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An Interdisciplinary Approach to Enhancing Sustainable Development Teaching in the Higher Education Built Environment Curriculum: Learning from a Curriculum Development Project at the University of Sheffield

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ABSTRACT

To achieve sustainable development in the future, there is an increasing need for teaching of interdisciplinary sustainable development skills in higher education institutions. However, there are also difficulties in achieving successful teaching projects. As part of the Royal Academy of Engineering Visiting Professors Scheme, an interdisciplinary staff team from the faculties of Engineering and Architectural Studies at The University of Sheffield has developed such a project to augment the knowledge, skills and awareness of students on professionally-accredited built environment courses with respect to sustainable development. The project encompasses all aspects of sustainability including social as well as environmental and economic issues. A multi-dimensional evaluation of the learning outcomes and experiences, undertaken with the University's Learning and Teaching Services department, shows that the pedagogical aims of the project are being met, although there are some organisational issues that require attention. While real-life student projects involving creative interdisciplinary team work can produce excellent learning outcomes, resourcing them presents challenges which may limit our ability to maximise the opportunity they offer.

INTRODUCTION

Sustainable development (SD) is the critical issue for the 21st Century, requiring action at all levels of society, including in a wide variety of professions. No single profession alone will be able to address climate change and sustainability; collaboration between professions will be essential for success. This requires that built environment professionals (among others), including new graduates, have the knowledge, skills and awareness to work with others to make a significant contribution to ensuring sustainability for the future. This has been recognised by UNESCO (2008), which has declared the years 2005 to 2014 to be the Decade of Education for Sustainable Development.

In higher education, as Garcia, Kevany and Huisingh (2005) note, "many new educational approaches are being tested", and, "through innovative sharing of ideas, concepts, tools, experiences learned in diverse contexts, it is anticipated that all of us will learn much that will help us help our respective educational communities and societies develop the abilities

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to make progress toward SD" (p757). This paper aims to contribute to that shared knowledge by presenting the results of an evaluation of the learning and teaching outcomes from an innovative, interdisciplinary curriculum development project that has been developed at the University of Sheffield to enhance learning and teaching about SD issues in professional degree courses related to the built environment. The paper has five further sections. The next section outlines the drivers leading to the change in the curriculum. In section three, the theoretical basis of the project evaluation is described. Section four sets out the nature of the University's involvement in the Royal Academy of Engineering's Visiting Professor scheme in Engineering Design for Sustainable Development. The interdisciplinary approach to SD teaching is explained in the section five, where the collaborative student project is also described. The sixth section sets out the key findings of the evaluation of the learning and teaching outcomes from the project, and the final section draws a number of conclusions.

SD AND THE BUILT ENVIRONMENT CURRICULUM IN HE

Whether 'sustainable development' is a meaningful concept and, if so, exactly what constitutes it, has been a matter of some debate (see, for example, Cullingworth and Nadin 1997). The UK's Forum for the Future, for example, describes it as a "dynamic process which enables all people to realise their potential and improve their quality of life in ways which simultaneously protect and enhance the Earth's life support systems" (Forum for the Future 2008). It is more often defined as, "[d]evelopment that meets the needs of the present without compromising the ability of future generations to meet their needs" (World Commission on Environment and Development 1987). As Steiner and Posch (2006) note, sustainability is no longer synonymous with environmental protection alone; it is now often conceptualised in terms of the 'triple bottom line' of environment, economy and society.

Thus, there are a number of models for SD. One of these, developed by the consultants Arup, identifies not three, but four domains of sustainability: societal, economic, environmental and natural resources (Fig. 1). For the University of Sheffield project, this was the preferred model of sustainable development, since it explicitly gives weight to both environmental inputs and outputs, as well as social and economic goals. There is an increasing acceptance that the next generation of town planners, architects and engineers needs to be aware of its responsibilities in all four of these domains.

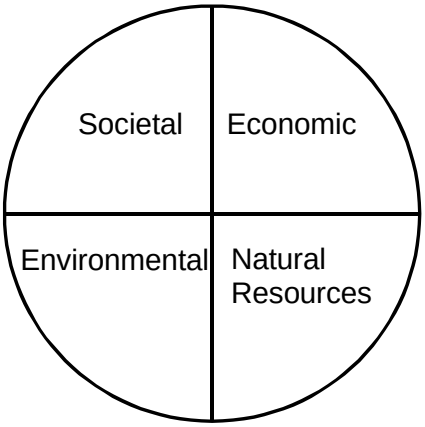

Figure 1: Four Domains of Sustainable Development (source Arup SPeAR^{TM})

In recent years, scientific concern about the effects of current development practices has prompted a number of political responses. For example, in the case of engineering, there has been an increasing volume of legislation affecting, amongst other things: how products must be treated when they reach the end of their life, such as for electrical and electronic equipment (EC Waste Electrical and Electronic Equipment (WEEE) Directive 2002/96/EC and 2003/108/EC) and for cars (The End-of-Life Vehicles (Producer Responsibility) Regulations 2005); the use of plastics (EC Packaging and Packaging Waste Directive 2004/12/EC); and storage of waste in landfill sites (The Landfill (England and Wales) Regulations 2002). If for no other reason, such changes in the law mean that SD principles must now be a critical part of the design processes and systems used by engineers and others.

