EMBEDDING SUSTAINABILITY IN THE CURRICULUM; ENABLING ENGINEERING TAKE CENTRE STAGE

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Abstract: Sustainability has been assuming a more central role within chemical engineering curricula and throughout engineering education as a whole. Meanwhile however, engineering has been fighting an uphill battle to attract a consistent proportion of high quality recruits as the profession suffers from a low public profile and uninspiring image. Engineers are generally seen (and see themselves) as uncritical agents of economic and technological development who simply take direction from policy makers and paymasters, albeit ones that provide innovative technical solutions for society. This sells the profession far short and drains from engineering much of the inspiration, excitement and opportunity to "make the world a better place". Engineering curricula with sustainability embedded as core would however, particularly in the case of chemical engineering, provide a unique opportunity to;
- align the curriculum with the policy lead taken by several professional institutions and hence realign the professional ethos, vision, role, practice and image of engineers.
- position engineers to play a more central role in shaping society through influencing policy and debate on creating a sustainable society, and hence increase the visibility, importance, status and reputation of the profession.
- act as a powerful marketing tool for prospective engineering students.

Keywords: Engineering education, sustainability, professional ethics, society, environment, enrolment, engineering profession.

1. SUSTAINABILITY AS INTRINSIC TO ENGINEERING

1.1 Increased recognition of issues surrounding sustainability by professional institutions

Over the past two decades, there has been a dawning realisation among the engineering profession (and others) of the pressing need to create a sustainable global society. This has manifested itself most visibly through the respective representative professional institutions. Engineers Australia developed a policy on sustainability in 1994 which required that "members, in their practice of engineering, shall act in a manner that accelerates achievement of sustainability" (Carew and Mitchell, 2006). In 1997, the report of the Joint Conference on Engineering Education and Training for Sustainable Development in Paris called for sustainability to be *"integrated into engineering education, at all levels from foundation courses to ongoing projects and research"*. It also called on engineering organizations to *"adopt accreditation policies that require the integration of sustainability in engineering teaching"* and notes that *"retraining all faculty members"* will be *"important in implementing the new approach"* (Joint Conference Report, 1997). Also in 1997, eighteen national and international institutions representing the chemical engineering profession globally signed the London Communiqué which pledged "to make the world a better place for future generations" (Batterham, 2003). This was followed up in 2001, at the 6th World Congress on Chemical Engineering, where twenty chemical engineering institutions signed the Melbourne Communiqué (2001), a one page document committing each of them to work towards a shared global vision based on sustainable development.

The Institution of Chemical Engineers (IChemE) drew up *"A Roadmap for 21st Century Chemical Engineering"* (IChemE, 2007), a type of strategic plan for chemical engineering largely based on moving towards a sustainable future. Engineers Australia launched a formal sustainability charter in 2007 (Engineers Australia, 2007), taking the broad view that *"sustainable development should be at the heart of mainstream policy and administration in all areas of human endeavour"*. It also notes that achieving this will not be easy since it *"requires a fundamental change in the way that resources are used and in the way that social decisions are made"*.

The United States National Academy of Engineering has formulated its vision of the Engineer of 2020 (NAE, 2004). Its report outlines a number of aspirational goals where it sees the profession taking a more central normative role in society and looks for engineers to be informed leaders in sustainable development, beginning in educational institutions and *"founded in the basic tenets of the engineering profession"*. It suggests that engineering curricula be reconstituted *"to prepare today's engineers for the careers of the future, with due recognition of the rapid pace of change in the world and its intrinsic lack of predictability"*.

Moreover, the codes of practice of most professional engineering institutions recognise a role for sustainability which requires it to be woven through professional practice. Engineers Ireland's Code of Ethics (2003) is typical where, for example, one of its three sections relates to environmental and social obligations and members are required to, inter alia, *"promote the principles and practices of sustainable development and the needs of present and future generations"* and *"foster environmental awareness within the profession and among the public"*.

1.2 Professional institutions and programme accreditation documentation

Despite the initiatives outlined above, the work of the institutions in repositioning sustainability as a *"core operating principle"* (Mitchell, 2000) does not appear to have fully trickled down into programme accreditation documentation. Most accreditation guideline publications require sustainability to be covered along with a number of other non-core issues such as health and safety, economics, etc., but none that the author is aware of explicitly suggest that sustainability should actually permeate right through the programme; i.e. that it should in fact be the context, or a lens through which programme material should be filtered.

