

Assessing Education for Sustainable Development (ESD) within engineering

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ABSTRACT: Engineers can play a key role in the development and implementation of sustainable development principles into everyday living. Therefore, it is essential that engineers have a practical understanding about, and can make engineering decisions for, sustainable development. In this paper, the authors highlight the importance of the assessment and evaluation of sustainable development within the engineering curriculum, and introduce the results from a *self-reported knowledge* survey on sustainable development, which was administered to engineering students at the University of Bristol in Bristol, England, UK. The results indicated that while students at the University of Bristol had a good knowledge of the terminology associated with both environmental and sustainable development principles, their understanding of some of the diverse subject areas and tools for sustainable development was discrepant. The need to deliver more effective Education for Sustainable Development (ESD) for engineers is briefly discussed and strategies for improvements are presented.

INTRODUCTION

In 2005, the United Nations (UN) declared a decade (2005-2014) for Education for Sustainable Development (ESD). The UN's aim here is to challenge global educational policymaking by highlighting the global significance and importance of ESD, and actively encourage the coordination and dissemination of best practice. According to the World Federation of Engineering Organisations (WFEO), it is critical that engineering graduates are equipped with the relevant knowledge and skills to effectively address such challenges in society [1]. The most significant challenge currently viewed is climate change.

One of the roles of ESD is to question the current educational systems that are in practice and determine their effectiveness at fostering how the principles associated with sustainable development and growth are taught.

The importance of sustainable development was clearly identified by the Engineering Council, UK, with its publication of the UK Standard for Professional Engineering Competence (UK-SPEC) [2]. This stated that Chartered Engineers must *undertake engineering activities in a way which contributes to sustainable development*. This commitment highlights the need for the increased use of appropriate technologies and practices, both in the developed and developing world, where resource consumption and environmental pollution have come to the forefront of scientific and public opinion.

In 2006, the Higher Education Academy (HEA), UK, produced a progress report on the subject of ESD for senior managers in higher education [3]. The document discusses the concept of *sustainability literacy* and defines it as *learning about how human actions affect the immediate and long-term future of the economy and ecology of our communities*; stating that sustainability literacy needs to be a *core competency for*

professional graduates. The purpose of the HEA report was to determine how 17 different subject disciplines (including engineering) were contributing to developing graduates who are *sustainability literate*, identifying and disseminating good practice in both teaching and curriculum development. The key findings of the report indicated that ESD is rising across all disciplines, but despite this rise, the overall coverage of ESD in the curriculum is uneven both within and across disciplines. The report concluded that there were three broad levels of progress in the embedding of ESD by subject disciplines: those who had effectively adopted ESD into their undergraduate and postgraduate courses (such as engineering); those who have made limited progress into embedding ESD (such as economics); and finally those who had an interest in ESD but had not embedded it into their curricula (such as mathematics).

There are numerous publications addressing the role that universities have on the creation of a more sustainable world future [4-6]. However, care must be taken to ensure that all sustainable development education is delivered within the context of engineering. If engineering content is *watered down* and too much emphasis is given on other subject areas pertinent to sustainable development, there is a risk of producing *poor* engineers. The aim is to produce a new breed of professional engineers who have proper regard to environmental, social and economic factors.

It is necessary to determine the *definition* or purpose of any teaching programme prior to its delivery. There is a clear distinction between education *about* sustainable development and education *for* sustainable development. The former simply implies an awareness of the issues and the ability to discuss them in context, while education *for* sustainable development implies not simply an understanding of the issues, but an ability to apply, design and operate systems which are sustainable [7]. An additional issue is the perceived format that sustainable development education should take. For example,

should it be taught as an independent subject or in the context of the *traditional* engineering subjects as case studies? The type of approach is dependent on what individual lecturers or institutions feel is most applicable to their teaching and curriculum, and will also be influenced by any existing materials/teaching resources. For either option, the lecturer/tutor needs to be at least familiar with the principles of sustainable development, ensuring that the taught *skills base* is sufficient to fulfil the educational requirements of the course and any external accreditation requirements such as the UK SPEC [2].

In order to achieve education for sustainable development, it is necessary to give individuals/students more than simply the knowledge and skills for recognising sustainable development, but also the capacity to develop sustainable development practices in their *own world*. Thus, the scale of the focus of the education must also be considered.

