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Approaches to the embedding of sustainability into the engineering curriculum – where are we now, and how do our graduates become global engineers?

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Abstract: This paper presents a resume of how the topic of sustainability can become fully-integrated into the engineering curriculum in the UK, and how this needs to evolve toward consideration of how graduates could be better developed as global engineers.

The paper begins by providing a justification as to why sustainability is an important feature of the already overcrowded engineering curriculum, and briefly reports, through illustrative examples, on alternative approaches which currently embed sustainability into the engineering curriculum. The paper makes the case that it is timely now to re-address the learning outcomes in order to enhance the students' experience beyond just the inclusion of new curriculum content It does this by consideration of the identified drivers that range from the accrediting bodies and from the aspirations of employers, through revised approaches to embed sustainability, to the consideration of students' own perceptions of sustainability and ultimately to their becoming employed as global engineers. The paper therefore discusses both the current and planned work toward supporting the development of engineering graduates into global citizens, with a greater emphasis upon their responsibility to ensure a sustainable future world, moving beyond sustainability awareness towards informed application of sustainability thinking.

Introduction

The topic of sustainability (and of sustainable development in terms of protecting our planet for future generations) has evolved in recent years from simply being something that scientists need to investigate and to solve, to have now become an everyday subject in the media of our daily newspapers, on television, and our life at home. As such, there is a growing expectation that sustainability should become included into everyone's teaching curriculum - from children in schools, through colleges to students on degree programmes (and across all disciplines) at university, where it becomes confusing to recall which is driving which.

Brundtland (United Nations 1987, RAEng 2005) described sustainable development as: 'meeting the needs of the present without compromising the ability of future generations to meet their own needs', where the social, economic and environmental issues are addressed from a technical base. Bruntland's description remains valid today and is widely cited in the literature.

In engineering, there is a long-standing expectation that engineers, by way of their training and education, are expected to find solutions to problems of significant complexity by the application of their ingenuity and imagination. Employers aspire to recruit such graduate engineers (Forum for the

Future 2000, 2005) whereby the graduate is already sufficiently skilled to apply their technical expertise with due consideration to the associated social, economic and environmental issues.

The Engineering Council (EC) is responsible for overseeing the accreditation of higher education degree programmes in the UK, working with the relevant discipline-specific professional bodies. The Council's UK Standard for Professional Engineering Competence (UKSPEC) recognises the expectations of a graduate engineer toward achieving either their Chartered or Incorporated Engineer status. UKSPEC states that accredited programmes must demonstrate both general and specific learning outcomes, where the specific learning outcomes must include the economic, social and environmental context, and in particular, '… understanding of the requirement for engineering activities to promote sustainable development' (Engineering Council 2008, p13). The Engineering Council has since produced its publication, Guidance for Sustainability (Engineering Council 2009) which promotes the role of the engineer through a commitment to achieving a sustainable world.

There is therefore an expectation that sustainability, and sustainable development, should somehow be included in the curriculum for engineering students in higher education. There is, however, also a recognition (even frustration) on how crowded that curriculum already is, indicating there is a growing need to find viable approaches, possibly of broader benefit, in order to facilitate that inclusion.

Approaches to the inclusion of sustainability into the curriculum

There would appear, nominally, to be two alternative approaches when considering how best to include sustainability into the teaching curriculum: to embed or to offer stand-alone material. However, the two options often blend to become indistinct, perhaps to establish a third approach. Chadha (Chadha 2006) refers to three alternative teaching strategies: embedded (where the emphasis is on the development of "know-how"), bolt-on (where skills are developed independently of the core discipline), and integrating (where skills are taught and developed explicitly within the core discipline).

The question therefore, is not the approach or strategy, but rather the learning outcome(s) to be achieved; do we require graduates to be aware of sustainable development, or (as suggested by UKSPEC) to be able to operate in a manner which may be considered sustainable?.

The choice of approach and development of strategy is best illustrated by the consideration of some examples.