However, more recently, it has been concern about environmental degradation, specifically climate change resulting from emissions of greenhouse gases, that has played a large part in raising awareness of the need for SD. It is now widely accepted by the scientific community that the earth is warming up and that man-made greenhouse gases, such as CO_2 are at least partly responsible (IPCC 2007). In the UK, the lighting and heating of buildings contributes 50% of CO_2 emissions, and the production of building materials a further 10% (Seager 2007), while, on a 'by source' basis, transport contributes 21% (House of Commons Environmental Audit Committee 2006). How and where we build our towns and cities, therefore, has a major impact on carbon emissions and, as a result, SD has become an increasingly prominent issue for all built environment professionals.

Yet concerns have been raised that built environment professionals are poorly equipped to address SD issues. For example, the Egan Review report (ODPM 2004) stated that:

> "A number of studies point to shortages of generic skills amongst built environment professionals, and there is evidence of people shortages in some core occupations (e.g. civil and structural engineers, town planners, transport planners). Both could hamper our ability to deliver the Sustainable Communities Plan." (p10)

A recent report from the Academy for Sustainable Communities reached a similar conclusion:

> "The key finding is that England faces a significant shortage of qualified professionals with the necessary skills to deliver sustainable communities between now and 2012." (Academy for Sustainable Communities 2007)

The result of all this is that the current generation of practising built environment professionals needs to become better informed about sustainability, including climate change challenges, but also addressing social issues, such as employment, education and social cohesion, and economic factors, such as efficient use of resources and standards of living. However, in order for the next generation of professionals to be able to design more sustainable products, buildings and settlements, professionally-accredited undergraduate and postgraduate courses in Higher Education Institutions (HEIs) need to incorporate learning and teaching in the principles and practice of SD.

HEIs, thus, have an important role to play in developing society's capacity to meet climate change threats (and to benefit from the opportunities that climate change may offer) and to foster socially, environmentally and economically sustainable development. One key aspect of this role is to provide learning opportunities which challenge traditional disciplinary boundaries. UNESCO's Decade for Education for Sustainable Development states that this entails "a review of existing curricula in terms of their objectives and content to develop transdisciplinary understandings of the social, cultural, economic and environmental dimensions of sustainability" (UNESCO 2008). Steiner and Posch (2006) argue that HEIs also need to look beyond the institutional boundaries: "different subjects and disciplines need to be integrated and university classes need to be connected to real-world problems and actors" (p877). Interdisciplinarity is also the first of the 'three great challenges' for HE identified by McEntee (2007). The second great challenge being to find spaces (both temporal and physical) within which sustainability teaching may take place and the third how the HEI engages with the wider community to develop sustainable practices. The curriculum development project described in this paper attempts to engage with all of these issues.

A number of commentators have argued that there are systemic, or institutional barriers to incorporating SD into HE teaching. Lozano (2006), for example, stresses the importance of engaging the support of senior managers, and the important role of SD 'champions. Kezar (2005) states that, "institutions are, generally, not structured to support collaborative approaches to learning", and that, as a result, "collaborative ventures struggle to emerge and be sustained with an over 50% rate of failure" (p832). Sustained collaboration, she goes on to argue, "seems highly dependent on redesigning campus systems from computing systems, to divisional meetings, to rewards and incentives, to the creation of new structures such as institutes, to new relationships" (p850). These institutional issues will be further discussed later, with respect to the interdisciplinary project at the University of Sheffield.

Many of the built environment professional bodies have recognised the importance of SD. One of these, the Royal Academy of Engineering (RAEng), set up a scheme for the appointment of Visiting Professors (VPs) in Engineering Design for Sustainable

Development. The primary aim of this scheme was to assist in the generation of teaching material for SD across all areas of engineering, not just design, and enhance the understanding of sustainability amongst both students and academic staff. More than 20 VP appointments were made, one of these being at The University of Sheffield.

