

Paper 119. An Integrated Approach to Teaching Multidisciplinary Design for Sustainability

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Abstract

This paper presents a case study for best practice in teaching multidisciplinary design for sustainability at Newcastle University. The case study highlights a module called ‘Design of Sustainable Engineering Systems2 (DSES2)’ offered to the second year undergraduate students on Civil Engineering programmes. As noted by Segalas *et al.* (2010), it is the responsibility of higher education institutions to ensure that their students are given the opportunities and right learning environments to develop moral vision and the technical capabilities required for sustainable design. In recognition of this, the School of Civil Engineering and Geosciences at Newcastle University introduced a redesigned undergraduate curriculum in 2009. The module forms part of a suite of subjects which aim to foster sustainable design competencies among students. The teaching and learning model used for this module combines a range of strategies including problem-based, design-based and self-directed learning methods. This approach facilitates a transformative learning experience by overcoming various challenges encountered in sustainable design teaching (Bourn and Sharma, 2008). Through the combination of traditional instruction, field-based learning, peer-to-peer learning and self-directed learning, this module aims to meet the requirements set by the Declaration of Barcelona (Engineering Education for Sustainable Development, 2004). The paper concludes by identifying some of the strengths and weaknesses of the pedagogical approach and considers some of the possible ways for enhancing student learning experience in the future.

1 Introduction

The second half of the 20th Century has seen the culmination of discourses on the humankind’s impact on the ecology and the exorbitant rate at which this planet’s resources have been and still are being consumed. The Earth Charter (Earth Council, 2000) raises its concern against the environmental devastation caused by the production and consumption methods that are commonly used and the inequity and injustice perpetrated within the social and political systems across all nations. The Brundtland Commission’s (1987) vision of sustainable development can only be achieved if the policy makers as well as the general populace realise and act in a sense that the human and the natural systems are dynamically interdependent (Dale and Newman, 2005). We need to develop and teach an understanding for the earth’s ecosystems and, especially, the exact nature of the humankind’s dependence on its resources. Higher Education (HE) and Further Education (FE) institutions have a profound responsibility in creating, not only among its students but also the wider community, a sense of passion and realisation of our dependence of our planet’s future.

The construction industry which plays a key role in every nation’s economic development is the largest consumer of natural and non-renewable resources (Howard, 2000) and is responsible for a significant proportion of the irreversible changes that happen in our ecosystem. The Institution of Civil

Engineers, UK recognises this predicament and urges its members of all grades to receive education and training in sustainability (ICE Sustainability Charter). Prince Charles stated in his recent address to the ICE: “If there is one profession that has awoken to the need for sustainable development, it is civil engineering” (Prince of Wales, 2012). It is worth noting that the Institution of Civil Engineers (ICE) has a vision of “Civil Engineers at the heart of society, delivering sustainable development through knowledge, skills and professional expertise” and a core purpose “to exchange knowledge and best practice for the creation of a sustainable natural and built environment” and to “promote our contribution to society worldwide” (ICE, 2012). Leading on from the ICE’s aspirations for a sustainable world, students on civil engineering degree programmes should be given the opportunity to develop a deeper understanding of sustainability and sustainable development so they are better equipped to develop and implement sustainable solutions in their professional practice. The sustainable development education carried out at HE institutions must be cross-disciplinary and broad while incorporating a good balance between the environmental and equity issues with social sustainability (Jucker, 2001; Mulder *et al.*, 2012). However, educating engineering students on sustainability is challenging (Bourn and Sharma, 2008). This paper will present the pedagogical approaches adopted at Newcastle University to deliver Sustainable Design Education (SDE) to second year undergraduate students on civil engineering programmes. The following sections of this paper will provide an overview of the context and teaching & learning and assessment strategies employed within the delivery of this module. The authors believe that this module contains best practices which can be effectively used by other academics imparting SDE. The Section 2 in this paper will describe the context for the provision of sustainable design education at Newcastle University. It will also state an overview of the design brief and the profile of the lecturing staff and students enrolled on this module. The Section 3 will illustrate the teaching & learning methods and the assessment strategies used in this module. Finally, some key observations made by the authors over the past three years of teaching sustainable design will be presented which could be of use to the wider engineering academic community.