The Royal Academy of Engineering "Visiting Professor" Scheme

The Royal Academy of Engineering has a number of well-established educational programmes, which includes its Visiting Professors' Scheme, and in particular its VPs in Sustainable Design. The Scheme was established in 1998, whereby prominent engineers were appointed on 3 to 5 year engagements as a Visiting Professor at a given university. VP's were established at 26 UK universities and the scheme continues. Each VP is contracted to provide teaching support in sustainable design based on their industrial experiences, and to work in partnership with an engineering professor at that university. Examples of their work are given in the Academy's Guiding Principles publication (RAEng 2005).

On first appearance, this is a stand-alone scheme; however, from exposure to these case examples, the students achieve learning outcomes where they become aware and engaged into the VP's specific topic in sustainability. In other words, they learn from and are able to apply the principles which they have learnt in sustainability to other areas, for their learning therefore to become transferable, and (by implication), for it to be considered as "know-how" plus bolt-on, and with the potential for integration.

An interdisciplinary module at the University of Manchester

The Engineering Subject Centre funded a Delphi consultation through its Mini-Project scheme at the University of Manchester (EngSC 2008), which aimed to produce guidance in designing modules to embed sustainability into the curriculum. Manchester already had an interdisciplinary pilot module developed with the Royal Academy of Engineering (EPS 2009a), where the students from across the

university took this elective module that investigated “wicked” problems in sustainability – ones without an immediate or obvious solution. This was subsequently informed by the Delphi consultation to establish the model for an enhanced module toward a programme thread [rather than a theme] in sustainability (EPS 2009b).

The establishment of a module at Manchester again suggests a stand-alone approach but because of its interdisciplinary nature, of student groups working on “wicked” problems, and of the university’s plans to develop the module into a thread, then this approach could better be described as a further example of embedding sustainability into the curriculum, and moving toward integration by the development of a thread woven through a given programme.

Resources websites at Cambridge and Loughborough Universities

At Cambridge University, Cruickshank (Cruickshank et al. 2006) led on an approach originating from a partnership with MIT (CMI 2006) which aimed to develop transferrable skills resources using sustainability as the vehicle. The resources were used to populate a website (ImpEE 2006), where it was recognised that teaching staff would require further assistance in sourcing reliable material for inclusion within their existing courses. A similar provision of teaching resources was developed at Loughborough through a project funded under the Engineering Subject Centre’s Mini-Project scheme. This established a website providing a Toolbox in the teaching of Sustainable Design (EngSC 2004) which gives the student access to lecture material, background notes, examples to use with students and sample lecture slides.

In both cases it was not the intention to displace current material to make space for a block of sustainable development teaching, but that the concepts in sustainable design should be explored through material that also addressed the wider issues in that field. Cruickshank cites the example of a course that examined the structural properties of a range of materials, arguing that this could be augmented by raising questions about social and environmental impacts of manufacturing that material, the waste implications at end of life, and the economic balances that must be made when assessing appropriateness for each given application.

On first appearance the establishment of resource websites suggests a standalone approach where the resources are intended for use by both staff and students. The resources are available outside the intended module, the aim being to provide students with readily transferrable skills towards their future employability, and could therefore be considered as being integrated into the students’ study.

Lessons to be learnt

The three illustrative examples given here each aim to demonstrate potential ways by which the topic of sustainability might be included in an already overcrowded curriculum. This is whether the inclusion is simply to inform and to provide a taster on the topic of sustainability (by embedding), or whether it is to do this whilst engendering independent thinking, critical appraisal and evaluation/recommendation (through either bolt-on, or preferably, by integration). The examples are: embedding externally-sourced expertise under the RAEng VP Scheme, the establishment of an interdisciplinary module, and the provision of bespoke resources in sustainability. Each gives due consideration to accreditation requirements, and aims to begin to meet employer aspirations of graduates from their respective programmes. However, the question remains: does this move the learning provision toward the formation of a global engineer?

As mentioned earlier, sustainability and the protection of our planet has now become a daily topic for everyone, and if there is to be a significant step-change in the teaching curriculum for engineers toward the notion of a global dimesion, then it is only appropriate that student and professional views are sought and acted upon, firstly with regard to the inclusion of sustainability.