Increasingly, therefore, SD will be required to address the consequences of climate change and to bring about wider social, economic and resource sustainability. The best employers of future graduates, undoubtedly, will seek out those who can bring SD knowledge and skills to their enterprises. Consequently, the initiative discussed in this paper sought also to enhance students' employability and competitiveness in the labour market, by developing their skills and knowledge in SD. The project has now run for two years and has been subjected to an in-depth evaluation of its effectiveness. In the next section, the theoretical framework of the evaluation methodology is set out.

THE EVALUATION FRAMEWORK

Evaluation of the curriculum development was vital to ascertaining its value to students in helping their learning and to informing the further development strategy for teaching of SD. Since little was known within the University of Sheffield about this type of multidisciplinary approach to learning and teaching, there was also potential for learning from the initiative that could be transferable more widely. Advice and support for the evaluation was therefore obtained from a member of the University's Learning and Teaching Services (LeTS) department, who had experience of evaluating curriculum development projects. The intended relationship between the project team and the evaluator was that of collaboration in planning and undertaking the evaluation.

The evaluation approach used embodied the principles of participative evaluation (Guba and Lincoln 1989) by accepting that links between intervention and effect in complex social contexts are constructed by the various participant stakeholder groups. It was broadly based on the Aspen Institute's 'Theory of Change' impact evaluation approach (Connell and Kubisch 1998) in its intention to develop understanding about, "how and why programs realize the results (or lack of results) that programs achieve" (Birckmayer and Weiss 2000 p407). The participatory philosophy seemed particularly appropriate to this project because of the number of different departments involved. The approach also made use of systems concepts (Beer 1985, Churchman 1971) to explore thinking about the context of evaluation holistically in the analysis and integration of data and information.

The approach therefore began by developing a 'theory of change' for the curriculum development with the team of academic staff involved in the project. This involved articulating their change strategy as fairly broad criteria describing their assumptions about its 'success', not only by the end of the project period but also how they saw this having an impact in the longer term. These criteria were also expressed holistically in terms of outcomes, process and enabling contextual factors in a tabular representation to help thinking about the connections between these components. The full table is not replicated here, but extracts are shown below in Table 1.

Drivers for change	**Resources/ Contextual factors**	**Activities**	**Intended outcomes for project period**	**Anticipated impact in longer term and in wider environment**
What are the current problems or opportunities for the project?	What is needed to do the activities leading to the desired outcomes for the project?	What activities need to be undertaken to achieve the desired outcomes for the project?	What is desirable and feasible for the project to have achieved?	What will be different for learning and teaching in the future as a result of the project?
e.g. Increasing legislation on sustainability which needs to be addressed in the curriculum Employers find graduates ill-equipped for interdisciplinary team work	e.g. Support required from educational technologists for development of the VLE resources (videos, image database, and their embedding in VLE) Electronic resources need to be accessible and usable by students	e.g. Teaching team motivate and facilitate student engagement with introductory interdisciplinary programme, multidisciplinary team project work and learning resources	e.g. Students have positive experience of L&T approach Students achieve intended educational outcomes	e.g. Graduates in construction design disciplines have improved range of employability skills A collaborative learning community is fostered across construction design disciplines

Table 1: Representation of a 'theory of change' for a curriculum development project

This framework was used to guide both the development of a plan for data collection and analysis and reflection on the meaning of that data in relation to making the following kinds of evaluative judgements about the change strategy:-

- how the planned strategy had been implemented and experienced by those involved;
- what had been learnt about the effectiveness of the strategy, in particular in enhancing the students' learning experience and their achievement of educational outcomes, and in influencing progress towards the intended longer-term and wider impact;
- the implications of any unintended outcomes and how these were influenced;
- desirable and feasible change to improve the strategy;
- use of resources and the sustainability of an improved strategy with available resources.

This reflection process also takes into consideration other information and intelligence that could have implications for change in the learning design. Inquiry methods attempted to explore the various participants' (staff and students) perspectives about outcomes and the connections they made between these and factors influencing them, as well as their rationales for their own behaviour in the learning context (e.g. in the case of staff their rationale for any changes made in the implementation compared to their original plan; in the case of students their explanations for choosing to join the module, how they used resources, etc.). A range of methods were used including student questionnaires and focus groups, reflective discussions with academic staff, email correspondence, and tracking of student access to electronic learning resources.

The results of the evaluation of the project outcomes are presented below in section six. The next section sets the context for those results by describing the wider approach taken to the teaching of SD in the project's participating departments.

BUILT ENVIRONMENT SD TEACHING AT THE UNIVERSITY OF SHEFFIELD

The approach to embedding and enhancing SD learning and teaching in built environment courses at the University of Sheffield, developed in the context of the RAEng VP scheme, has three main elements:

- development of the professional curriculum within each department to better reflect knowledge and awareness of SD issues;
- a programme of 'inspirational' speakers to inform, enthuse and energise students (and staff) to take on board SD in their work;
- an interdisciplinary fourth year student case study project to provide practical experience of collaborative working and innovative problem solving.

