The Global Engineer

Incorporating global skills within UK higher education of engineers

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ENGINEERS AGAINST POVERTY

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DFID Department for International Development

CONTENTS

ABBREVIATIONS

CETL	Centre for Excellence in Teaching and Learning
CPD	Continuous professional development
CSR	Corporate social responsibility
DFID	Department for International Development
DIUS	Department for Innovation, Universities and Skills
EAP	Engineers Against Poverty
EC UK	Engineering Council UK
EWB-UK	Engineers Without Borders – UK
FCO	Foreign and Commonwealth Office
HEFCE	Higher Education Funding Council for England
HEIs	Higher education institutions
ICT	Information and communication technology
LDCs	Less developed countries
NGO	Non government organisation
RAENG	Royal Academy of Engineering
SD	Sustainable Development
SETI	Science, engineering, technology and innovation
STEM	Science, technology, engineering and maths
UK-SPEC	UK Standard Performance for Engineering Competence
VC	Vice chancellor
WEDC	Water Engineering and Development Centre

Executive Summary

Engineering is a global industry undergoing a period of unprecedented change. The future of engineering (and the world economy, in general) is being framed by global forces which transcend national boundaries such as the impacts of globalisation, rapid technology advances, climate change and inequality. Through the application of science and engineering, humanity has the potential to meet all of its basic needs: water, sanitation, food security, shelter, energy, transport. Growth markets in infrastructure, construction and the extractive industries are increasingly in the developing countries. Technological and scientific advances especially at the interface of advanced computing, biology and physics are leading exponential growth of innovation and opening a world of new possibilities and markets.

It follows that engineering higher education needs to constantly strive to keep pace with these advances and in particular the contribution of engineering to these global opportunities and challenges. Higher education needs to prepare engineers of the future with the skills and know-how they will need to manage rapid change, uncertainty and complexity. Key here is the ability to tailor engineering solutions to the local social, economic, political, cultural and environmental context and to understand the impact of local action on the wider world. Although there is a global dimension within all subject areas, engineering and technology has unique importance in addressing global challenges, delivering environmental sustainability, international poverty reduction and economic growth. This publication looks at **why** the global dimension is critical to engineering, **what** this means for engineering education and **how** this can be implemented. It specifically considers the importance and relevance of poverty reduction within the global dimension.

However as a recent study amongst engineering academics[1] found, there would be strong opposition to any reduction in 'core engineering' content or dilution of course content with peripheral subject matter and this was confirmed by dialogue which informed this study. There are strong drivers supporting greater inclusion of the global dimension within higher education and engineering higher education in particular. However, as there is little space within the curriculum for additional content, the challenge is to identify solutions which address the constraints engineering departments operate under and the need to protect 'core engineering' content. This publication captures some of approaches currently being applied within UK universities and attempts to draw out wider lessons.

Over the past 18 months, Engineers Against Poverty and the Development Education Research Centre at the Institute of Education of the University of London has facilitated a series of university workshops and key stakeholder dialogues to better understand current practice and thinking within engineering higher education. In particular the work looked at

- Current understanding of the global dimension of engineering education
- The importance and contribution of the international development / poverty reduction agenda to this global dimension
- The alignment and tensions with related agendas within education such as global skills, education for sustainable development and education for global citizenship
- The barriers and constraints to change within engineering education
- The business and policy drivers supporting change
- Examples of innovation within teaching and curriculum design
- The role of partnerships in delivering the global dimension

The case for radical and urgent change is a strong one. Climate change policy requires an urgent and fundamental change within engineering to mitigate and adapt to climate change, both within the UK and globally. This is especially important in the areas of transport, energy generation and construction. Climate change may increase water scarcity, soil and habitat degradation, food insecurity, natural disasters, conflict and international migration. It will hit the poorest and most vulnerable first and hardest. These are the issues which frame the global dimension of engineering and define engineering's contribution to sustainable development. Encouragingly the past 5 years has witnessed a sea change in the UK policy environment. There is wide spread support from across government, the engineering institutions, academia, employers and students to embrace the global skills and sustainability agendas. The importance of global skills in science and engineering education to UK competitiveness is reflected in UK government policy and course accreditation guidance. Since 2004, it is mandatory for engineering courses to incorporate sustainable development.