Evidencing views on the inclusion of sustainability into the curriculum

Student and professional body views – Northumbria University

The Engineering Subject Centre funded a Mini-Project at Northumbria University (EngSC 2007) that investigated student perceptions of sustainability. The study obtained data from both questionnaire and focus groups at Northumbria, Newcastle and Durham Universities. The questionnaire established a measure of the students' concern for the environment and their views of their university's demonstrative commitment to operate in a sustainable way. It also gave an insight into the students' perceived level of knowledge of topics relating to sustainable development and how it should be taught.

Focus-group participants said they were very concerned about sustainability and the majority also thought that huge problems are being created for future generations as a result of the excessive consumption of natural resources. The participants gave a mixed response to the mode of the teaching of sustainability, but indicated better inspiration from an integrated approach rather than being taught as a "bolt-on", discrete module, with a preference for delivery as an enquiry-based activity.

"Not one discrete module. It wouldn't make any sense. It would never occur to me

to have it any other way than integrated across the whole course" (EngSC 2007)More generally, this investigation highlighted students' concerns over the perceived need to be challenged by complex views, both among themselves and by those of the profession, as well as generational issues and the need for staff development, both of which they perceived as barriers to the embedding of sustainability into their curriculum.

"Peer pressure counts for a lot. It's a generation thing isn't it – the older generation ….don't really understand the concept yet." …..... "We get a lot of theory but no practical or up to date examples"……"Same here. I don't think the lecturer knows enough about the subject to enable us to incorporate it into our work"…(EngSC 2007)

Indicators from the study also identified a clear need for universities to be seen as providing leadership and a clear demonstration of sustainable behaviour.

"It should be university policy to be sustainable." …... "There is a big problem with paper wastage" …….. "Well look at today, here – the heating is still on, it's boiling hot outside"……. "The computers are always on. Always. That's pretty bad." (EngSC 2007)

Design education – Ecodesign or Sustainable Design at Bournemouth

A study was undertaken at Bournemouth University that looked at the future of design education (Humphries-Smith 2007) and the potential to embed sustainability into the curriculum. The study looked at the significance of citing "sustainable" in the title of a degree programme – and how the teaching content differed from its predecessor.

For example, how does BSc Sustainable Product Design differ from BSc Product Design? The study sought the views of academics, students and employers, and concluded by noting that ecodesign is well-understood and practised, but there was scope to upgrade this to sustainable design. It also identified that sustainable design should be part of a designer/engineer's role and should therefore be integrated into their programmes of study.

Assessment against Learning Outcomes toward graduate employment

The examples given here are intended to provide evidence and assurances that accredited degree programmes have moved on from the simple recognition of students' attainment (what they know) to the specification of learning outcomes (what they can do) and students' assessment against those outcomes under UKSPEC (2008). Mitchell, Carew and Clift (in Azapagic 2004) promote the following principles towards the writing of specific learning outcomes that are demonstrable of the embedding of sustainability (and equally representative of engendering students' skills for future employment by integrating through their programme of study):

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

An excellent example that demonstrates this in application is given in the ethics case studies developed by the IDEAS CETL at Leeds (IDEAS 2009). The chosen case study looks at the conflict between environmental issues (in this case using sustainable timber) and protecting heritage (by replacing like-for-like in a listed building). The case study gives the scenario and group discussion questions that aim to challenge the student to extend their engineering thinking beyond the techno-centric, and into the social, and the econo-centric aspects of sustainability.

