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SUSTAINABLE DEVELOPMENT FOR DESIGN ENGINEERING STUDENTS: A PEER ASSISTED PROBLEM BASED LEARNING APPROACH

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ABSTRACT
The Engineering Council's UK Standard for Professional Engineering Competence explicitly incorporates sustainable development (SD) encouraging engineers to take a leadership role and goes beyond "eco-design" to include social and cultural aspects. This is reflected by the Royal Academy of Engineering describing a *"new integrative principle, not a new set of skills"*. To provide first and second year Design Engineering students with an understanding of SD a primer was developed from the ongoing research incorporating the concept of "social-usefulness". A problem based learning approach was adopted with no didactic element. Instead, students learned through investigation, presentation, discussion and reflective learning with both sets of students working together. Data indicated a change in perception of SD with understanding of the complexity evident. Providing the course early in the students' education enables aspects learned to be developed in future study; Learning so gained becomes normal practice when the graduate enters the profession and contributes to improved design practices and future sustainability in an ever more demanding environment.

Keywords: Sustainable Development, Problem Based Learning, Design, Education, Social, Cultural

INTRODUCTION

Sustainable development (SD) is a complex and diverse subject covering a wide range of disciplines. The Brundtland report defined it as *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs"*[1]. However, interpretation can vary, an early report for the World Bank on SD concepts found more than fifty definitions[2], with more than forty assessment methodologies recently compared[3]. Defining the basic idea of sustainability is straightforward, the real problem is one of identifying what can be sustained, what should be sustained, and for how long[4]. The recent economic crisis highlighted the realities of unsustainable practices; the chairman of the UK Financial Services Authority, Lord Turner, asked *"..consider what percentage of highly intelligent people from our best universities went into financial services?"* commenting *"...some of it is socially useless activity"*[5]. This is equally valid for design: How many of our most gifted designers engage in socially useless activity? The question leads to an excellent model for understanding SD within the context of engineering and design[6]:

1. Is it socially useful?
2. Or, is it a waste of the Earth's natural resources?

In other words, does it make a positive contribution to society and does that contribution outweigh the economic, environmental and human costs?

SUSTAINABLE DEVELOPMENT WITHIN THE DESIGN CURRICULUM

The origins of education for sustainable development (ESD) can be traced back to 1992 and the United Nations Agenda 21 programme of action from the Earth Summit at Rio[7]. The challenge faced by universities is reflected by the UN Decade of Education for Sustainable Development (DESD): *"...integrate the principles, values, and practices of sustainable development into all aspects of education and learning. This educational effort will encourage changes in behaviour that will create a more sustainable future in terms of environmental integrity, economic viability, and a just society for present and future generations."*

Despite this, and the clear reference to the social sphere of sustainability within the wider literature, the focus has been towards aspects of environmental impact, recycling and materials; essentially eco-design[8, 9]. A survey of academics, students and employers within the UK found misconception extends beyond academia and into the business environment[10]. Respondents believed they had a working knowledge or high understanding of sustainable design issues and strategies. Definitions, at best, concerned minimising environmental impact, recycling and reducing the carbon footprint: essentially eco-design. The misconceptions may be understandable given the limited scope within undergraduate design courses for adding additional units to explore the topic in depth and the fear of dilution [11]. The engineering department at Cambridge University found a familiar set of barriers to change: *"...perceived threats to the integrity of subject material,* ...low *intra-departmental interaction, ...successful tradition ...and a sceptical attitude to change*."[12]. They also found a tension caused by the introduction of "*subjectivity and judgement*" while traditional engineering methodologies were challenged by the broader scope or open ended nature of SD. Some students simply fail to recognise the importance of SD and their own role, as a designer. A recent study of 200 undergraduate design students explored their design priorities and concluded they were a direct reflection of their purchasing aspirations with quality, aesthetics and cost factors outweighing sustainability issues[13].

Institutional Guidance

The drive for SD within the curriculum is reflected in the engineering competencies published by the Engineering Council UK (ECUK) [14]. This requires Chartered Engineers to *"Undertake engineering Activities in a way that contributes to sustainable development"*, consider *"...environmental, social and economic outcomes simultaneously"* and *"Understand and secure stakeholder involvement in sustainable development".* The ECUK provides additional guidance and principles to *"guide and motivate engineers when making decisions for clients, employers and society which affect sustainability"*[15]. Specifically they should understand *"relevant social and cultural structures outside of their normal community of practice"*, the impacts of their decisions may be *"global and long-lasting"* and they should *"consider the views of the community"*. They should also "*be aware that there are inherently conflicting and un-measurable aspects of sustainability"*.

