environmental, legal, political, social and technical issues. Table 1 briefly describes each of the student exercises and the sustainability aspects that it was designed to feature.

4 Facilitators and facilitation

At an early stage we took the decision to hire post-doctoral researchers to look after the facilitation of the student groups. Each of these was given six hours training in facilitation skills and in problem-based learning; the response to the training was also used for the final selection of facilitators.

Two induction/training sessions were held before the final selection was made. The first two hour induction session included an introduction to the project and its aims followed by a general discussion about the nature of problem-based learning and how it can be applied as a means of developing skills and knowledge. The candidates then took turns to practice facilitating small group discussions, on 5-minute controversial discussion topics. The second two hour session gave a briefing on groupworking – group properties and stages of development, conflict and dysfunctional groups, and examples of criteria for assessing group interactions. The candidates were then introduced to a method of analysing problems by listing the information known about the problem, hypotheses or possible solutions and questions that need to be followed up to test each hypothesis or solution. Having been split into three groups, the candidates were then observed facilitating the rest of the group in tackling a ten minute exercise using this technique, by members of the project team. The results of these observations were part of the means of selecting successful candidates. The criteria used to select the successful candidates were that they should be good listeners; good communicators; encouraging to students; sensitive to students' concerns; confident; able to resist the temptation to direct the group, and; open to new ideas. The selected candidates came from a wide range of disciplines, mostly different from those of the students, and of different nationalities.

Although we had six student groups, we hired eight facilitators in order to provide cover for absences; as it turned out this was a wise precaution. One of the challenges was to get the facilitators to understand that they were not required to

Table 1: Scenarios.

Title	Aspects	Task
Wheels	Implementing change within a company; Sustainability definitions, tools and techniques; Corporate attitudes; Understanding stakeholders' perspectives.	Recommend sustainability initiatives for a manufacturing 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	Implementing change across national boundaries. Impacts of natural disasters on communities; Stakeholder cooperation; 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 on different stakeholders; Impact on supply chain: Minimising life cycle impacts.	Provide guidance for small companies regarding the UK's implementation of new EU Directives concerning electronic equipment manufacture (e.g. WEEE, EuP and RoHS), produce a press release describing how negative life cycle impacts are minimised by the Directives and identify other stakeholders who will be impacted by the legislation.
Energy	Implementing change through new technology; Cost-benefit analysis; Barriers to new technology; Infrastructure support for new technologies.	Assess social, financial and environmental impacts of e.g. wind-turbines, solar water heating, geothermal heat pump and photovoltaic cells, with an initial cost-benefit analysis to determine their viability. Understand the implications of and barriers to introducing new technology.
Procurement	Implementing change driven by investor pressure; Supply chain management; Assessing sustainability; Benchmarking.	Evaluate a fictional supermarket chain against industry good practice in terms of corporate social responsibility, review criteria for industry benchmarking and develop proposals to ensure approval by the ethical investment community.

'teach' and, hence, did not need full specialist knowledge of the subject matter: this accords with Cynthia Mitchell's view, expressed above, that moving to PBL requires a shift in mind-set. The degree of support was tapered so that the facilitators would intervene readily on process issues – though they would not yield the additional information, with which they had been provided, unless specifically asked – in the initial exercise, with reducing intervention in subsequent exercises.

After each weekly session, the facilitators met as a group with members of the project team to provide feedback, share concerns and to reflect on their own learning. In these sessions they would also be briefed about forthcoming exercises.

Table 2: Assessment summary.

		Contribution	
		Individual	Group
Outcomes	Cognitive	MEQ-based exam	Group report
	Group skills	Peer assessment	Staff observation

5 Assessment of students

A further area of complexity was in the design of both formative and summative assessment of the students. Some of the outcomes sought by the second advisory group related to generic and transferable skills and many of these needed to be demonstrated in a group context. We were constrained by a need to comply with institutional rules and regulations, but needed to design student assessment to reflect, on the one hand, individual as well as group contributions and, on the other, both the cognitive aspects of the learning as well as group skills. To balance these we developed a range of assessment:

- Modified essay questions (see Feletti and Engel [10]). A one-hour examination was designed to deliver two 'mini-scenarios' to test individuals' comprehension of sustainability and approach to problems. MEQs were also given after each of the scenarios, both to familiarise students with the approach and also to reinforce learning points.
- Staff observation. For the final case study the groups were observed by a facilitator from another group with a checklist of attributes of group collaboration to record factually. The project team used criterion referencing to base assessments on the recorded observations. Students were advised, well in advance, of the factors that would be noted.
- Group report. At the conclusion of the final exercise each group submitted a written report, which was marked on the basis of the application, to this task, of the knowledge and understanding gained over the duration of the course.
- Peer assessment. After the examination, and under controlled conditions, each group member was given a checklist and asked to indicate the presence, or otherwise, of a number of contributions to the final group task, from each of the other members of the group. These anonymous judgements were collated and used for the allocation of marks to individual members of the group by the team of assessors (see, for example, Conway, Kember, Sivan and Wu [11]).

The results of these assessments yielded a wide scatter of component marks but, added together, the range decreased somewhat. The only fails were in the examination questions and this did not prevent anyone from passing overall; the method of combining the scores, however, appears to have reduced the spectrum of marks.

6 Evaluation

The evaluation of the project is ongoing and will look at issues of acceptability and effectiveness as well as efficiency and sustainability (e.g. resources expended by the stakeholders). The evidence is being gathered from a number of sources:

- The reflections of the project team as we have gone along.
- Weekly debriefings of the facilitators, as a group.
- Students' self-perception questionnaires.
- Student and facilitator feedback through use of the nominal group technique (see, for example, Mackay [12]).

Interestingly, one of the few negative aspects expressed by the students was the number of evaluation questionnaires!

We administered three questionnaires at the beginning and end of the module. We adapted Mattick and Bligh's [13] Readiness for Inter-Professional Learning questionnaire from a health scenario to a more generic one; we slightly modified the ETL Project's [14] SETLQ learning styles questionnaire by changing one question that related specifically to a lecturing situation and; we also administered a questionnaire, specially designed in our own School of Education, testing students' confidence in sustainable development. Unfortunately, the pattern of results for the first two of these was such that it was difficult to test for improvement in scores – the data had a high mean but with a significant skew that led to the mean being less than half a standard deviation from the maximum. This rendered the results somewhat inconclusive, despite slight suggestions of improvement and change. However, there does seem to have been an improvement in students' self-perception of their confidence in various aspects of sustainability literacy. Students also completed the university's standard module questionnaire and the results of this were highly favourable.

The nominal group process has a number of variants. For pragmatic reasons, the student nominal groups were based on their task groups: the facilitators explained the process initially and then withdrew. Each group was asked to devise a list of positive and negative factors and then to rank them by voting on them. The informal feedback suggested that students had much more difficulty in coming up with negative aspects than with positive ones and this was borne out by the fact that most of the positive comments received the unanimous support of group members, but few of the negative ones did.

From the end-of-semester administration, there was unanimity 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 – many groups met in between their timetabled sessions - to lack of enthusiasm for 9am starts! Timing also came into view 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. 'Unassessed' work also featured negatively – in this context the concern was not that the work had not been assessed, rather that this did not count towards the final mark. 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 nominal group process for the facilitators was also conducted on two occasions. The results of the mid-semester exercise showed the key positive points, for them, 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 for themselves. 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 (we had recruited eight facilitators to cover six groups, but it meant that for some weeks there were facilitators present without a group to facilitate: in such cases the 'reserve' facilitators usually helped with other project tasks, such as the design of the assessment). 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.

7 Conclusions

In a separate, though related, project we have been conducting a Delphi consultation on education for engineers in sustainable development. The initial results confirm and support much of what we have found in our pilot project.

With hindsight, we would have liked rather more time for the entire process and perhaps a more generous climate of financial flexibility. Some decisions were pragmatic, for example the choice of the second semester in the students' third year was conditioned by timetabling difficulties.

For the pilot course we 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 we were heavily oversubscribed and had to find ways of sifting down to the required number. We had similar problems in recruiting post-doctoral research staff and had to turn away some very good candidates.

Congratulation is due to those, both staff and students, who had not been familiar with the quite rigorous requirements of problem-based learning and yet adapted remarkably quickly. At the same time we need to acknowledge that ours has been a difficult and complex task that will call for more time to overcome the inevitable inertia and vested interests in maintaining sustainable development in a narrow, single-discipline fashion.

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