IChemE (2005) prescribe that graduates must achieve specified learning outcomes under five headings, three of which explicitly mention sustainability, though it is generally mentioned as one among many considerations (health and safety, business, ethical, etc.) rather than as a wholly intrinsic consideration running though all programme outcomes. Engineers Australia (2006) promote a similar approach which is divided into professional engineering competencies under three headings; knowledge base, engineering ability and professional attributes. Sustainability is emphasised under the second of these. Engineers Canada require that graduates satisfy a list of twelve general attributes, one of which; *"impact of engineering on society and the environment"* mentions sustainability, and then just in terms of understanding concepts and interactions. In the USA, ABET (2007) have eleven requirements of graduates, including *"an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability"* and *"the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context"*. Engineers Ireland (2007) simply advise that undergraduate degree level programmes *"need to develop an awareness of the social and commercial context of the engineer's work"* including an understanding of the constraints imposed by the environment, codes of practice and others. The Engineering Council of South Africa makes similar provisions in terms of being *"critically aware"* and *"competent"* to assess the impacts of engineering activity on a number of levels such as for example, social, legal, health, safety, and environmental (von Blottnitz, 2006).

Accreditation guidelines are important because they play a vitally important role in achieving change. The Royal Academy of Engineering (2007) highlighted this in their report on educating engineers for the 21st century when they recommended that *"the accreditation process for university engineering courses should be proactive in driving the development and updating of course content, rather than being a passive auditing exercise"*.

2. ENGINEERING; IMAGE, ROLES AND RESPONSIBILITIES

2.1 Public image of engineering

Engineering projects a startlingly low level of recognition and understanding on the public's radar. A recent study at Imperial College London showed that over half of engineering students themselves did not know what an engineer was before entering their programme (Alpay *et al.*, 2008). Another British study (RAE & ETB, 2007) of attitudes to engineering among the public confirmed this profile; perceptions of engineers and engineering were quite vague and attitudes towards engineering were generally mixed, with both positive and negative feelings expressed. While it was felt that engineers were responsible for providing many modern conveniences, they were also held *"responsible* *for key problems in society, such as climate change"*. Engineering was also perceived to be *"part of a type of commercialism that acted in the interests of money and progress rather than the good of people"*.

2.2 Perceived and actual societal roles and responsibilities of engineers

With respect to engineers own conceptions of their roles, two modes have been proposed (see Buciarelli, 2008). One is that of the value neutral *"gun for hire"*; essentially technical "paid hands" albeit ones that provide innovative technical solutions for society, but who do not see it their place to engage outside their safe technical sphere, instead taking direction from their paymasters and relevant policy makers. The other mode dictates that engineers have a broader remit incorporating an explicit commitment to social responsibility.

The former mindset Bucciarelli (2008) argues, is *"implicit in all of our teaching in the core of our disciplines"*. Proponents of this mode feel uncomfortable with engineers dwelling on the "soft" side of problems. Others hold that engineers can align themselves more in concert with the needs of society if they fully take on the tenets of sustainability, which would in turn bring them into new, less familiar territories and into contact with other professions and stakeholders (Mitchell, 2000; Batterham, 2003; Symkowiak, 2003). Chemical engineers generally profess a positive disposition towards the principles of sustainability (Furlong, 2004). However this masks a wide spectrum of views among practitioners on how far their responsibilities go; there isn't even widespread agreement among engineering academics on how they conceive sustainability (Carew and Mitchell, 2006; Lundqvist and Svanström, 2008). Accordingly IChemE (2001) have intimated that engineers have in the past fallen short, and suggest that "moving towards the goal of sustainability" will require the profession *"to examine and improve other aspects that have not traditionally been given much attention, at least by practicing engineers."* On the other hand, on the occasion of its one hundredth anniversary, the AIChE suggested redefining their constitutional definition of chemical engineering (Evans *et al.*, 2008) but chose not to use this opportunity to introduce the concept of sustainability.