An early paper from 1984 reflecting an author's views on the education of engineers acknowledged a shortfall in the level of public education for the understanding of social, industrial or technological innovations; and made the observation that unless wider technological understanding is applied, the *rising demand for products will be accompanied by a rising resistance to its social impacts* [8]. The same paper also discussed the growing need for engineers to be familiar with an increasing range of disciplines in order to impart the necessary breadth of experience and learning. Overall, the paper stressed the importance of engineers having a new range of skills and knowledge, in particular relating to the overall UK economy and social aspects (such as communication and management skills) but failed to directly mention a role for engineers to consider the environment, resource consumption or those subjects currently considered to be integral to sustainable development.

Today, the focus has changed; the question is how engineers can potentially save the planet by making all their decisions with the correct consideration to the potential environmental, social and economic impacts.

EDUCATION FOR SUSTAINABLE DEVELOPMENT AT THE UNIVERSITY OF BRISTOL

The theme of Sustainable Development (SD) is now high on the agenda and people are starting to look beyond the concept to some practical solutions. This vital component has been introduced across the engineering programmes at the University of Bristol in Bristol, England, UK, with a particular focus on design and project activities.

Professional Studies (PS) is a cross-faculty programme (Aeronautical; Electronic; Civil; Mathematics; Mechanical; Computer) at the University of Bristol. This programme has been innovatively structured around the latest requirements of the Engineering Council for professional accreditation. It complements the technical tools of engineering with the knowledge and skills of business and management, with a special emphasis on sustainable development. PS comprises two units, which are taken by more than 600 students each year. The PS course is designed to provide the generic professional knowledge and awareness required to meet the accreditation criteria of relevant professional institutions. It is structured around the five *Principle Learning Outcomes* specified in the latest professional accreditation guidelines issued by the Engineering Council covering the following topics:

- Commercial and economic;
- Management techniques;
- Sustainable development;
- Legal framework, and health and safety;
- Professional and ethical conduct [2].

In addition to enabling professional accreditation, the PS programme aims to stimulate the acquisition of knowledge and skills. It also is aimed at introducing visionary goals for the role and value of engineering in society.

The programme was designed to provide guidance and insight into the professional engineer's personal, organisational, and health and safety roles and responsibilities. The course addresses the interrelationship between engineering processes and the wider context within which they operate, focusing on sustainability and covering commercial drivers, legal frameworks, health and safety, environmental, and professional and ethical issues. As part of the PS units, students work in teams to audit real life engineering companies regarding their sustainable development practices and make recommendations for possible improvements.

Sustainable energy and transport are now afforded additional attention within the PS units and other specific engineering programmes, for example, through research and design projects. There are also other taught units such as *Engineering for the Built Environment* (sponsored by the Royal Academy of Engineering, UK and ARUP), *Building Systems*, *Energy Management*, *Power Generation for the 22nd Century*, and a cross-faculty open unit (*Sustainable Development*).

ASSESSING ENGINEERING KNOWLEDGE OF SD

Assessment is an integral part of teaching and learning [9]. It is an ongoing process that is aimed at the following:

- Understanding and improving student learning;
- Involving making course and institution expectations explicit;
- Setting appropriate criteria and standards for learning quality;
- Disseminating how well performance matches those expectations;
- Using the information available to improve performance [10].

Elizondo-Montemayor goes on to state that the main purpose of the assessment process is to evaluate the standard of competence, based on a framework of reference criteria that clearly emphasises the achievements of standards [11].

There has been little previous research undertaken to determine the level of knowledge on sustainable development attained by engineering students. One international study, which sought to evaluate student's knowledge on sustainable development, surveyed undergraduate engineers from 21 different universities in nine different countries [12]. The survey was carried out between October 2000 and June 2002, and involved a brief two-page tick-box style survey being delivered to a total of 3,134 engineering students across several disciplines and at different stages of their courses. The survey was divided into four parts starting with information about the students, their level of knowledge and understanding of the environment and sustainable development, the perceived importance of sustainable development by the students, and previous environmental/sustainability education.

The survey results indicated that although the engineering students were knowledgeable about high profile environmental issues, such as acid rain and global warming, the level of knowledge relating to 15 particular aspects, including ISO 14001, the Kyoto Protocol and the Rio Declaration, industrial ecology, components and approaches to sustainable development and inter- and intra-generational equity, was very poor, with some students acknowledging that they had not previously heard of these concepts. The survey also highlighted differences between countries, with students from some areas of Europe (Sweden and Germany) and the Far East (Vietnam) having the highest knowledge and understanding of sustainable development. More encouragingly, however, despite a relatively low understanding of sustainable development by the engineering students overall, most students recognised sustainable development to be either *important* or *very important*.