The global skills agenda presents particular challenges for engineering education. Firstly there are number of notable constraints which inhibit curriculum change such as an already crowded curriculum, funding constraints, a perception that research is more highly valued than teaching, a lack of relevant experience and knowledge amongst some teaching staff and resistance to any dilution of core engineering content within the curriculum. Secondly, there is a risk that different interpretations and language can result in a lack of policy coherence, competition between different agendas and initiatives and a marginalisation of the poverty reduction agenda within the wider global skills agenda. For example, within the global skills debate, the focus is often on advanced engineering and advanced and emerging industrialised markets to the exclusion of intermediate technology and markets amongst the world's poorest billions. Similarly, within the education for sustainable development debate, the focus is often on the environmental rather than social and political dimensions of sustainable development. The publication sets out why the poverty reduction and development agendas are essential components of the sustainability and global skills agendas especially within engineering education. It also suggests solutions to overcome the barriers identified.

It unpacks the concept of global skills and shows how many of the skills and attitudes which define global skills (such as

critical thinking, multi-disciplinarity, team working, the ability to work across cultures and contexts, systems thinking and strong inter-personal and communication skills) are equally relevant to international development practice. It argues that instead of seeing the contribution of engineering to poverty reduction and development as detached and separate from 'mainstream' engineering, it should be aligned within the global skills agenda and embedded across the curriculum and result in a redefinition of 'mainstream' engineering in a global context.

Finally and most importantly, the publication presents a framework of approaches for embedding the global dimension and examples from current practice to illustrate these approaches in action. One of the clearest findings to emerge from the university workshops is the value academic staff place on sharing experience with their peers as part of their professional development. Teaching staff require the space, resources and external support to share lessons and experience in curriculum development and awareness of the wealth of work that already exists.

The publication concludes that continued reform of the engineering curriculum is urgently needed to better reflect the challenges and opportunities of a globalised world. Sustainability and poverty reduction are essential departure points for understanding this global dimension. It recognises the constraints and barriers that engineering faculties operate under and proposes steps to reduce these. Through practical examples, it demonstrates how embedding the global dimension can help deliver against a range of mandatory learning outcomes set out in the Engineering Council's UK-SPEC for higher education accreditation and not merely the requirement to address sustainable development. It also seeks to demonstrate how these reforms are achievable and manageable and in the long term interests of UK universities, students and employers.

Recommendations

HIGHER EDUCATION INSTITUTIONS

All HEIs engaged in engineering education to undertake a review of existing courses to consider the extent to which the global dimension is adequately reflected.

All HEIs engaged in running courses that include sustainable development and international development to consider ways in which these agendas can be brought more closely together

HEIs to consider the role of partnerships with business and civil society in moving forward the global dimension within both the review and delivery of engineering courses.

HEIs to develop international partnerships with engineering departments elsewhere in the world with a view to furthering cultural understanding and respecting different views and perspectives on global issues and sustainability.

Higher Education Academy through its engineering subject centre to promote professional development around the concept of the 'global engineer' incorporating links with existing initiatives on sustainable development and internationalisation.

HEFCE to consider ways in which the concept of the 'global engineer' can be taken forward within their strategy on sustainable development and to increase funding to HEIs and professional bodies to implement this strategy.

GOVERNMENT

DFID and DIUS to consider developing joint policies and initiatives for incorporating the global dimension within higher education including providing additional support to HEIs and professional bodies who demonstrate commitment to implementing this agenda.

UK government to support initiatives within higher education that demonstrate the contribution of engineering to global challenges and skills debates.

