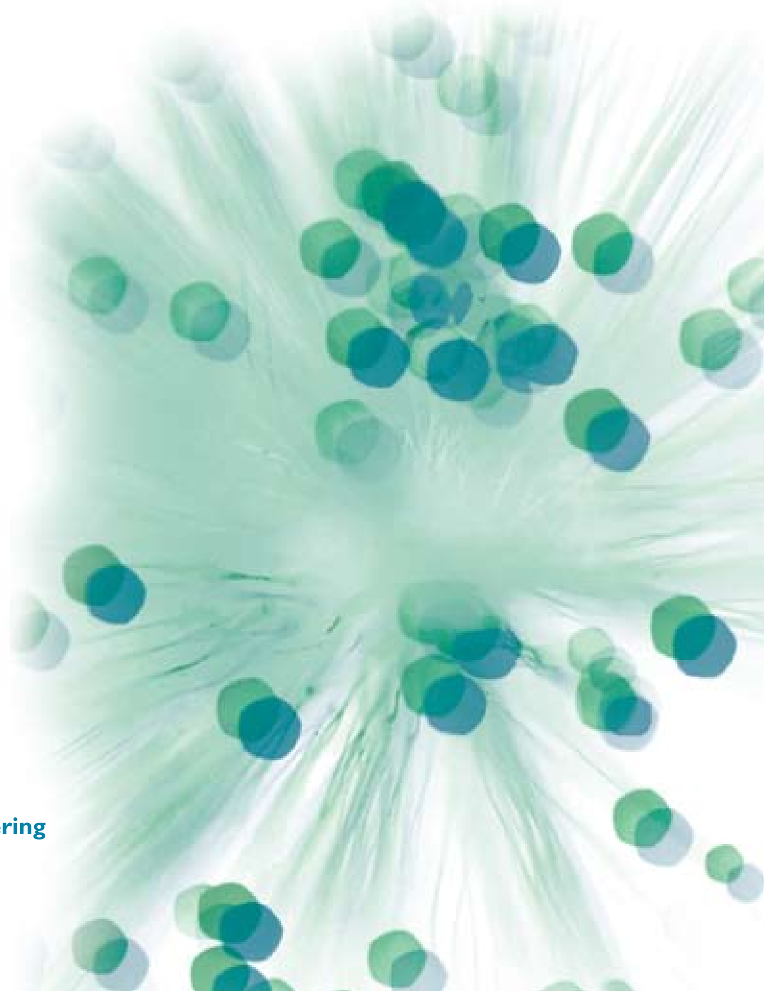
An Introduction to Sustainable Development in the Engineering Curriculum

an **Engineering Subject Centre** guide by

Roger Penlington and Simon Steiner



The Higher Education Academy
Engineering Subject Centre

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An Introduction to Sustainable Development in the Engineering Curriculum

Use of terms
The engineering discipline has a dominant role to play in sustainable development and therefore engineering education holds a position of considerable responsibility. With this in mind we have employed the term *Engineering for Sustainable Development* (EngSD) throughout this guide to distinguish it from Education for Sustainable Development (ESD).

Overview

This guide is intended to stimulate thought and consideration amongst those who:

- as members of teaching staff, may wish to introduce EngSD into their teaching
- as leaders of engineering programmes, may wish to consider the broader ethos of their curriculum.

The guide looks at why and how EngSD is included in the engineering curriculum and considers embedded versus discrete approaches. It discusses approaches to teaching and learning for EngSD, including examples of EngSD within the curriculum and a ‘what next?’ section, which points the reader towards further areas of study and practice. As an introduction to EngSD within engineering programmes, this guide does not seek to prescribe courses of action but rather aims to outline the main opportunities, sources of guidance and educational resources which may enable informed debate and decision making.

Both personal action and leadership are required in equal measure if graduate engineers are to meet the needs of society, even when society itself may not be taking action (Blincoe, 2009). Readers of this guide should, therefore, feel empowered toward personal action and leadership in the encouragement of their future graduates in becoming effective global engineers.

Background and definitions

Engineering for Sustainable Development is a wide-ranging topic and, as such, may be considered to mean different things to different people. For this reason broad definitions of sustainable development provide a good starting point, such as *Our Common Future*, the Brundtland *Report of the World Commission on Environment and Development* (United Nations, 1987):

meeting the needs of the present without compromising the ability of future generations to meet their own needs.

Why is Engineering for Sustainable Development in the engineering curriculum?

Brundtland's broad definition can be readily applied to an engineering context, satisfying the personal responsibility felt by the student and enabling us as teaching staff to identify what future employers' expectations of engineering graduates will be in terms of sustainability.