Towards a global engineer

We are now over half-way through the United Nation's Decade [2005 – 2015] for Sustainable Development (2005), and the future lies in taking the sustainability agenda forward. As noted by Short (2008), sustainability goes beyond the environment, but is not purely an 'engineering problem' so work needs to be done that will consolidate the topic of sustainability with further skills and capabilities that will enable engineering graduates to become globally aware, and to work as global citizens in the future. (Bourn and Neal 2008) identified the global dimension as including:

- the ability to take a broader perspective – and the application of curricula across countries
- an appreciation that what we do in developing countries impacts upon ourselves
- the 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
- the recognition of finite resources in the world and the impact of globalisation
- the potential role of different technologies
- mitigating and adapting to climate change

There is, perhaps, a more formal need for globalisation to become specified in the curriculum, for example as a further learning outcome on accredited programmes. These currently recognise engineers' '*obligations to society*' (UKSPEC 2008) which could be extended to specify a global responsibility for engineering activity. This would enable graduate engineers to demonstrate their capability to understand global issues and to be eligible to work around the world. Bourn and Neal remain aware of the overcrowded curriculum and work remains in exploring the most effective way to add the global dimension into this overcrowded curriculum. This is the focus of a recently-commissioned 3 year project funded by the Department for International Development (DFID) entitled A Global Dimension for Engineering Education (EngSC 2010).

Current examples toward globalisation include the work of student-charitable organisations such as Engineers Without Borders (UK-EWB 2009) and Engineers Against Poverty (EAP 2009). The emphasis here is to encourage students' work to move from enquiry-based activity through problem-based learning toward active project-based learning, in this case by undertaking development projects for the Third World on topics that originate from seeking to address sustainability and poverty issues.

Examples of student project activity such as Arnold (Arnold 2003) and Okonjo (Okonjo 2010) demonstrate that students are motivated to undertake projects which are founded in a desire to seek technological solutions to the basic needs of less developed communities. Ongoing work at Northumbria with engineering students is identifying the pivotal role that engineering plays in the world with its impacts extending beyond those first anticipated.

Students are being surveyed for their opinion on a number of questions regarding the global dimension, with initial responses including:

What is meant by the global dimension of engineering?

> *"Global dimension of engineering means covering all aspects of impact which engineering might have whether it is economically, environment, health and wealth" - student quote*
> *"Ways we can hopefully improve peoples lives around the world through engineering solutions" - student quote*

What drivers are increasing the global dimension within engineering?

> *"Climate change, resource limits, technology" - student quote*
> *"Environmental issues, global warning, government legislation" - student quote*

How can the global dimension of engineering be incorporated within engineering education?

> *"through reaction as we simply haven't grasped the scale of the problem" - student quote*
> *"to be made aware of certain issues, know responsibilities of global dimension, experience – shown what companies do" - student quote*

What do global skills look like?

> *"communication, teamwork + commitment to help each other solve these problems" - student quote*
> *"the skill is knowing what effect different engineering aspects have on the planet" - student quote*

This work is identifying a significant understanding of the global dimension and a sense of responsibility within the student body so perhaps it is timely that we recognise the need for a new pedagogical approach, of learning in partnership. This would recognise that the student body is already well-equipped to comprehend global issues and the use of communication technologies in its ability to impact on the rate of change around the world - whereas staff can, in many cases, only offer their experience of the application of technology (often without any consideration of more than local impacts). This learning in partnership could be further enhanced if consideration is also given to the increasing drive for the internationalisation of the curriculum and to the global recruitment of students to UK degree programmes.

Concluding Remarks

Sustainable development has become something of an everyday term to include the teaching of sustainability at schools with an expectation that it is also integral to study at university – from the curriculum right through to the campus environment. This paper has discussed the initial embedding of sustainability into the HE curriculum, citing examples where embedding has become integrating, to show it is readily-achievable and to propose that it is an important step on the way toward ensuring a global dimension to engineering curricula. Initiatives and published work elsewhere highlight moves to address the campus environment, sometimes with a blend of both – for example the Ecoversity Project established in 2005 at Bradford (Ecoversity, 2010a, b). The challenge remains in students' learning of sustainability in the engineering context, to consider technological options within an industrial, social, regulatory and ethical framework.

The Engineering Council cites six principles that define the role of professional engineers. The first of these encompasses the societal requirement for engineers to “Contribute to building a sustainable society, present and future” (Engineering Council 2009, p2). When engineering curricula and approaches to teaching and learning have incorporated the global dimension, they may then be considered as containing the learning experiences necessary in meeting all six of those principles.

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