The authors of this research acknowledged their perceived difficulties of teaching sustainable development to engineers as engineering students *needed to see an immediate and direct relevance between the theory of sustainable development and engineering practice* [12]. One reason for this is the perception by engineering students that sustainability is often perceived as *soft-science* rather than the *hard-science* of engineering [13].

ASSESSMENT OF EDUCATION FOR SUSTAINABLE DEVELOPMENT AT THE UNIVERSITY OF BRISTOL

Although course evaluations are conducted for every module and a wide range of student assessment techniques (eg examinations, assignments, reports) are used to determine the effectiveness of student learning and understanding; a greater rationale of the student knowledge of SD is required in order to determine the level of understanding of SD among engineering students undertaking the PS programme at Bristol University.

The survey design was identical to that used within the previously-discussed study as its parameters accurately reflected the educational topics administered in the PS programme, and also to facilitate the direct investigation and comparison of results [12]. The survey was *posted* to the electronic *Blackboard* network during March 2006, following the completion of the PS programme. This approach allowed access to all participating PS students (608 in total). Unfortunately, by this time, many students did not access their PS learning resources, but to present the survey earlier would have been prior to the completion of the programme. It is also understood that not all students access the electronic *Blackboard* system, or have the capacity to do so, once outside the teaching environment.

The survey received a response rate of 18% (108 students). Table 1 provides the breakdown of responses by different variables. The variables stated in the survey responses are reflective of the overall variables/demographics across the Faculty of Engineering at the University of Bristol. It is appreciated that the results from the Bristol study did not canvass the same number of students as the previous study [12]. As such, the specific analysis and comparison of participants' nationalities and engineering disciplines was not undertaken due to a lack of significance.

Figure 1 shows the level of understanding of environmental issues across Years 1 and 2, and Years 3 and 4 at the University of Bristol compared to the results of the Azapagic et

al study [12]. While the level of understanding is similar between year groups, it is clearly lower than the previous findings [12].

Figure 2 shows the level of understanding of the principles of sustainable development. Year 3 and 4 Bristol University students were particularly confident with the definition, concepts, components and approaches to SD. Figure 3 shows the level of students' self-reported knowledge regarding the range of environmental tools and technologies.

Table 1: The breakdown of responses by different variables.

		Number	%
Gender	Male	89	82
	Female	19	18
Year of Study	Year 1 or Year 2	54	50
	Year 3 or Year 4	54	50
Discipline	Civil Engng.	30	28
	Mechanical Engng.	29	27
	Electrical Engng.	10	9
	Aeronautical Engng.	23	21
	Engineering Maths	3	3
	Computer Science	6	6
	Engineering Design	7	6
Nationality	UK	86	80
	France	7	6
	Other European	6	6
	Other Countries	9	8
Total		108	100

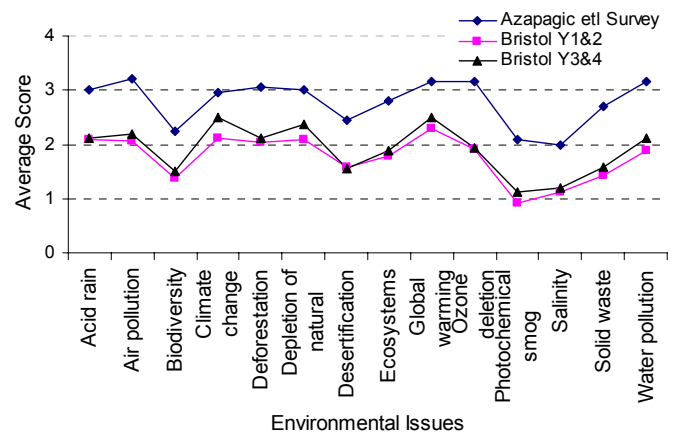


Figure 1: Understanding of environmental issues.