The Engineering Council has defined the role of professional engineers in sustainability using the following six principles (Engineering Council, 2009):

1. Contribute to building a sustainable society, present and future.
2. Apply professional and responsible judgement and take a leadership role.
3. Do more than just comply with legislation and codes.

4. Use resources efficiently and effectively.
5. Seek multiple views to solve sustainability challenges.
6. Manage risk to minimise adverse impact on people or environment.

In keeping with these principles, a primary objective of higher education engineering curricula is to produce graduates who will seek membership of one of the engineering institutions and, subsequently, professional registration. This requires programme learning outcomes that are aligned with UK-SPEC (Engineering Council, 2008), which states that a Chartered Engineer is expected to be able to:

undertake engineering activities in a way that contributes to sustainable development.

The teaching of EngSD is not new, and present-day academics have the benefit of a solid foundation which has already been laid by prior guides and reports, such as the guiding principles of EngSD as developed by the Royal Academy of Engineering's Visiting Professor Scheme (Royal Academy of Engineering, 2005) and the outcomes of a three year initiative of the Higher Education Partnership for Sustainability (HEEPS) programme in Learning and Skills for Sustainable Development, *Developing a sustainability literate society* (Forum for the Future, 2004).

A case has been made for broadening the undergraduate engineering curriculum (Beder, 1989) for the benefit of a wider intake of students, their gender balance and the professional competence of graduates expected by employers. Despite the overcrowded curriculum, a key component is the addressing of social concerns and environmental awareness (Beder, 1989/90) which illustrates the wider consequences of engineering activity. Sustainability may also attract university applicants to engineering, especially female applicants (Male, Bush and Murry, 2009; Pelly, 2007).

How does Engineering for Sustainable Development fit within the curriculum?

EngSD has a motivational value, which means that it may be used to broaden the learner's perspective. The linking of learning with professional formation and the recognised need for graduates to be self-reflective has led Mitchell, Carew and Clift (2004) to propose the following principles:

- help the learner appreciate why consideration of sustainability is in their interest
- use appropriate pedagogies for active engagement with issues
- help learners gain plural perspectives
- encourage learners to continue thinking about issues beyond their formal education.

Alternatives: embedding versus discrete

A first step towards the introduction of EngSD into the existing engineering curriculum could be through a discrete, often optional, module with a clear discipline focus. This may stimulate student demand for a broader curriculum and offer attendant opportunities for stimulating, collaborative and interdisciplinary learning. This can make a strong contribution to reinforcing the curricula in meeting graduate competencies required for professional registration.

An in-depth example of such an approach may be found in the Engineering Subject Centre Mini-Project Report, *Education for Sustainable Development in Engineering: Report of a Delphi Consultation* (Tomkinson et al., 2008). This study sought consensus from a panel of experts to derive guidance in designing practices that could lead from a discrete module to the embedding of sustainable development within the curriculum.

Another example of the progression from the discrete to the embedded comes from the Centre for Sustainable Development at Cambridge (Fenner et al., 2005), where the initial introduction of an elective at the end of a programme led to the recognition that students were coming from their pre-university system with an increasing awareness of environmental and societal issues which they then expected to further during their higher education and professional careers. This approach is supportive of the further integration of EngSD thinking into HE at levels 4 and 5.

A wider study (Holmberg et al., 2008) examined the outcomes of differing strategies of integrating sustainable development into the curriculum over a number of years and recognised that institutional commitment is absolutely necessary for the transition from discrete to embedded approaches. The autonomy of individual academics within their discipline requires management commitment if a long term strategy of cultural shift and deep curriculum renewal is to be gainfully employed.

Alternative approaches to the incorporation of EngSD into the curriculum have been considered in more depth and illustrated through examples in Steiner and Penlington (2010) and Steiner (2010).

Approaches to teaching and learning for Engineering for Sustainable Development (EngSD)

This guide sets out to articulate opportunities for good educational practice which support a learner-centred approach to EngSD. It also aims to illustrate that integration of sustainable development within a course offers much in terms of a student's understanding and a wider appreciation of their role as a professional engineer.

Integration versus depth of ability has been investigated by both Humphries-Smith (2007) and by Tomkinson et al. (2008). The latter gives an example of developing EngSD through an inter-disciplinary problem-based approach, where it was found that more aspects of EngSD could be incorporated into a module than had previously been expected.