The overall philosophy for curriculum development and the embedding of SD teaching material is outlined in Fig. 2. This was based around a four year professionally-accredited degree course, such as the MEng or MPlan. Obviously, it could be tailored appropriately for varying degree lengths. At each level, key knowledge and skills were identified and a matrix of these was devised. Individual departments selected appropriately from this matrix to find an appropriate approach for meeting their students' needs. In the early years of the VP scheme, the focus was on embedding the basics into the early years of courses and creating streams of SD teaching.

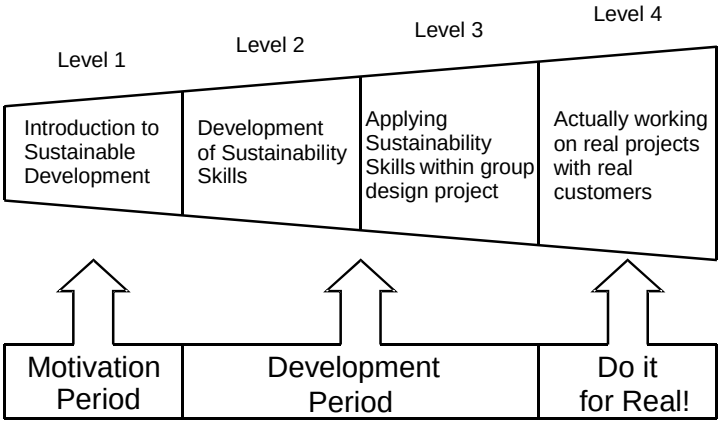

Figure 2: Curriculum Development Model

The second element of SD teaching through the RAEng VP scheme is a programme of inspirational speakers. These lectures take place six times in each academic year and have included Sir Crispin Tickell, former British diplomat and renowned expert on climate change, Pooran Desai, director and co-founder of BioRegional and developer of the

BedZED eco-housing project, and Peter Head, director of Arup and leader of the Dongtan eco-city project in China. Many of the invited speakers have strong links with enterprise and business, reflecting the scheme's focus on building into the curriculum an appreciation of the role of both public and private enterprise. Audiences of up to 300 have been achieved and the series has proved to be very effective in raising interest and awareness among students, staff and external visitors from the local authority, local business, etc.

However, what distinguishes the SD VP scheme at the University of Sheffield is its multidisciplinary nature. Not only are the departments of Civil and Structural Engineering and Mechanical Engineering involved in helping students to learn about SD, but also the departments of Architecture, Landscape Architecture and Town and Regional Planning. All of these professions are closely involved in the development of the built environment and have a role to play in securing more sustainable development in the future. Yet only limited interaction occurs between departments and practically none between students. To remedy this, the third element of the SD VP scheme was the development of a student project, based on a case study from an authentic regional development area, in which students from the six departments would have the opportunity for collaborative working on a SD theme.

At an early stage, discussions took place with the Regional Development Agency, Yorkshire Forward. The purpose of this was to identify a real development site for which sustainable development proposals could be drawn up by students. Working on a real case, at the behest of an outside organisation, lends a degree of authenticity to the students' design work and helps them to more readily appreciate the value of the work to themselves in terms of their own personal development and employability.

The aims for the project were:

- to raise students' awareness of the importance of sustainability;
- to embed studies of sustainability in the various professional higher education curricula;
- to promote interdisciplinary learning;
- to improve students' employability through development of new skills and knowledge;

Within these overall aims, the objectives were:

- to provide an authentic, interdisciplinary learning experience for students that reflects the work and contributions they would be expected to make in professional practice;
- to capture and present to students perceptions of multiple stakeholders (such as Yorkshire Forward, developers, residents, local business, potential employers, Leeds City Council etc), so these can be presented to students;
- to facilitate students' access to the site chosen for the case study, e.g. by including a site visit and providing images, a video database and maps of the site (including panoramic views), now and as it is developed;
- to emphasise, in design curricula, the importance of sustainability;
- to involve students in an interdisciplinary group design project.

THE INTERDISCIPLINARY STUDENT PROJECT

The case study site that was selected is Holbeck Urban Village. This is a Yorkshire Forward development area near to the centre of Leeds. Their vision is to develop it using sustainability principles over a ten year period. The site is currently only partially developed so it will be usable for a number of years as a case study and the students will be able to see first hand how it has been developed. There are a number of interesting aspects to the site. It is mainly industrial, and includes a number of listed buildings, including the Temple Mill, as shown below in Fig. 3. There are patches of contaminated land, small businesses set up in viaduct arches, a disused railway line and a canal. The areas in Holbeck Urban Village that have already been developed include mill buildings converted to offices and factory buildings converted to flats and apartments. This means there is plenty of scope for students' designs to consider a wide range of issues of relevance to engineering, architecture and town planning.