The RAEng provides higher education with guidance on embedding SD within engineering and design courses through its visiting professors' scheme. This has led to the development of the RAEng's twelve guiding principles on SD derived from seven case studies[16]. These describe SD as *"a new integrative principle, not a new set of tools, so that the concept cannot simply be regarded as an 'add-on' to existing engineering skills and educational programmes."* Models developed through the scheme include those described below from Manchester, Cambridge and Bournemouth University.

Existing Approaches

Approaches to integration of SD have varied across and within universities. Delft University of Technology in the Netherlands has adopted a three stage strategy[17]:

1. All students take an introductory course "Technology in sustainable development".
2. The concepts of SD are embedded into all regular courses.
3. Provide a "sustainable development specialisation" within each faculty.

Within this is "boat week", during which students appreciate the complexity of sustainability problems and, since it is on a boat, no one can leave. A follow up course uses backcasting to enable students to understand the long-term consequences of the decision making process [18]. However, a study of Industrial Design Engineering students at Delft found that *"unless specifically asked to integrate sustainability issues, students have no incentive to proceed with them..."*[19]. Students also had to be reminded that SD was more than the environment, defining it as *"beneficial to society"*.

At Cambridge University (UK) the process of embedding SD has evolved "opportunistically" over time[12] with the establishment of a core of expertise in SD teaching. Within this context SD lecturers are given to first year undergraduate students as well as integration with a compulsory project unit. In formalising the process they believed that embedding required *"...a cultural shift, not just the provision of an extra optional course or two."* Essentially, the approach has been to encourage students to question their own assumptions and reflect upon a wider range of perspectives.

At the University of Manchester (UK) an interdisciplinary SD course was introduced to engineering and physical sciences programmes[20] where cross disciplined groups of undergraduates worked on a range of sustainability problems. Problem based learning (PBL) rather than formal teaching was used, with responsibility for learning resting with the student. Each problem set was a "wicked problem" in that there is no definitive answer[21] and while groups were assisted by facilitators, students learned through investigation, collaboration and reflection. The course was not formally assessed and restricted to third years yet drew comments *"why couldn't we learn this way before?"* The Authors suggest that students should be engaged with SD through PBL from an earlier stage.

At Bournemouth University (UK) SD has been integrated within the design curriculum through two distinct paths: embedding within the existing framework and developing discrete courses. Within the postgraduate framework "MSc Sustainable Product Design" includes three sustainability orientated units and requires the final dissertation to reflect relevant issues. The undergraduate and postgraduate programmes have also benefitted from an interactive online learning and assessment environment developed through the RAEng visiting professors' scheme [9, 22]. The learning environment provides toolsets, course materials, case studies and assessment on Life Cycle Analysis (LCA), Design for Waste (DfW) and Sustainable Product Development (SPD)[23].

GUIDELINES FOR SUSTAINABLE DEVELOPMENT IN DESIGN EDUCATION

In order to successfully embed SD within the curriculum it must be embedded into the students, staff, university and society as a whole. In essence, it must be a "cultural shift". To encourage this, there needs to be an intrinsic interest in the subject and students need to understand the wider impacts of their decisions, both as designers in the wider community and as consumers. For such a shift in values to be successful, it should be introduced as early as possible in the student's academic career, especially if it is to be developed as a long term strategy. Engaging students within a single activity of defined duration (with no other academic distractions) should lead to full engagement. Utilising a group project will also encourage student participation through their peers, especially if the activity is also peer assessed. By utilising a project with clear social usefulness students can appreciate the relevance of the social sphere, or pillar, of SD. Introducing subjectivity and uncertainty to project work can help develop the students' ability to think outside of their comfort zone and to develop their life-long learning skills. These are also key benefits of PBL as a whole[24].

PROJECT OVERVIEW

To provide a primer for first year Design Engineering students a live project incorporating peer assisted learning (PAL) and PBL methodologies was used. Students were issued a brief to design a child's (under five) mosquito tent for use (and manufacture) in the Niger Delta region of Nigeria. The exercise was cross disciplinary and linked to a Development Partnerships in Higher Education: Department for International Development (DelPHE) funded programme. The project ran continuously during the first week of study, during which no other units were taught, with teams comprising a mix of first and second year students. There was no didactic element; instead students presented their findings at regular briefings, the first after two hours. After each presentation, students were asked to reflect upon their findings and those of their peers through open discussions. Questions posed through these sessions were used to convey the complexity and diversity of SD. During the final two days teams constructed prototypes, justified their design decisions and delivered their final presentation. Upon completion students were asked to agree distribution of their marks.