A wider study (Dawe et al., 2005) of education for sustainable development (ESD) identified that skills and attributes which support teaching and learning in ESD are, however, not easy to teach by traditional means. Their research identified three orientations in the teaching of sustainable development:

- the educator as a role model
- experiential learning by focusing on real and practical life issues
- holistic thinking.

Many approaches to learning encompassed by Enquiry Based Learning (EBL), such as problem based learning, project based learning and modes of self-directed learning, are reported by Khan and O'Rourke (2005) as being especially suited to the achievement of EngSD derived learning outcomes. These approaches employ the extrinsic motivation of a real world problem where often the identified goals may include the sociological as well as the technological aspects of the problem. This can present opportunities for students to practice higher skills such as dealing with uncertainty or incomplete data in complex situations.

In addition to the suitability of EBL approaches, there is also a strong case for applying EngSD to approaches that consider the linking of research and teaching. As a continuously developing topic, EngSD is especially suited to a learning approach where students are taught to learn in research-like ways. This approach nurtures students' transferable and confidence-building skills (Fasli et al., 2007), where students report outcomes such as:

understanding how my study impacts on the real world and *you don't just take [sic] what other people say.*

By being based at the interface between technology and society, these approaches also develop valuable workplace skills of judgement and reasoning. Technology based and analytical subjects must relate and contribute to social policy based topics. These may also have an analytical content, such as energy use audits, and may explore policy and emissions trading issues (Hill, 2005).

Appropriate technology

It is widely accepted that students are motivated by 'real world' or authentic learning experiences; it may be suggested that this is even more apparent where there is an added social benefit. Using appropriate technology as the basis for design projects in the developing world has been outlined by Clifford (2005) through the constructive linking of fundamental knowledge and the engineering skills of its application:

By undertaking projects based around difficulties encountered in developing world contexts, students are encouraged to reflect on the technological challenges involved as well as the availability of materials, workshop resources etc.

Examples of Engineering for Sustainable Development within the curriculum

There are a wide range of published examples of EngSD teaching and classroom resources. The Engineering Subject Centre's Sustainable Development webpage (http://www.engsc.ac.uk/sustainable-development) provides a comprehensive introductory selection to complement this guide, including links to both resources and wider networks. A small selection of examples have been given here, drawn in part from *Sustainability Education: Perspectives and Practice across Higher Education* (Eds. Jones et al., 2010).

Royal Academy of Engineering Visiting Professors' Scheme

(http://www.raeng.org.uk/education/vps/default.htm)

Engineering for Sustainable Design: Guiding Principles (Royal Academy of Engineering, 2005) provides a summary of the Royal Academy of Engineering (RAEng) *Visiting Professors in Engineering Design for Sustainable Development Scheme*, with case study illustrations of how EngSD has been included in the curriculum. The

RAEng scheme illustrates how stimulating student activity may be derived from real issues within EngSD, such as socially responsible water use or the chemical and manufacturing engineering issues of laundry cleaning products, as well as through scenario activities, such as mock planning enquiries.

Many of the questions raised by EngSD may be interpreted across a broad range of engineering disciplines, for example design, manufacture, use or disposal. All branches of engineering education need to seek solutions to the question raised by Richard Dodds, Visiting Professor at the University of Liverpool, in ‘Extending product life – the forgotten challenge’ (Dodds, 2004).

Toolbox for Sustainable Design Education
(http://www.lboro.ac.uk/research/susdesign/LTSN/introduction/Introduction.htm)

This provides a structured series of guidance, teaching materials and reading lists. A particularly helpful feature for those new to EngSD is a glossary of terms.

The Natural Edge Project
(http://www.naturaledgeproject.net/default.aspx)

This Australian resource provides fully prepared teaching materials that are technically detailed and fully contextualised in terms of the wider social benefits of ESD.

Design-Behaviour
(http://www.design-behaviour.co.uk)

Although it does not include prepared teaching materials, this resource in 'design-behaviour' provides examples of how ESD issues have been interpreted by students considering the impact of design upon user behaviour. (See also Lofthouse and Lilley, 2008).

Socio-centric sustainability
(http://sociocentricdesign.com/)

The purpose of this resource is to give undergraduate engineering and product design students a better understanding of the implications and human expectations of sustainable engineering design solutions. The accompanying mini project report (Humphries-Smith, 2010) looks at the development of a resource for undergraduate engineers and designers with an aim of aiding their understanding of the socio-centric dimension.

