18. Education for Sustainable Development: can engineers be satisfied learning interdisciplinary sustainability skills collaboratively?

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Abstract

Manchester's course units for simultaneously educating engineering undergraduates in professional skills, interdisciplinary collaboration and change for sustainable development, together with students from other disciplines, through problem based learning (PBL), have been well reported (see: Dobson and Tomkinson: 2013). The 2007 Manchester pilot unit was designed to apply an interdisciplinary approach to issues of global societal responsibility using PBL. The university has now moved on from courses across science and engineering disciplines to a broader student mix. Despite research suggesting that an inter-disciplinary approach is better suited to teaching sustainable development, it has also instituted mono-disciplinary units due to practical reasons.

This paper highlights concerns that differences in approach to learning of students from different backgrounds alter the ways in which PBL works in different settings. The culture of the discipline influences staff and student expectations and so can support or impede the acceptance of innovative pedagogic approaches.

A study of learning styles amongst students from two courses with mixed engineering and social sciences backgrounds showed that, although national cultural differences can have some impact on learning preferences, greater differences are shown across discipline boundaries.

This paper discusses the implications of these studies for inter-disciplinary teaching of sustainable development.

1. Background

Inter-disciplinary course units in sustainable development and other aspects of global societal responsibility have been developed at the University of Manchester. From an initial focus on undergraduate science and engineering programmes (supported by the UK Royal Academy of Engineering), the scope of these units has extended to include students from a wider range of disciplines and also Masters level programmes. A problem-based learning (PBL) approach was adopted as an essential tenet of these units. This was underpinned by a Delphi study (Tomkinson et al: 2008) that suggested that, at least in the Engineering field, student-centred approaches were the most appropriate to this type of issue.

2. Introduction

Some of the ways in which students differ one from another are obvious: size, age, ethnic origin, gender. Some differences are less visible; for example: subjects previously studied, type and level of qualifications, command of the language of tuition, underlying pedagogy of previous education, life/work experience, personality (Tomkinson, 2007), and cognitive style. These characteristics impact on how students think, learn, prefer to work and prefer to be assessed.

At Manchester, engineering students have been learning collaboratively in interdisciplinary groups about how to achieve change towards sustainability through undertaking live projects. They have been learning from their literature research, from their own experiences and from each other as peers. Interdisciplinarity is nothing new, except perhaps in being labelled as such: Jenny Uglow (2002) suggests that the inter-disciplinary nature of the Lunar Society helped build the English Industrial Revolution.

In the context of the value of approaches to issues of sustainable development education, particularly in engineering, the Delphi study (v.s.) suggested that the approach must be ‘essentially enquiry-based or problem-based’, as well as interdisciplinary. PBL requires students to engage in research as an integrated team, supporting each other as peers. Boud and Lee (2007) highlight that “a necessary feature of peer learning is that it is reciprocal”. This can create tensions. Sometimes there is wide variation in students’ commitment and enabling experience or skills such as the ability to conduct academic research or write to a professional standard. The one-sidedness of the peer learning in such situations has the potential to create resentment within the team. As reported by Horwitz (2007), “Although team diversity can potentially create a positive organizational synergy, the same idiosyncratic expertise and experience that leads to advantages can also engender significant difficulties resulting from co-ordination, tension and intra/intergroup conflict”.

Originally an entirely elective unit, more recently the “Interdisciplinary Sustainable Development” (ISD) PBL module was designated as compulsory for a large cohort of electrical and electronic engineering (EEE) undergraduates. This made up approximately 75% of the whole course. The ‘compulsory’ and ‘elective’ undergraduates then studied together in 24 mixed interdisciplinary teams, each of 6-8 students. In the same semester, a cohort of postgraduate management students also took a very similar unit “Skills for Sustainability and Social responsibility” (SSSR) as a compulsory part of their Masters degree. The 10 teams of management students were mono-disciplinary in that they were studying the same course, but multidisciplinary in that they had a diverse range of first degrees.

3. Student Satisfaction Survey Results

A questionnaire was used in May 2012 to assess the student satisfaction with the ISD and SSSR course units. This asked whether the students would recommend it to others, and also asked them to assess how their own learning had developed as a result of the course. One of the key results of this small study was the differences in levels of satisfaction between the students who had chosen the unit as an option and those who were undertaking it compulsorily (table 1). A high proportion of the engineering and science students who chose the unit as an elective did recommend it at the end of the course. However, some stated that they would not recommend the course specifically because of the attitudes of students undertaking the unit compulsorily. Of the undergraduate students undertaking the unit compulsorily a majority said they would recommend the unit. However, this majority is significantly lower than for the elective participants. The compulsory postgraduate management students were the least satisfied with the experience.