PROFESSIONAL BODIES AND INSTITUTIONS

Professional bodies engaged in engineering education to consider ways in which the concept of the 'global engineer' can be promoted within HEIs.

Professional bodies to identify ways in which the global dimension can enrich initiatives in areas such as engineering ethics, sustainable development, enterprise and professional and personal skills.

Professional and research bodies to support further research on the impact and value of the 'global engineer' concept in the contribution of engineering to positive world change and meeting the skills needs of the UK workforce.

EMPLOYERS

Engineering employers to promote the concept of the 'global engineer' to their senior managers and staff responsible for human resources.

Engineering employers to identify to HEIs and professional bodies the specific global skills they seek within engineering graduates particularly with reference to poverty reduction and sustainable development.

Engineering employers to review the ways in which their staff can acquire global skills through professional development, secondments, mentoring and partnerships with civil society organisations and universities and how this links to reforms with engineering higher education.

CIVIL SOCIETY

Volunteering organisations to consider how they can work more closely with HEIs and support the global learning and citizenship within their programmes.

Development NGOs to engage with HEIs on the relevance of international development to engineering education.

Introduction

This publication aims to provide UK engineering faculties and higher education institutions (HEIs) with practical guidance on incorporating global issues and sustainable development within the engineering curriculum. The issues, examples of practice and recommendations have emerged from dialogue with a range of universities around the UK and with the key stakeholders in engineering education. The publication is seen as a document to initiate further debate and dialogue within higher education institutions and the engineering profession more widely. It aims to build on existing research and practice within a number of institutions on sustainable development and international work, to bring together a range of different initiatives within a proposed framework and to make suggestions for curriculum development and partnerships for the future.

Part 1 addresses 6 key questions:

- What is meant by the global dimension of engineering?
- What is the global dimension of engineering education?
- What are the drivers for increasing the global dimension across higher education?
- What do global skills look like?
- How does development education fit within the global dimension?
- What are the key barriers to change and what opportunities exist to overcome these barriers?

Part 2 provides a framework and guidance for incorporating the global dimension within student learning including:

- Embedding within the curriculum.
- Innovative partnerships and strategies for collaboration at national and international levels.
- Extra-curricula learning.

Part 1: Key questions about the global dimension of engineering education

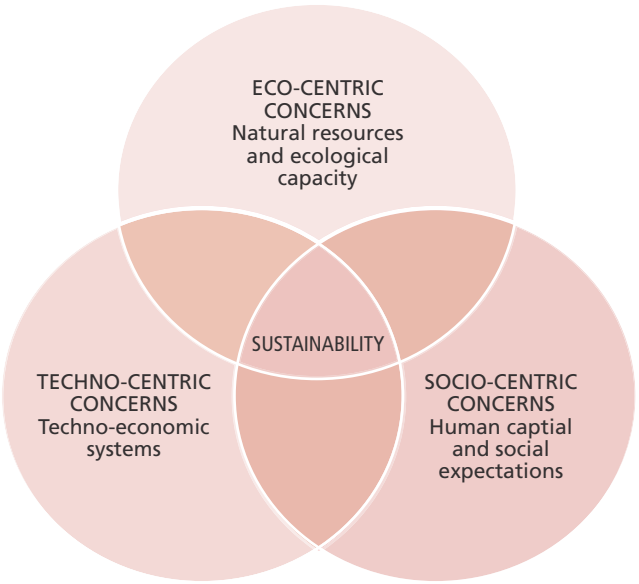
What is meant by the global dimension of engineering?