SORTED, Sustainability On-line Resource and Toolkit for Education
(http://www.eauc.org.uk/sorted/embedding_sustainable_development_in_the_curric1)
(http://www.eauc.org.uk/sorted/creating_the_conditions_for_embedding_sustainab1)

From the Environmental Association for Universities and Colleges (EAUC), this provides guides for curriculum development and also outlines the conditions and leadership required for successfully embedding ESD within the curriculum.

[All online references in the text were accessed on 17 June 2010.]

What next?

There are many opportunities for classroom activities which bring together the application of technology to real-world problems with a social dimension. An item as familiar as water (Clark and King, 2004) may provide numerous stimulating topic areas for engineering solutions.

To illustrate the opportunities EngSD can provide in supporting high value learning through complex situations, Tomkinson (2009) describes how problem-based learning across engineering disciplines can approach problems for which there are no "right" answers. Examples given include: water, shelter, energy and problem spaces. Each is characterised by being set in a situation which is realistic to the future professional interests of the learner but which will only have an outcome with a qualitative value of "good or bad", rather than "right or wrong".

As described in the Royal Academy of Engineering's *Guiding Principles* (2005), EngSD will be considered to have been achieved when the three spheres of Techno-centric, Eco-centric and Socio-centric concerns coalesce into one unified activity (see Figure 1), with the openly recognised aim of protecting future generations from the impact of the actions of this generation.

As the teaching of EngSD moves beyond the application of technology or technological tools and towards environmental and eventually social issues, the understanding and skills needed by graduates will evolve and become more interdisciplinary in nature. This will require further evolution of teaching and learning through the integration of EngSD into the fundamental core of engineering programme learning outcomes.

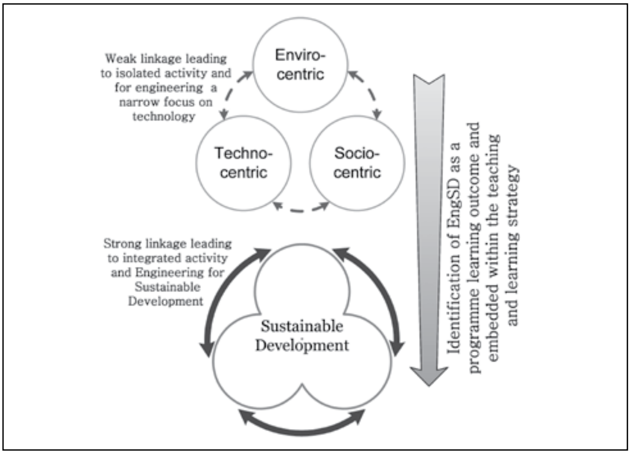

Figure 1. EngSD being achieved through integrated activity and identification within programme learning outcomes

This evolution of teaching may require a re-evaluation of the balance of the acquisition of knowledge and the development of skills within the curriculum, although this in itself requires a clarification of our understanding of the skills required by a graduate engineer beyond those of communication, numeracy, the use of information technology and learning how to learn, as identified by Dearing (1997).

Higher level cognitive skills have been identified by the Henley Report (Spinks et al., 2006) such as those which lead to systems solutions to problems of increasing complexity and which require both specialist and non-specialist knowledge.

The complementary nature of approaches employed in the teaching of professional ethics to those used in EngSD supports the rationale for integrating the global dimension of engineering into the engineering curriculum. Engineering academics have identified the global dimension as including (Bourn and Neal, 2008):

- the ability to take a broader perspective – application of curriculum across countries
- an appreciation that what we do in developing countries impacts upon ourselves
- understanding that our culture doesn't have all the answers and there is more than one perspective and approach
- understanding the local context of development
- coping with uncertainty
- dealing with global issues doesn't necessarily mean going to developing countries
- challenging stereotypes
- recognition of finite resources in the world and the impact of globalisation
- potential role of different technologies
- mitigating and adapting to climate change.

When engineering curricula have incorporated the global dimension, then they may be considered as containing the learning experiences necessary to meeting the six principles defining the role of professional engineers (Engineering Council, 2009), the first of which encompasses the societal requirement for engineers to:

contribute to building a sustainable society, present and future.

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The Engineering Subject Centre's Sustainable Development resources

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This is one of a series of peer reviewed booklets looking at various aspects of teaching and learning aimed at all those involved in engineering education. The complete series is also available on our website.

About the centre:

The Engineering Subject Centre is one of the 24 subject centres that form the subject network of the Higher Education Academy. It provides subject based learning and teaching support for all engineering academics in the UK.

The Centre's Mission is:
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It achieves this through its strategic aims: sharing effective practice in teaching and learning amongst engineering academics; supporting curriculum change and innovation within their departments and informing and influencing policy in relation to engineering education.

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