Table 1: Satisfaction of compulsory v elective students

Proportion of students who upon completion would recommend the Unit to others	
Elective Undergraduate Students (Mainly Mechanical and Civil Engineering & Environmental Science)	75.0%
Elective Undergraduate Students (as above), excepting those specifically complaining about the behaviour of the compulsory students	87.1%
Compulsory Undergraduate Students (Electrical Engineering)	53.4%
Compulsory Postgraduate Students (MSc Management)	35.7%

Those choosing the unit are more likely to be satisfied by the experience, having chosen to learn about sustainable development and in a collaborative active-learning environment. The anecdotal negative feedback from the undergraduate students was that they wished the unit to be more interdisciplinary (wider range of disciplines) and to only include elective students. Elective students criticised compulsory students for being less engaged and not taking the work seriously. This is particularly important to final year students, who perceive group-work as high risk given the impact of others' contributions on a mark that counts towards their degree.

Table 2: Student Perceptions on Learning from the Unit

2a. Response by students who stated that based on their experience, they would recommend the unit to others (5 point Likert scale where 1 = no learning, 5 = extensive learning)

	Employability	***Research Skills***	***Problem Solving***	***Sustainability & Change***	***OVERALL LEARNING***
UG elective students	3.37	3.52	3.07	3.22	3.30
UG compulsory students	3.47	3.57	3.47	3.72	3.56
PG compulsory students	3.48	3.40	3.76	3.76	3.60

2b. Response by students who stated that based on their experience, they would not recommend the unit to others (5 point Likert scale where 1 = no learning, 5 = extensive learning)

	Employability	***Research Skills***	***Problem Solving***	***Sustainability & Change***	***OVERALL LEARNING***
UG elective students	2.44	1.22	2.11	2.44	2.06
UG compulsory students	2.54	2.88	2.29	2.56	2.57
PG compulsory students	2.73	2.89	2.82	2.71	2.79

Compulsory and elective students also had different perceptions of the value of the unit to their learning and skills development (Table 2b). Compulsory students perceived a greater achievement of learning in all areas than did elective students, whether or not they would recommend the course to others. Elective students were less satisfied by the course in this respect. This is perhaps due to their higher expectations or it may signify an adverse effect on learning of mixing disciplines or of mixing elective with compulsory students. The environmental science undergraduate elective students in particular started the unit with skills in research, referencing and writing and an understanding of sustainability far in advance of the engineers. They reported that they spent much of the unit guiding and coaching their peers rather than advancing their own skills and knowledge.

Collaborative learning will suit some students better than others. We were interested to explore in more detail the learning style preferences of these students, to determine whether engineers do differ from the management cohort and to explore the potential impact of this on choosing whether or not to implement enforced collaborative mono-disciplinary or inter-disciplinary learning experiences.

4. Review of Learning Styles Theory

The concept of learning styles theory is a contested one, both in terms of validity and reliability. Frank Coffield and colleagues (2004) question its validity initially by suggesting that the purpose is for determining individual teaching approaches to individual students, although this is not normally claimed by proponents. More seriously, Coffield et al found that many authors of tests were unwilling to share data on reliability. A number of other authors have critiqued individual learning styles instruments, but this paper is not primarily concerned with wider issues of learning styles; the authors have tackled this elsewhere (Hill, Tomkinson & Hiley: submitted). Lowery (2009) makes the point that different learning styles have different strengths and weaknesses, and stresses the importance for all learners to develop proficiency in all learning styles. By comparison, Vermunt (1998) suggests that deliberate mismatching of teaching method to preferred learning styles may create “constructive friction”. Cuthbert (2007) suggests that ‘learning styles’ and ‘learning approaches’ are two different schools of thought, but that both offer usefulness to the teacher though not to the student. In practice the two ideas overlap and differences can be semantic. Juan Gilbert and Cheryl Swanier (2008) found that student preferences for learning mode changed during the course of a structured learning experience, although their report is unclear about the learning styles inventory employed.