Figure 3: Temple Mill (grade 1 listed); (b) small business locations; (c) disused land

The students' design project is not, in itself, a separate, distinct module for teaching purposes, but instead constitutes an integral part of a named module in each department. In almost all cases, these connected modules are optional rather than compulsory for students.

The design project was introduced into these modules for the first time in 2006-07, with 67 registered students across the four departments. The assessment weighting of the project activity in the overall module mark was not the same for all students. For many of the undergraduate students the interdisciplinary project component was weighted at 50% of the module marks for a 10 credit or 15 credit module, with the other 50% of the overall module marks resting on some other individual piece of work (reflective essay from Mechanical Engineers and Planners, and a report from Civil Engineers). However, for the Architects registered for one-year postgraduate Masters courses the project was embedded within a 30

credit module and weighted at 10% of the module assessment, so the overall weighting for them was less. In other words, the number of actual credits that the project work represented to students varied from 3 (for architects) to 7.5 (for planners). This led to some students having a greater incentive than others to commit time and energy to the project.

To undertake the project work, students were divided into 8 multidisciplinary teams. Variations in numbers of students from each department meant that teams were not able to have an equal number of students from each discipline, which was the ideal, although every team had someone from all of the disciplines. This aspect was closely monitored and was explored as part of the evaluation of the project (see below) in order to find out what impact this had on the teams' dynamics. Each team was given the task of producing sustainable development design proposals for Holbeck Urban Village. An additional complication was that a small group of four postgraduate students participated who were undertaking an MSc involving water engineering, but it was not possible to integrate them into teams on the basis of one per team unless the teams were to be very large. This group was therefore set up as a team on their own to act as 'consultants' to the other teams.

A site visit to Holbeck took place, where a talk was given by a representative of Yorkshire Forward, on their vision for Holbeck. The interdisciplinary learning experience then ran for three weeks. It began with a series of lectures on how each profession is engaging with climate change and SD and on issues more specific to Holbeck which the teams had to address, such as dealing with contaminated land, energy supply and social inclusion. These lectures were given by a variety of external and internal speakers and introduced to students the breadth of sustainability issues they needed to engage with in their proposals. Subsequently, there were three 'interaction days', when teams began the process of developing a vision and masterplan for Holbeck Urban Village, a development proposal and detailed designs for a development. Students from each discipline took the lead role at different stages of this process, with planners being more heavily involved at the beginning and engineers and architects at the end. The final output for each team was a poster illustrating their design proposals and an accompanying presentation to show how they addressed the SD agenda in their design. The presentations took place before an invited panel of judges, who awarded a prize of £250 to the winning team (courtesy of the RAEng). The winning poster then went on to the national RAEng student poster competition in July, 2007.

Learning resources were developed in collaboration with educational advisors and learning technologists based in one of the University's professional services departments responsible for supporting learning and teaching activity. These resources were aimed at supporting students' project work. Many of these were housed on a web-based learning environment, and included a visual database with panoramic views of Holbeck Urban Village linked to an interactive map of the area, and video clips of interviews with key stakeholders connected with the case study site. In addition, the inspirational lectures programme and the lectures introducing the project context and task were captured on the web environment using Camtasia video editing software. By doing so, students had at their disposal a range of opinion and knowledge in the form of audio files linked to Powerpoint presentations. Most of the documentation mentioned above was also added to the web-based resources site. In this way, it was hoped that students' need to undertake time-consuming literature

searches or site visits would be minimised, leaving the maximum amount of time for creative thinking and discussion.

To enable students to undertake evaluations of the level of sustainability of their ideas and designs, two sustainability assessment tools were made available to them. For individual buildings, Ecotect, a building design and environmental analysis tool, was used to assess environmental aspects of the design. The sustainability assessment tool developed by Arup, called SPeAR^{TM} (Sustainable Project Appraisal Routine), was used to evaluate the overall sustainability of the students' development proposals for the area. This spreadsheet-powered software essentially is used to assess how a scheme performs in the four domains of SD shown in Fig. 1. A typical SPeAR^{TM} output plot is shown in Fig. 4 (Raman, 2005), indicating how a development scheme rates, in terms of sustainability, in the four domains and their associated sub-domains. This tool provided for students both a guide to how to improve the sustainability of a scheme and a benchmark against which such improvements could be measured.