2.3 Student recruitment to the engineering profession

There has been a general decline in the relative proportion of students undertaking engineering programmes over the past number of decades in many developed countries (RAE, 2007; NSB, 2008). Moreover, the lack of progress in increasing the proportion of female engineering graduates has been an ongoing cause for concern (NSB, 2008; Conlon 2008). This situation has led to some exasperation among educators since at a time *"when our young people are increasingly interested in how they can help to save the planet, we are failing to persuade them that engineering careers are exciting, well-paid and worthwhile"* (King, 2007). However, there is not universal despair; Jennings (2009) reports an increased demand for energy led programmes. In chemical engineering too, entry numbers have been increasing recently and reached record levels in 2008 (IChemE, 2008). While chemical engineering graduate numbers have suffered a decline throughout the decade in the US, enrolment patterns show that this trend will be reversed presently (Rhinehart, 2008).

3. SUSTAINABILITY; ENABLING ENGINEERS TAKE CENTRE STAGE

3.1 Global and societal context

Applying an engineering systems approach (material and energy balances) around the envelope of mankind's influence within the system that is the natural environment, clearly reveals a wholly unsustainable pattern of activity. Appropriation of ever greater flows of materials and energy mean we are hurtling, as Pereira (2008) inelegantly puts it, along *"a brutal collision course"* with our natural (and only) environment. In this context, tinkering around the edges with a few well intentioned marginal improvements on efficiencies will not suffice. In fact, progress here is often accompanied by a process known as rebound, whereby gains in industrial efficiency are merely offset by greater consumption levels (Clift, 2006). Thus material and energy flows need to be placed in socioeconomic and biophysical context to see how each influences the other (Ruth, 2006). A new mindset is therefore required – a revolutionary paradigm shift which encompasses thinking, ethos and actions, not just of engineers but of all society's leaders and professions and well as the general population (Segalàs *et al.*, 2008). This has clearly not yet happened; *"the consumption driven modern way-of-life continues un-abated in all fronts, everywhere"* (Pereira, 2009). The penny probably won't drop until precipitated by major economic, social or environmental shock(s) or perhaps a combination of each. Until the global mindset has fully embraced this new paradigm, top down initiatives based on incorporating economic externalities (i.e. social and environmental factors afforded equivalent economic values) such as Kyoto are likely destined to fail (Prins and Raynor, 2007; Lohmann, 2009). A systems approach here would show that any environmental gains achieved by closing say, a cement factory due to reduced overall consumption are negated if carbon emissions are simply reapportioned to another activity via some carbon credit trading scheme.

3.2 Realigning the professional role, practice and image of engineers within a new sustainability paradigm

It is clear that many engineers remain unconvinced of the need for a new sustainability based paradigm and the resultant social, economic and environmental challenges that this presents. Indeed, a significant proportion of engineers remain sceptical that climate change is anthropogenic; an online IChemE survey (TCE magazine, May 2007) found a majority of respondents (54%) believed it to be caused by sunspot activity. Similarly Ziemlewski (2008) reports scepticism among many respondents to an AIChE survey looking forward at the profession over the next quarter century. This is perhaps unsurprising given the limited role that sustainability has played in engineering education in the past.

However, if the initiatives proposed by the various institutions which place sustainability at the core of engineering (reports, communiqués, charters, codes of practice, roadmaps, etc.) are to be carried through to their logical conclusion, then one might expect this ought be reflected in respective accreditation documents and through to programmes. A paradigm-like change in engineering education would be required to achieve a fully integrated sustainability curriculum; thus necessitating a degree of programme reform. (Mitchell, 2000; Bucciarelli, 2008; Holmberg *et al.,* 2008). Such a realignment also requires the development of attributes related to values, ethics, complexity and the critical thinking required to relate various interests; social, political and environmental with technical and economic (Bucciarelli, 2008; Segalàs *et al.,* 2008) and an outward looking, collaborative approach with both an ability and desire to engage with other professions who have a deeper understanding of some of the other elements of sustainability, including environmental and social scientists, economists, sociologists, planners, politicians, policy makers and the general public.

Progress on moving towards sustainability embedded curricula can be slow however; even universities to the forefront in terms of embracing sustainability over the past two decades have faced substantial difficulties, not least due a narrow conception of sustainability among faculty (Holmberg *et al.,* 2008). The widespread realization of a sustainability embedded curriculum therefore will only come about once the professional institutions explicitly require this in their accreditation documentation; the onus is principally on them to elicit fundamental change (Batterham, 2003). Failure to do this risks the ghettoisation of emerging sustainable, energy and green engineering programmes being left to address not only the increased demand for specialists in alternative and renewable energies (Jennings, 2009) but also being left to exclusively incorporate sustainability. Such an outcome would not be in anyone’s interest (Szymkowiak, 2003) and a sort of schism could emerge with respect to ideologies and ethos regarding sustainability among engineers. Progress on integrating sustainability for remaining programmes would perhaps remain an elusive goal. Moreover from an engineering image and enrolment standpoint, this would also be an regrettable outcome.