2 Design of Sustainable Engineering Systems

2.1 Sustainable Design Education at Newcastle University

The undergraduate (UG) and postgraduate (PG) courses offered by the School of Civil Engineering and Geosciences (CEGs) at Newcastle University are accredited by the Joint Board of Moderators (JBM) on a five yearly basis. The JBM includes four major civil engineering professional bodies: The Institution of Civil Engineers (ICE), the Institution of Structural Engineers (IStructE), the Chartered Institution of Highways and Transportation (CIHT) and the Institute of Highway Engineers (IHE). Further to the accreditation visit in 2007 and a critical review of their course provision, the CEGs management team entrusted a group of senior academics with the responsibility of redesigning the UG curriculum. This group of senior academics, referred to as the Strategy Group, sought the invaluable guidance of practicing engineers from various disciplines within the civil engineering sector. The redesigning process eventually led to a set of programmes which are richly entrenched in sustainable design philosophy and contain the vital elements of SDE. The current curriculum for UG Civil Engineering programmes contains a theme of modules called ‘Design of Sustainable Engineering Systems (DSES)’ which allows the students to integrate the concepts and learning outcomes gained from the other, more traditional civil engineering modules. A module from the DSES theme taught during the Stage 2 (2nd year) of the UG civil engineering programme is referred to as ‘CEG2001 Design of Sustainable Engineering Systems 2 (DSES2)’. The teaching and assessment model used for

this module is best described by Figure 1. Bramald *et al.* (2013) provides an overview for the DSES module taught during the Stage 1 of the degree programme.

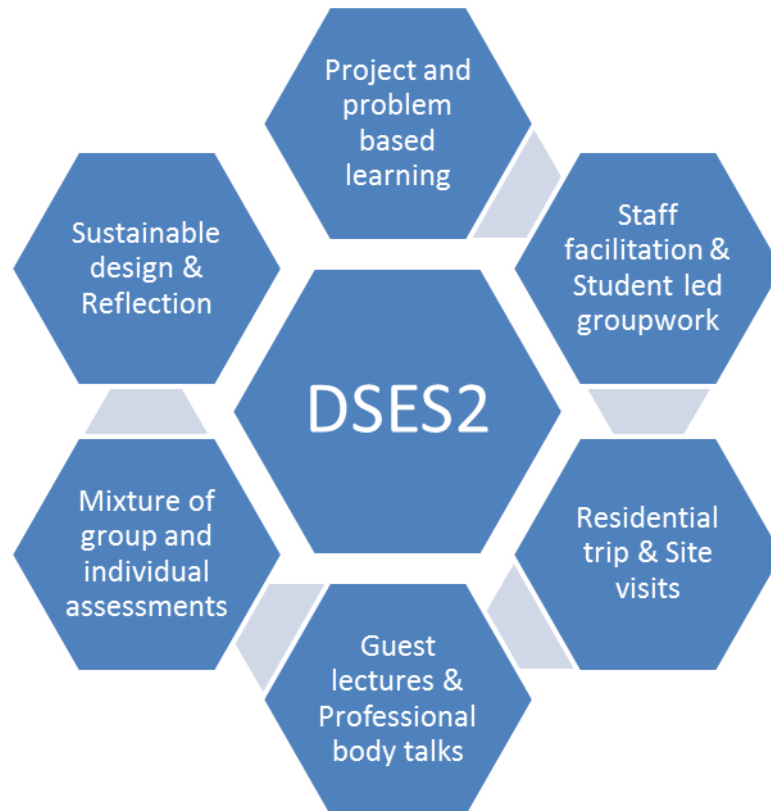


Figure 2.1: DSES 2 Teaching and Assessment Model.

2.2 *The Design Brief*

Due to economic and social developments in Tyne and Wear (and more generally throughout the North East region) during the past few decades, there has been an increase in the daily vehicular traffic using the original Tyne Tunnel crossing built in 1967. A second tunnel has been designed, constructed and opened to the public in 2011 to alleviate the current and future problems resulting from the original tunnel running severely over-capacity (such as severe congestion on the approaches to the tunnel and stressful driving conditions). It was hoped that this new tunnel would ease movement within the A19 corridor and, in turn, stimulate economic and social development. However, it is considered that the lack of a suitable crossing elsewhere on Tyneside is having an increasingly detrimental effect on the ability of people living on either side of the river to access key activities including employment, education, retail and leisure opportunities. The design brief for the DSES 2 module is set within this regional context and requires the students to work in design groups to develop feasibility studies and conceptual designs for a more sustainable (e.g. non-car) modes of travel. Typically, the conceptual designs involve the construction of either bridge or tunnel structures at a suitable location across the river Tyne. See Keep Tyne and Wear Moving (2011) for a better understanding of the region's transport infrastructure.