People learn by listening, watching, reading, by understanding processes, and by actively doing things. Individuals learn together, and on their own, and each has a preference of how to learn (Kapadia: 2008, Felder and Silverman: 1988). Students and teachers are themselves often unaware of their learning style preferences, but an experienced teacher will vary the styles offered in order to connect with all of the students. Students who are taught in ways that support their preferred learning styles can be expected to enjoy learning and to proceed better academically (Shaugnessy, 1998). But are there differences in learning style preferences between students in different disciplines? To study this, the Memletics Learning Style Quiz (MLSQ) was chosen because of potential access to data from other countries (Abidin et al, 2012) and because it looks at a wider range of dimensions than many others. Reliability and validity data for this instrument are scant, but we were able to establish face validity and results between years were comparable, indicating a degree of reliability.

5. Learning Styles Study Methodology and Results

The main study was undertaken by administering the MLSQ to students on two PBL course units, one offered from within Engineering, and one from within the Business School. These courses draw on a variety of backgrounds but mostly from engineering/natural science disciplines or social science/business studies backgrounds. Both cohorts contained significant proportions of students from overseas. There may be some bias as the cohorts studied were from elective PBL units and the students had chosen to undertake a unit that they knew would be dependent on groupwork. However, initial results from a subsequent study into whether the students studying on elective PBL units differ in learning style from the whole cohort suggest that there is no significant difference.

5.1 Comparison of Engineering v Business students

The students' preference scores were normalised to a percentage of their individual total preference score and averages were compared (Figure 1).

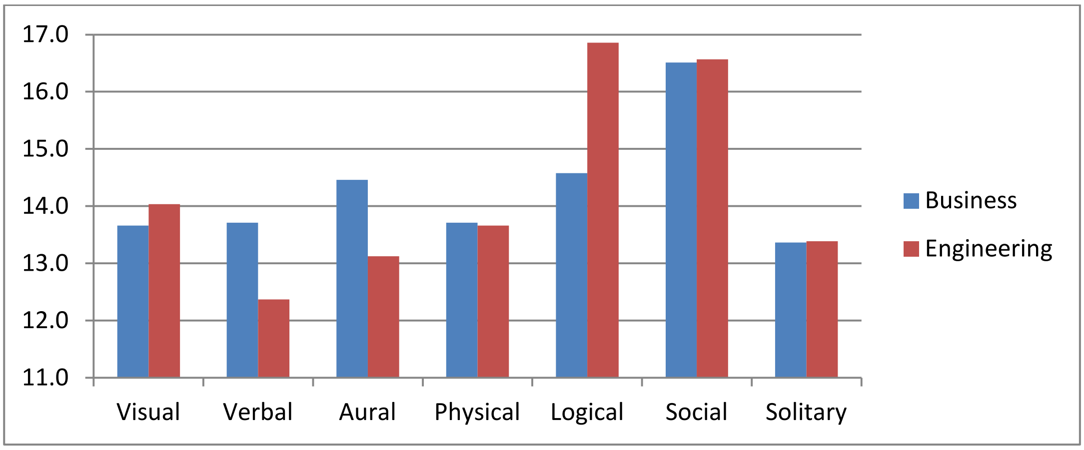

Figure 1: Normalised scores of Business and Engineering students

The business students express significantly higher preferences for verbal (p=0.001) and aural (p=0.02) learning styles than the engineers, and the engineering students express a very significantly higher preference for logical style (p=0.0001) than the social scientists. Other differences were not statistically significant. The significance levels for normalised scores were notably stronger than for raw scores and this difference is an important consideration in asserting the importance of normalisation.

A primary aim of the investigation was to compare the learning style preferences, of one style over another, of Engineering students with those of Business (or other) students. Once the preference differentials had been computed for each student, their averages were tested (as matched samples) for significance. The two groups' average differentials could then be compared, and the differences between the two groups could be tested for significance (as non-paired, independent samples). Ten of the 21 comparisons showed significant differences between the two groups (Table 3).

Table 3: Stronger preferences shown by students in one discipline than the other

Discipline	**More preferred style**	**Less preferred style**	**Preference differential**	**p- value**
Engineers	Logical	Verbal	3.7	0.000002
	Logical	Aural	3.6	0.0001
	Logical	Solitary	1.4	0.0005
	Logical	Physical	2.3	0.0063
	Logical	Visual	1.9	0.0082
	Verbal	Visual	1.7	0.018
	Aural	Visual	1.6	0.022
	Social	Verbal	1.4	0.046
	Solitary	Verbal	1.3	0.047
Business	Social	Logical	1.6	0.0048

From the substantially greater number of differentials achieving the significance threshold it can be seen that the Engineering students were a more homogeneous cohort, and have much more clearly defined learning style preferences than Business students. Most of these show engineers having a strong preference for "logical" over other styles. The only significant preference from the business students was for social over logical.