Delivery and Initial Outcomes

Initial presentations were conducted just two hours after the brief was issued and took the expected path of offering design solutions to the problem without examining the wider context. Subsequent presentations were delivered by first year students, although second year students were present to answer questions for their group. Discussions after the presentations involved all groups with staff acting only as facilitators. Issues discussed included: how malaria is caught, local beliefs, barriers to use, approved materials, distribution, re-treating, disposal, encouraging correct use. Students began to appreciate the broader concepts of SD and the importance of the qualitative, social aspects. Within their presentations students identified a reluctance to use mosquito nets, citing a long standing belief that malaria is not caught from the mosquito; instead malaria was attributed to spending too long in the sun or eating too much fatty food. Others identified the role of traditional healers and attributed severe malaria to evil spirits and hereditary factors. Students identified that for their product to be successful they had to overturn, or challenge, this existing cultural belief. Indeed, it can be argued that changing accepted western cultural belief is the real challenge of sustainable development!

Programme Evaluation

A questionnaire was issued both prior to the project brief and immediately after concluding the project with data processed separately for first and second year students. Question one asked students to match stakeholders against seven issues with responsibility ranging from none (0) to high (3). Issues evaluated were: product cost, environmental impact, human cost, social impact, profit, disposal and packaging. The sustainability issues were segregated and combined to form a sustainability index and overall change in perceived responsibility (Figure 1).

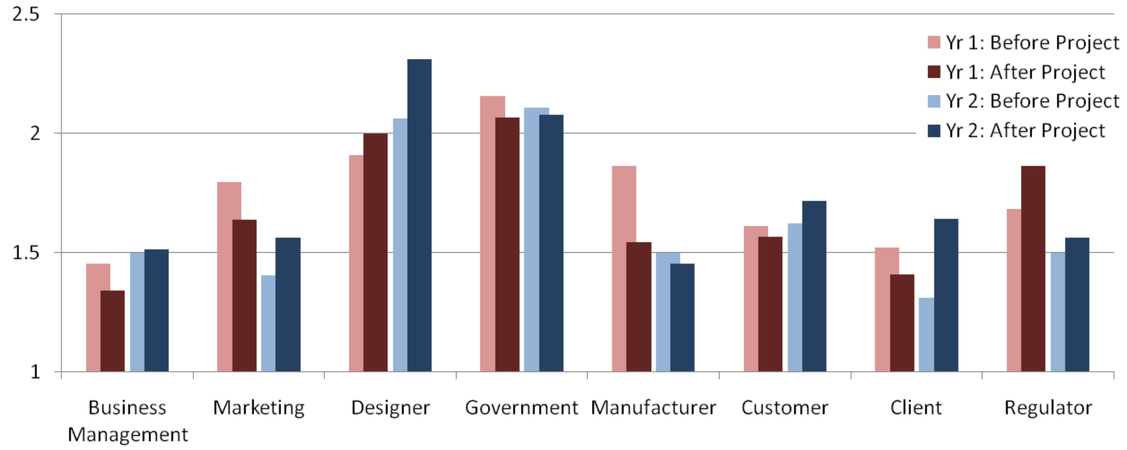

Figure 1. Perceived Responsibility (Sustainability Index)

The results illustrate first year students' belief that responsibility for these issues rests with the designer, government and regulator. For second year students the customer holds more responsibility than the regulator. The change in students' perception of responsibility is marginal but in both cases the designer has a higher level. First year students believed the manufacturer held less responsibility after the project while second years believed the client has more responsibility than before. Question two asked students to rank a list of design criteria in order of importance, the arithmetic mean calculated for both before and after the project (Figure 2).