2.3 *Lecturing Staff Profile*

Bonnett (1999) suggested that the development of sustainability involves the adoption of a certain frame of mind that questions the socio/economic/political constructs and motives which give rise to

the ecological problems. The collective of academics involved in the teaching of sustainability education must therefore have the metacognitive skills necessary to explain our understanding of ourselves as specie and our dynamic relationship with the ecological world. The key elements of DSES2 are taught by a carefully selected collective of academics who have a deep sense of concern for the environment. During timetabled lecture sessions spread over the entire academic year, nine academics based within Newcastle University deliver material covering the following key areas: transport planning and engineering, structural engineering, bridge and tunnel structures, economics, risk and reliability, geotechnical engineering, environmental engineering, climate change and hydraulic engineering. In addition to the university academic staff, a number of practicing engineers are invited each academic year to provide information on relevant technical issues such as recycling and waste and sustainable energy systems. Additional lectures are held to raise students' understanding of aspects such as the importance of effective team working and health and safety in the construction industry. There are also guest presentations describing the delivery of large scale engineering projects, such as the London Olympics venue and the New Tyne Crossing.

2.4 Student Profile and Design Groups

The student profile for the most recent three academic years is as below.

Table 1: Student profile for DSES2 for last three academic years.

	2010-11	2011-12	2012-13
Total number of students enrolled on DSES2	84	103	92
Total number of female students on DSES2	13	28	13
Number of international students	6	9	12
Number of EU students	10	12	7

Students are put into groups, referred to as 'Design Groups', so they can work together to produce the deliverables as required by the design brief. Each design group consists of eight to twelve students of varying academic abilities. International and EU students are spread among various design groups to make sure that these students are given the opportunity to befriend and work alongside UK origin students. Design groups are recommended to appoint a chairperson to lead the group in developing a collective understanding of the brief and then to accomplish the objectives set by the design brief.

3 Effective Teaching and Assessment Strategies for Sustainable Design

3.1 Rationale and Structure for Teaching Methods

The teaching methods and the contents of the courses delivered at HE institutions are of critical importance as the students enrolled on these courses are capable of creating lasting differences in the future (HEFCE, 2009). The module leaders for DSES2 are conscious of the multiple challenges associated with the delivering of SDE and its long-term influence on the students. They have, therefore, invested a considerable amount of time in planning and designing a set of teaching methods which they consider to be most effective in SDE. Some key aspects of these teaching methods are described as below.

Formal lectures: The lectures given by the university staff and external speakers form a significant element of the module with some 35 hours of formal contact. These lectures are held in large classrooms equipped with data projectors.

Electronic access to learning material: All lecture materials are made available to students in advance of each session via the students' Virtual Learning Environment (Blackboard) and all lectures are recorded for playback at a later date using the University's ReCap system.

Attending professional body lectures: Students are strongly encouraged to attend relevant evening lectures from professional bodies in the region (such as the ICE, CIHT and IStructE). The evening lectures attended by students are often based on topics such as feasibility studies for infrastructure projects and conceptual design of bridge and building structures.

Progress review meetings: To monitor each group's progress on the design exercise, three meetings (called Client Meetings) between the group chairmen and module leaders are held at strategic timings during Semester 1 and 2. In advance of these meetings, each group is required to prepare and submit a short progress report to 'the client' which they must talk through and answer questions on during the meeting.

Small group tutorials: Weekly hour-long sessions are also timetabled when key lecturing staff are available to 'sit in' on group discussions and contribute, steer and answer questions as appropriate.

Residential field trip: A key element of the module is a three-day residential field trip to the central belt of Scotland: this involves a range of activities designed to assist the students' learning including: technical lecture and site visit to the Forth Replacement Crossing; a bridge building exercise to develop design and team-working skills (involving design, costing, construction and decommissioning), a visit to the Falkirk Wheel as an example of a sustainable design solution, and presentations focussing on the feasibility aspects of High Speed Rail in Scotland and the engineering design aspects of novel wave energy systems.

Regional site visits: Local site visits are also arranged to major construction sites in and around Newcastle, and the wind turbine blade testing facility hosted by the National Renewable Energy Centre (NAREC) in Blyth.