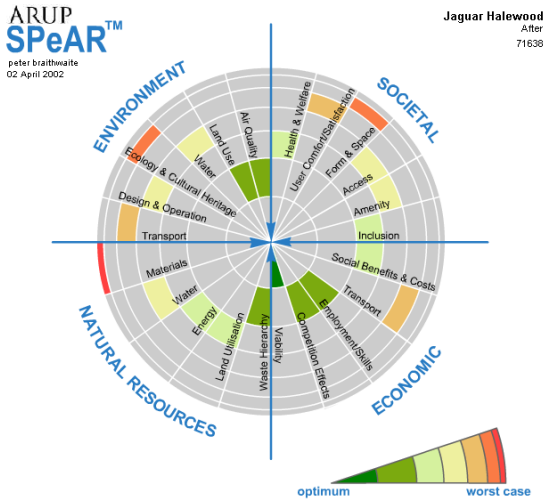

Figure 4: Example of the SPeAR^{TM} Output for a Typical Project (Raman, 2005)

RESULTS OF THE FORMAL EVALUATION OF THE PROJECT

The student learning experience

Judgement about the extent to which the pedagogical approach, detailed above, was a success in leading to a positive experience for students was largely based on the extent to which it engaged students, enabled them to contribute to their full potential, and was perceived meaningful to their future practice. Students were only marginally positive about these issues in the questionnaires, although in the focus groups they stated that the perceived relevance to their future practice was one of the main reasons for choosing the module. Based on their own experiences and the student feedback, the teaching team's

impression was also that, overall, students were engaged with the introductory lecture programme and with the project activity.

Analysis of factors influencing student perceptions of their learning experience indicated that they did experience fundamental features of the learning and teaching design positively. The factors which counterbalanced this and generated more negative feedback were related to organisational and communication issues, and issues specific to integrating the approach into the discipline-specific modules. For example, students were particularly positive about the interdisciplinary dimension to the project work and the opportunity this provided to hear the perspectives/viewpoints of those from other disciplines, and in particular the relevance of this experience to their future practice. Many students commented that it had given them a big advantage in starting their careers.

> "That's what I think is really good, the interdisciplinary thing. I think that's one of the best things. There's some things I just wouldn't think of as a mechanical [engineer] as opposed to [being] an architect."
>
> "I enjoyed working with people from different disciplines. I would love for this to be done more often."
>
> "Working with students from other departments has been long overdue."
>
> "But that's the best part of the module. You are coming now to the [job] market and you've got to work in a big company, and it's multidisciplinary, the company, and you don't know how to communicate because you never learnt this. With this module it helps you to have an image of how a team works."
>
> "If you think about the point of a degree, it's to get you ready for the business world. I think it's absolutely essential. You just learn so much. I mean you can sit and look at your notes and revise for an exam, do an exam, and forget about it after a month, but with this ...– you'll remember it when you go into a job."

Students were also positive about the extent to which the project had improved their awareness of sustainable design issues that fall outside the traditional boundaries of their own discipline. They also thought the experience had helped them to develop or consolidate other more general and transferable employability skills such as communication and IT skills. The teaching team were also pleased with the extent to which the students had achieved the intended educational outcomes; they thought they had produced good quality posters in the time available. Both the Visiting Professor and the representatives from external organisations thought the approach highly relevant to introducing students to issues and experiences that they will face in practice. The other factors positively contributing to the students' experience and their perception of its relevance were the fact that the project was based on a real site, and the opportunity to visit and explore that site.

The main factors that appeared to be contributing more negatively to students' experiences were team dynamics, lack of clarity in the students' brief, and workload issues.

As stated earlier, the project was an integral part of separate modules in each participating department. This gave maximum flexibility to departments to tailor the project to their own curriculum requirements. Overall assessment for each module, and the contribution of the project to that assessment, was determined by each department. The mark for the project's final output was awarded on a team basis, with each member of the team receiving the same mark. Individual departments could then require additional work to complete the specified module. This was usually an individual piece of work. In the first year, variations in the credit value that departments allocated to the project led to some students having a greater incentive than others to commit time and energy to the project, which led to comments on team dynamics in students' evaluation feedback. Therefore, in the second year, the credit weightings were adjusted in order to reduce this effect. However, in the second year, the project's success and popularity, coupled with limited staff availability, resulted in very large student teams. It became more possible, therefore, for a student to make a less than proportionate input into the project. While each team was encouraged to report to staff any student who was not making an appropriate contribution to their work, this tended to happen only when a student was entirely absent from team work.