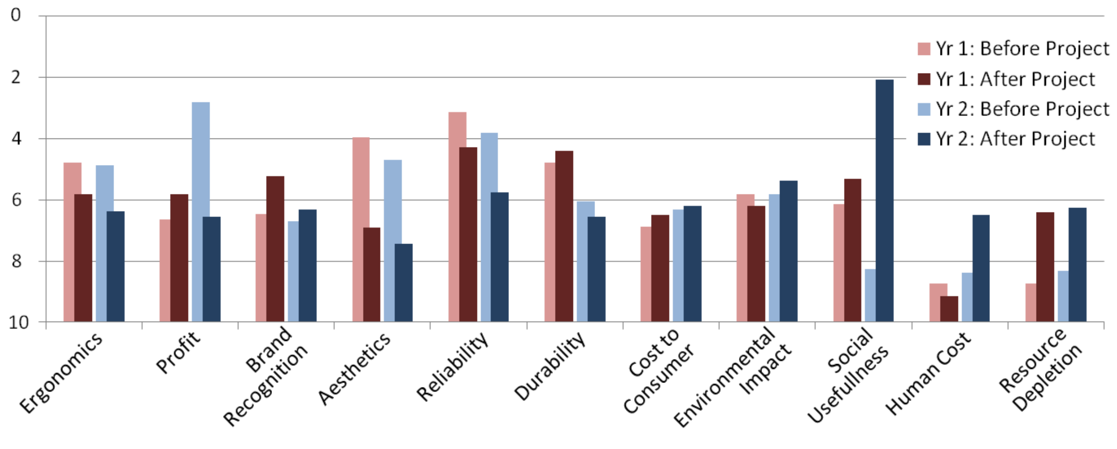

Figure 2. Ranking of Design Criteria

It is clear that first year students' understanding of design criteria had been changed by the exercise with conventional criteria such as aesthetics and ergonomics becoming less important than before and others such as durability, resource depletion and social usefulness ranked more important. For second year students chart demonstrates a more profound change in understanding. Before the project conventional criteria were ranked higher than sustainability issues. After the project, students ranked social usefulness as the highest criteria by a significant margin with low deviation between the remaining criteria. Question three asked students to rate their level of understanding of the concepts of SD choosing from: very high, high, some understanding, little understanding, none. The responses were collated and compared to a subjective evaluation of the students' actual understanding where they were asked to define SD within the context of design using 80 words or less (Figure 3). The chart clearly shows that first year students' claimed understanding was significantly higher than demonstrated through their own definition. However, the actual level of understanding was significantly higher after the exercise. The chart also shows that second year students claimed understanding was significantly higher than that of first years and that actually demonstrated. However, the actual level of understanding and the change in understanding much greater after the exercise than for the first year students.

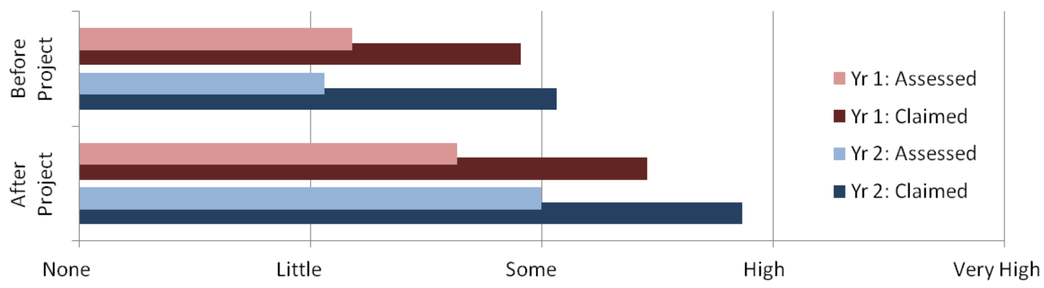

Figure 3. Change in Claimed and Evaluated Understanding

Interpretation

The results for first year students were less clear cut than for second year students. For the first question any changes in student perception of stakeholder responsibility are slight and within a margin of error. The reasons for this are twofold: Firstly, the students may not be familiar with terminology used; secondly, the answer matrix was overly complex with 56 cells. This aspect could be alleviated by providing students with their "before" questionnaire prior to completing the "after" questionnaire, reducing errors and recording only changes of opinion. For second year students there is clearer insight into students' perception and changes are more discernible. The second question yielded more significant results. Both student cohorts demonstrated a change in values for design criteria with social usefulness considered extremely important. This change was significantly greater for second year students. The final questions evaluated both a change in understanding of SD concepts and the level of over-perception. Both sets of students claimed greater understanding than they actually had. This was the case both before and after the exercise. However, there was a significant change in understanding demonstrated by the subjective evaluation of their answers, especially amongst second years. This understanding was also demonstrated in the project presentations and open discussions. The course met both the proposed guidelines as well as the institutional, particularly the ECUK requirements:

- Consider *"…environmental, social and economic outcomes simultaneously"*
- Understand *"…social and cultural structures outside of their normal community of practice"*
- Impacts may be *"global and long-lasting"*
- *"Consider the views of the community"*
- *"Be aware that there are inherently conflicting and un-measurable aspects of sustainability"*

CONCLUSIONS

Utilising a PAL/PBL approach engaged both first and second year students within the same groups, as a result first year students acquired basic design skills directly from their peers while second years gained experience of managing the design process. By focusing upon a project with clear, social benefits the "social usefulness" model could be introduced to meet the guidelines of both the ECUK and RAEng, taking students beyond the normal "eco-design". This promoted an understanding of the impacts of decision making, often outside of their traditional sphere of influence. As a result all students gained an understanding of the broader concepts of SD and impact on the wider community. In addition, one of the key skills developed through the PBL approach is self-directed learning, something that is essential if students are to develop beyond university through life-long learning.

For design students to utilise sustainable development they must evaluate the social contribution against the economic, environmental and human cost. This approach can be adapted to all aspects of the engineering design curriculum; all that is required is the asking of two simple questions.

1. Is it socially useful?
2. Or is it a waste of the Earth's natural resources?

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