3.2 Formative and Summative Assessment Methods

A mix of individual and group assessment exercises are used to measure student performance. With regard to individual student assessment, the first element involves a set of three individual summative tests in Semester 1, based on Blackboard, which covers material on economics, climate change, and risk and reliability. These tests carry varying weights (3%, 10% and 7% respectively) to reflect the differing amount of material being assessed. The second aspect of individual assessment is a student's log book which accounts for 20% of the overall assessment. The log book is designed to represent a chronological account of a student's progress through the module and can include material such as: meeting notes and actions; details of concepts and ideas; drawings and sketches; health and safety issues (e.g. personal risk assessments for site visits); notes from lectures and site visits; document reviews and referencing details; group planning, management and operational issues; and personal insights and reflections. Log books are introduced, but not assessed, in Stage 1 as part of the Design of Sustainable Engineering Systems 1 (DSES 1) module. In DSES 3, log book contents are used as the information source for an assessed reflective report. Group assessment for DSES 2 is carried out in two phases to reflect the two parts to the design process – the feasibility study in Semester 1 and the detailed crossing design in Semester 2. For each of these parts, groups must submit a report. Design groups must also give a 20 minute presentation (and question and answer session) to the client team

towards the end of Semester 1. At the end of the module students prepare a poster-based exhibition of their design. This exhibition is open to all staff and students in the School and external lecturers and members of the Industrial Advisory Panel also attend.

3.3 Feedback on Assessed Work

All feedback is provided electronically via the Blackboard system. Groups receive feedback on their two main reports, and their Semester 1 presentation. Stage-level feedback is provided on the log books which are assessed at the end of Semester 1 and then again at the end of Semester 2. The poster exhibition is peer assessed and feedback provided to each group. At the end of the module students have the opportunity to assess the individual contributions of their group members. There is considerable research evidence that the process of peer assessment can create considerable benefits for students. These include: improved student learning; supporting the development of generic skills such as critical reflection; enhancing motivation and enthusiasm; and improving future student performance. Students are asked complete a peer assessment table, scoring (on a scale of 1 to 10) themselves and each of their group members for the criteria shown in Table 2. A score of 1 given to a group member implies a least favourable score while a value of 10 refers to their outstanding contribution.

Table 2: Peer Assessment Table for DSES2.

	Person A	Person B	Person C
Cooperation during and outside group meetings			
Effectiveness in communication			
Enthusiasm and Creativity			
Self-Organisation, Planning and Time keeping			
Overall contribution and effort			

The information provided by these tables is used in assessing a student’s overall performance on the module and marks may be moderated (adjusted up and down) in appropriate circumstances.

At the start of the module each year, the introductory lecture is used to pass on key ‘lessons learned’ from previous cohorts. These lessons typically include:

Responsibility: Establishing an ethos of collective responsibility and ensuring all group members have equal input throughout the process to avoid frustration and tension developing within the group;

Communication: Giving all members of the design group the chance to have an input and acknowledging that there will be different needs within the group (e.g. language skills, personalities);

Project management: Every design group must set realistic targets and make sure to monitor their progress in pursuit of these targets. Have meetings that are effective (with an agenda, minutes, action points, date of next meeting etc.).

4 Conclusions

This planet has suffered a considerable amount of devastation as a result of humankind’s consumption of its resources. The construction industry which plays a crucial role in maintaining and improving the quality of life for humans is responsible for a significant proportion of the damage experienced by the Earth’s ecosystem. It is crucial and even urgent that the HE institutions teach Sustainable Design

Education (SDE) to its students through courses which are cross-disciplinary and broad. Civil engineering students must develop a deeper understanding of the sustainability and acquire skills in order to produce design solutions which are sustainable.

This paper presents the case study of a module, DSES 2 taught at Newcastle University. The students enrolled on this module found the learning experience to be enriching and the following are some of the comments made by some of these students from the academic year 2012-13.

“The broadness of the module was good.”

“Useful to have a module devoted to the design process.”

“Links all the other modules together.”

“Interesting fieldtrips and design project.”

The Joint Board of Moderators (JBM) showed great appreciation of the Sustainable Design Education (SDE) delivered at the School of Civil Engineering and Geosciences, Newcastle University during their accreditation visit in the year 2012. As noted by other researchers, teaching sustainable design is a challenging task. However, the module presented in this paper addresses these challenges by employing an effective mix of project-based and problem-based teaching methodologies.

The module leaders found that it requires a collective effort from the academic team in order to deliver SDE to their students. It is worth noting that the management teams leading the institution as well as the individual departments must show leadership if sustainability and sustainable development is to be integrated into UG and PG courses.

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