The team dynamics of the interdisciplinary group work, thus, presented a challenge for students, and some thought there had been too little time allocated at the start of the process for team-forming and organisation. Their feedback highlighted typical problems that often arise with respect to team working e.g. personality clashes, differences in work ethic and willingness to contribute. This was further complicated by the diversity of the team members in terms of their different levels of previous knowledge and experience, the extent to which the work conflicted with other course requirements for the different disciplines, and the difficulty of scheduling time to work collaboratively given the number of different course timetables associated with the group members, and, as discussed above, the different assessment weighting of the poster and presentation for the different disciplines.

Although the teaching team stated that they had not always been able to directly observe the team dynamics, as this did not always take place in situations where it could be observed, they had formed the impression that students had found this difficult. However, the teaching team and the Visiting Professor made the point that some of the experiences students reported on negatively were still valuable learning experiences that were appropriate as a means of introducing them to the realities of practice, and this was one of the main educational aims of the course.

The second drawback reported by students was that there was a lack of clarity in the project brief and communication about what was required of students, in particular with respect to the extent that the designs should be constrained or be more creative. Example comments from students were:-

> "I think in a way they wanted us to be realistic but also have more creativity at the same time. That is really hard to balance."

> "Many people, even lecturers, were unsure what exactly was needed."

The teaching team agreed that they had perhaps not done enough to make students confident in making more creative design choices, and had perhaps given inconsistent messages to students about their expectations. However, they also felt that some of this negative feedback stemmed from students' over reliance on staff for guidance.

The third issue raised by students in the evaluation was that the amount of work involved in the programme and project was more than expected and, for some, disproportionate to the weighting of the assessment of this component in their overall module.

Whilst nearly all students reported using the electronic resources intended to help their learning, and no significant problems were reported regarding access, students were only marginally positive about their experiences of using the resources and the extent they helped learning. Students' explanations were that there was really *too much* information to be helpful. There was some uncertainty about whether it was really necessary to consult all of this information. Lack of clarity about what was required to meet the assessment criteria also made it difficult for them to assess what material was useful.

The staff learning experience

As well as benefits for students, it is very important to note that there have also been benefits for staff. Whilst the teaching team had found the pedagogical approach a challenge to operationalise, all of the team stated that they had enjoyed the experience and learnt a lot from it, in particular in relation to:-

- how interdisciplinary group learning processes work;
- issues relating to the integration of an interdisciplinary programme into a discipline-specific programme;
- issues relating to the communication and co-ordination required for an initiative of this scale and complexity.

Staff themselves have also gained a good deal of new knowledge of sustainability issues, especially from outside their own disciplines, and have gained insights into new teaching and learning methods.

> "I've learned a great deal about sustainable development and changed the way I think and act. That should not be undersold. We academics need frequent injections of enthusiasm to give us a reason to come to work each day. This project does that for me - I like it and I like being involved."

> "I have learnt a lot about different teaching methods and how modules and curricula are arranged in other subject areas, which has helped immensely in my own teaching in engineering."

The project has also provided opportunities to work with a variety of non-academic departments within the university (e.g. Enterprise at Sheffield, the Learning Development and Media Unit (now part of LeTS), the Office for Corporate Partnerships), thus enhancing the efficiency and effectiveness of staff teaching and learning practice, in a wider sense.

Implications for change in the project learning design

After reflecting on the results of the formal evaluation of the project, the teaching team did not believe there was any need to change their overarching pedagogic strategy as articulated in their 'theory of change', but agreed the following improvements were both desirable and feasible in the way it should be operationalised in the future.

Firstly, the site visit would include some student team building activity, which would be further developed during the introductory lectures, in the week prior to the interaction days in which the group work commences. The intention would be to help student teams to bond more quickly and thus to work more effectively together from the start of the project.

The clarity of what is required of students could be improved by making the initial team forming activity involve consideration of the project brief, requiring teams to come up with a set of questions to put to the teaching team to seek this clarification. This would provide the explicit opportunity and time for this, whilst not shifting responsibility for their own learning away from the students.

The assessment weighting, particularly in the architecture modules, would be more equitable. There would also be improved transparency about the various assessment weightings of the disciplines in order to manage the expectations of the contributions of different team members. The intention here would be to improve the situation with respect to some of the negative influence on team dynamics. Peer assessment also will be introduced into the project so that an individual's contribution to the team will be given weight by their peers. The precise form the peer assessment will take is still under discussion.

The student brief for the project would also be changed to improve how the different disciplines are integrated into the process, particularly with respect to water engineering students and their role. This would still be an issue if there were too few of them to be integrated into the other teams without the teams becoming too large. The brief would also make clearer the purpose of the final assessed presentation and the role students should adopt in this process.

Clearer signals would be given to students about independence and responsibility for their own learning, and the value of this experience for their future employability.