3.3 A central role for engineering

There are a number of fundamental reasons for suggesting why engineering should play the central role in reconstructing society in a sustainable manner. On the most basic level, the engineering systems approach that chemical engineering in particular applies, is the only basis upon which sustainability can be determined. The second law of thermodynamics and the related concept of entropy is also central to understanding energy flows through the natural system that is earth. By examining these issues in relation to the creation of a sustainable society, engineers can play a lead role in communicating with other professions and stakeholders. For example, a commonly held view among neoclassical environmental economists is that “sustainability does not require restrictions on material consumption” (Illge and Schwarze, 2009). This example indicates why engineers should (and must) work with economists to create a new paradigm which decouples consumption from economic growth, where the latter can be maintained through increased value of services. Of course engineers can also learn from others, particularly in relation to social and environmental standpoints, and this multi-faceted approach can be applied to achieving positive results in tackling complex multi-disciplinary societal problems and requirements. A second reason for placing engineers in a central role in the quest for a sustainable society is because it is engineers who will devise the actual products, processes and projects that will be required to transform society during the present century. This will be a huge challenge, but the greatest obstacle will be changing the prevailing mindset. Once this is achieved, things can move very rapidly as individuals will rapidly change habits (RAE, 2006) and governments may put R&D spending *"on a wartime footing"* (Prins and Rayner, 2007). Thirdly, engineers have an ethical responsibility to create a sustainable society; and this responsibility extends beyond mere technological development; engineers have a duty to both share their expertise with others in society and work with them to change hearts and minds towards a new paradigm and to construct such a society, as opposed to simply being uncritical "paid hands".

3.4 *Attracting new engineers*

The integration of sustainability into engineering programmes will broaden the perspective of the profession and fundamentally re-evaluate its role within and responsibilities towards society. This offers the potential to reinvigorate the profession as engineers perceive a more central role in making a positive contribution to society. This broader outlook will have the effect of widening the pool of potentially interested applicants. A recent British study (RAE & ETB, 2007) found that both the potential to effect large scale change to the world in a positive way and the expression of social responsibility i.e. bring benefit to people and society, were two of the factors that had the greatest potential to engage people with engineering. Embracing sustainability throughout programmes may thus result in increased levels and quality of enrolments in engineering programmes, in particular chemical engineering (Clift, 2006). Indeed, it appears this may already be happening to an extent; 2008 saw record numbers of chemical engineering enrolments in the UK (IChemE, 2008). This is probably as a result of increased public awareness and employment opportunities in sustainability related fields (energy, environmental, etc.) as well as the efforts of programmes and professional institutions to align more closely with these emerging areas, both in practice and image.

Embedding sustainability into engineering programme curricula also offers the potential to increase the proportion of females in the profession. A recent study found that *"making a difference to the world"* was the top aspiration among females, whereas it only rated third among males (Alpay *et al.*, 2008). Similarly, a recent CEP survey showed that an appreciably higher percentage of females (84%F v 70%M) consider that sustainability issues will impact significantly on chemical engineering over the next quarter century (Ziemlewski, 2008).

4. CONCLUSIONS

Sustainability will be the context within which engineering is practiced throughout the 21st century and beyond. While the professional institutions have shown some lead through various initiatives, it is imperative that they make the systemic embedding of sustainability a key requirement for accreditation. This will help precipitate the paradigm change that will occur in society as a result of the consequences of a global society engaged in continued unsustainable practices. It is the ethical responsibility of engineers to lead on altering the attitudes of society, given their unique position in understanding and applying systems approaches and due to their capacity to design and develop the products and processes that will realise a sustainable society. Engineers also have a duty to engage and learn from other stakeholders. The result of this will be a shift in engineers' self-perception, ethos and role, and a correspondingly greater capacity to influence positive change; the profession can be reinvigorated as it moves centre stage. This will result in an enhanced public profile and image and one which will have increased capacity to attract potential recruits to the profession.

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