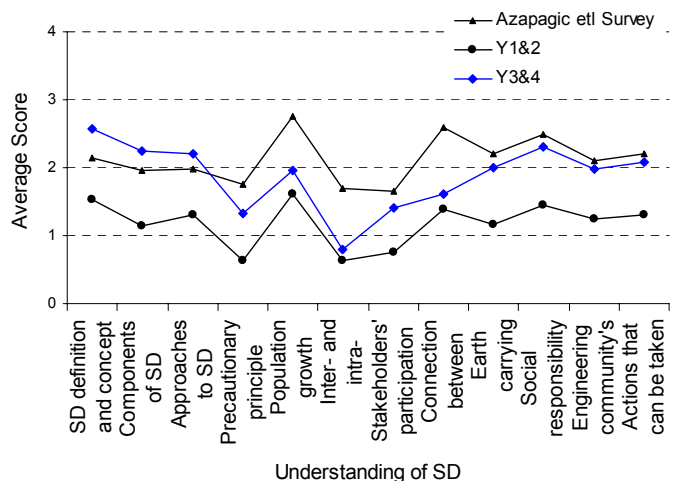


Figure 2: Understanding of SD principles.

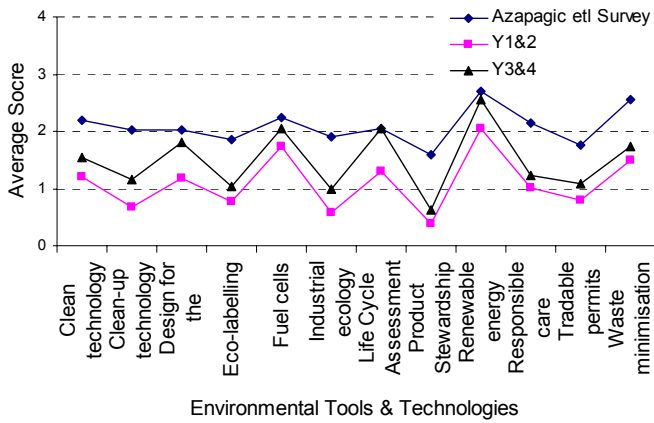


Figure 3: Knowledge of environmental tools and technologies.

While the previous survey shows a consistent level of knowledge across the range, the students at Bristol University (across both year sets) demonstrated variable levels of knowledge across the range of tools. This may be as a result of the differences in the sample sizes. However, all survey results indicated increased knowledge (or possibly confidence) regarding renewable energy and waste minimisation, perhaps because these areas contain synergies to a range of core engineering subjects. Correspondingly, the level of knowledge for certain areas, such as industrial ecology and product stewardship, were all low, which was consistent with previous results [12]. This may be due to these concepts not being closely related to engineering and also possibly beyond the *comfortable teaching scope* of some engineering tutors/lecturers, consequently reinforcing the importance of interdisciplinary teaching opportunities.

Overall, the results indicated that education for SD at Bristol University is progressive. For example, in all cases, the level of knowledge and understanding of environmental and SD principles increased over the duration of study, with Year 3 and 4 students exhibiting higher levels than Year 1 and 2 students.

CONCLUSIONS

There is an increasing demand for engineering graduates who have experienced *joined-up* learning experiences and have developed interdisciplinary skills that are essential for modern forward-thinking organisations, and it is essential that universities provide students with the best opportunities for success in the job market and furnish them with enough understanding to make decisions that assist rather than hinder the advancement towards sustainable development [7]. Therefore, it is essential that institutions can qualify the level of understanding of SD by their students. However, a demonstration of the ability to work within SD principles and to best practice may only be effectively exhibited within the workplace or during practical industry-based projects.

Universities who fail to deliver high quality education for sustainable development will find that their courses do not meet the requirements of the accrediting institutions and the Engineering Council, resulting in their students being unable to demonstrate their ability to *undertake engineering activities in a way which contributes to sustainable development* and ultimately unable to gain Chartered status without further study. Engineering courses that do not furnish students with the ability of becoming Chartered will ultimately be unpopular

and, in the increasingly competitive higher education sector, will become obsolete while potentially harming the reputation of the institution. The PS programme at the University of Bristol allows engineering students to meet their requirements under the UK SPEC without further study requirements after graduation. However, the survey has indicated that some principles and tools for SD appear not to be adequately covered or that engineers are failing to understand the significance of these principles. To address this, additional teaching and learning resources are being made available during lessons and also via electronic media. These resources include case studies that demonstrate SD in practice [7].

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