The electronic resources would be reorganised so that the more helpful/important documents and resources are more prominent. This would involve more careful integration with the teaching to provide more pointers to students as to when they might find the material useful and for what purpose.

Finally, the project would be more explicitly linked with the Personal Development Planning (PDP) process to encourage deeper engagement by the students with reflection on the learning process and the transferable learning from the experience.

Resource Issues

It was noted earlier that there are often institutional or systemic barriers to implementing SD teaching in HEIs. This was found to be the case with respect to the interdisciplinary project. In organisational and resource terms, there have been a number of challenges. It is crucial to acknowledge that this project resulted from a substantial grant from the RAEng; without this external source of funding, the project would not have happened. In particular, staff have highlighted the importance of the role of the dedicated coordinator in progressing the initiative and developing it. Without a coordinator with a good vantage point across the disciplines and the vision to incorporate relevant strands, it may be difficult to maintain the quality of the student experience. Additional project funding from Enterprise at Sheffield through Business in the Curriculum and from a Learning and Teaching Development Grant was vital in enabling development of the project. Yet, such funding is invariably short-term and, therefore, intrinsically unsustainable. With interdisciplinary initiatives high on the HE agenda, it is imperative that they are adequately resourced.

As well as additional resources, it is also crucial that enthusiastic individuals are present. This project resulted from the dogged commitment, over several years, of individuals from across the participating departments, operating on a personal interest level rather than as formal departmental representatives. In that sense, it has been a bottom-up, rather than a top-down project. Securing more formal commitment from departments for the project has not been completely achieved; it has relied on individual staff being able to manipulate their own department modules and timetables.

SUMMARY AND CONCLUSIONS

The University of Sheffield has implemented a new approach to the teaching of sustainable development skills and knowledge to students wishing to enter into careers in the built environment professions of engineering, architecture and town planning. The new approach places interdisciplinary collaborative team working and a real-life project at its core, and attempts to meet the ‘three great challenges’, identified by McEntee (2007), which confront HEIs trying to teach sustainability.

A formal evaluation of the project has shown that the benefits to students have been increased knowledge and awareness of SD issues, greater understanding of the role of their own and other professions in the creation of the built environment, enhanced personal development and greater employability. This appears to indicate that the fundamental pedagogical approach designed by the project team has been positively experienced by students, is effective in helping students achieve the intended educational outcomes, and students consider these to be relevant to their future employability and experience outside the educational context.

Academic staff working in the interdisciplinary curriculum development and teaching team have also experienced benefits: sharing of teaching material, teaching methods and ideas has taken place and the new contacts made have helped in creating opportunities in other areas, such as research. More broadly, the initiative also appears to have been successful in

that there is evidence of good practice in the collaborative team teaching approach in which members of the team are actively engaged at all stages of curriculum design, implementation and evaluation, helping their own learning about interdisciplinary approaches to sustainable design, and also about how they can facilitate the development of these skills in students. The success of the project was recognised by the conferment, in 2007/08, of a Senate Award for Learning and Teaching for Excellence in Collaboration. This is awarded to teaching teams who clearly demonstrate that they have worked collaboratively to improve learning and enhance the students' learning experience and aims to encourage and promote good practice and raise the status of teaching and learning as a scholarly activity. The award took the form of a personal prize to each member of the project teaching team and a substantial grant to be spent on learning and teaching activities which support the project itself.

However, the SD project also encountered a number of constraints and barriers, including resource issues. These have been temporarily alleviated by the securing of additional sources of funding from within the University. However, such funding sources are short-term and do not provide a sustainable platform of resources on which to build.

Since this paper was originally presented, the interdisciplinary project has run for a second year. The number of students increased from 67 to 104, illustrating the attraction of interdisciplinary working to students. However, increased student numbers also put further pressure on resources, such as staff time and accommodation, and highlighted pedagogic issues, such as student team size and the appropriate method of assessment to reflect each student's level of participation.

The key factors in the success of the interdisciplinary project at Sheffield have been the existence of a dedicated group of committed individual academic staff ('champions'), a long-term source of funding (the Royal Academy of Engineering), and a central coordinator to drive forward change. However, to some extent, and with some notable exceptions, success has been achieved in the face of a lack of appropriate support and resources at the institutional level. There is a need for specific institutional support from the University if interdisciplinary learning and teaching is to flourish.

This paper has added to the literature on SD teaching in HE by providing a case study of one interdisciplinary project in one academic area: built environment professional teaching. By doing so, it is hoped that it will prove helpful to academics and others in other HEIs trying to increase society's ability to confront the serious issues of climate change and to help to bring about sustainable development.

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