5.2 Comparison of Home (UK) v Overseas (International) students

Whilst comparison between the Manchester results and those of overseas collaborators indicates some potential cultural differences in style, the Manchester study also attempted to look at differences in learning styles within the cohorts, based on national cultural background. Some difficulties were encountered in accurately establishing the national background, as students moved between countries at different stages, but the results showed no significant differences in learning styles between groups of different regional nationalities. This has high relevance for Universities such as Manchester where a high proportion of students are from overseas. One might have assumed from national stereotypes that certain students might be less inclined to engage in group discussion due to their background and so be disadvantaged by PBL, but that is not borne out by this data. Language skills will certainly have an impact on student performance in a unit which relies heavily on reading literature, fast paced verbal discussion and accurate writing. However, aside from that issue, the UK and overseas engineers showed very similar traits which were very different to the preferences of the humanities students.

6. Discussion

This paper has brought together a number of perspectives on the teaching of sustainable development using problem-based approaches. The main perspective has been that of learning style and the differences that result both from national culture and also from disciplinary background. The differences seen were more marked between disciplinary cultures than national ones and this links to the second issue, that of inter-disciplinary v mono-disciplinary teaching. However, the issues of mandatory v elective modules appear to cloud the results of looking at inter-disciplinarity v mono-disciplinarity.

A PBL approach relies, to some extent, on peer learning and this can more readily adapt to the varieties in learning style. “I developed my professional skills using this course as a catalyst and I gained knowledge about different work culture being in a multidisciplinary team” (University of Manchester student in Bessant: 2012). This also highlights the crossover of this teaching and learning mode with the values of intercultural competencies (Goldfinch, 2012). In the same way that students need support to develop their capacity to work across cultures, they do need to learn to work with colleagues with other sets of learning and operating styles. Groupwork, in mixed teams, can support both of these dimensions. In particular, engineering students, with a high preference for a logical learning style, with a single “correct” answer, may benefit from tasks which make use of multiple approaches, and for which the “solution” is more “open”. This enables a range of interpretation, and is open to valuing input from many cultural perspectives.

However, the perception of some students is to question the relevance and significance of sustainability education to their degree and this can be cause problems when such courses are made mandatory. This can impose two significant challenges to inter-disciplinary group learning. It can overwhelm the groups with students from a single discipline and single perspective. It can also introduce a more disenchanted, and possibly more disruptive, group of students into the unit, producing a greater degree of tension.

Some of the key challenges in designing interdisciplinary problems for PBL were described by Dobson and Tomkinson (2012).There is a tension between schools wishing units to be tailored to their own discipline (e.g. with only civil engineering or electrical engineering problems to investigate), and the need for broader challenges to encompass a wider range of issues. The limited evidence so far suggests that creation of a mono-disciplinary course weakens the learning experience for those students.

7. Conclusions

It is clear from the positive survey feedback from students, and results of the assessments, that engineering students can learn effectively through PBL in collaborative interdisciplinary teams and be satisfied by this learning format. Although the ISD unit is considered here as an interdisciplinary unit, in practice the cohort is largely made up of engineers and scientists. A unit with a more even science/humanities balance might produce different results. The postgraduate management students surveyed were less satisfied with the mono-disciplinary sustainability PBL unit they experienced.

The normalisation of MLSQ scores per student has provided a clearer and stronger picture of learning style differences between cohorts of students. Significant differences have been found, with engineering students in University of Manchester clearly preferring logical and social learning styles over visual and verbal styles more strongly than their Business/Social science peers, whose preference for a social learning style over a logical learning style was significantly stronger.

The diversity of learning style preferences found in the study, and echoed in the literature, strongly indicates a need for a variety of teaching styles to be employed in working with these undergraduates. Use of a mixture of group (social) learning tasks with open-ended questions is advocated, to better engage students across a range of learning style preferences, as well as to enhance their subsequent employability and professional skills.

PBL does not present content to students in a straightforward, logical way, instead requiring messy, iterative investigation of complex problems that incorporate some ambiguity. Engineers used to didactic, well-structured teaching may therefore benefit from additional support when learning by the PBL method.

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