"Amongst the greatest challenges we face in the world today are those of delivering growing, secure and affordable supplies of clean water and of energy, to meet the needs and expectations of an expanding population, whilst reducing our CO2 emissions and the human contribution to climate change. The implementation of innovative engineering solutions is fundamental to addressing these challenges, whilst also offering exceptional opportunities for economic growth to the nations which are able to deliver them".[2]

Professor Julia E King, Chair of the Educating Engineers for the 21st Century Working Party

In essence the global dimension is the sum of the social, political, technological, cultural and environmental issues which are shaping engineering at the global level. In a recent independent review of strategic global trends up to 2036, the UK government concludes human activity will be dominated by 3 pervasive 'ring road' issues: climate change, globalisation and inequality, which between them frame the environmental, economic and social pillars of sustainable development. It is not that the 3 pillars can be reduced down to just these 'ring road' issues, but addressing them will define what sustainability looks like. Sustainability lies at the interface of all 3 agendas and with the alignment of solutions and dimensions.[3] What are the relationships between the economic, social and environmental dimensions of engineering and the relationship between global and local systems? What are the global drivers of change? How will these global drivers impact upon engineering? What is the contribution of engineering to positive world change? What technologies and approaches offer the most promise? These are all questions which define the global dimension of engineering and engineering education.

The Stern Review[4] on the economics of climate change concludes that 'business as usual' is unsustainable and we have a brief, 10 to 15 year window of opportunity to address climate change and move towards sustainability or face far greater costs and threats in the future. As Stern concludes, *"We have the time and the knowledge to act. But only if we*



From Engineering for Sustainable Development: Royal Academy of Engineering, 2006

act internationally, strongly and urgently." And as Hilary Benn, former Secretary of State for International Development states *"The truth is if we don't do something about climate change, aid from rich countries will look pitiful by comparison with the consequences and the costs for developing countries"*. Crucially, the reverse is also true.

Addressing climate change cannot be separated from tackling extreme poverty and the needs of developing countries. The extent to which global poverty and climate change are addressed will define the future of globalisation and the future markets and regulation of world manufacturing, construction, transport, agriculture and energy. Globalisation, climate change and poverty are closely inter-connected and are the driving issues which will shape engineering over the coming decades.[5]

What is the global dimension of engineering education?

Responses from UK engineering academics when asked what the global dimension meant to them?

- The ability to take a broader perspective - application of curriculum across countries
- An appreciation of what we do in developing countries impact upon ourselves.
- Understanding 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

Source: University stakeholder meetings, 2007

The scale and urgency of the challenge make sustainability and poverty reduction the defining issues currently facing engineering and engineering education. It is suggested here that this should be the starting point for higher education institutions (HEIs) in considering the global dimension within engineering education. Considering the global dimension of engineering education is therefore about much more than influencing engineering practice in the 'developing world'. It is above all about recognising that engineering is a global industry. To be a global engineer requires not only to understanding the global context but also recognising the contribution engineering can make to securing economic and social change.

Although economic, social and environmental concerns are often seen as competing agendas with trade-offs, their interdependence means that if we are to address the causes and not merely the symptoms of poverty, a holistic view is necessary. A review of the primary anticipated growth markets for engineering and construction companies shows they are concentrated in the developing countries and in regions prone to conflict and entrenched poverty. They include:

- Investment in oil, gas and mining with over $600bn projected expenditure over the next 10 years in Africa alone.
- Expansion in infrastructure investment especially slum upgrading and urban infrastructure in developing countries. In 2005 the G8 nations pledged $150bn additional aid for African infrastructure in the next 10 years. By 2015 it is estimated that 80% of new infrastructure will be in developing countries.[6]
- Public utilities and infrastructure such as water, transport, electricity, communications and irrigation with a growth in private-sector participation, public-private partnerships and market deregulation.
- Increased investment and support for enterprise based solutions to poverty including 'base of the pyramid' marketing and social entrepreneurship.
- Opportunities arising from the global application of emerging computing, energy, nano and bio-science technologies.
- Sustainable technologies / approaches especially in the energy, transport and construction markets resulting from both adaptation and mitigation of climate change.

These markets present complex and unfamiliar challenges especially for those engineers only familiar with western markets. Investments are often in part supported by the official donor development assistance and subject to their scrutiny and social and environmental safeguards. In addition civil society and poverty and environmental pressure groups scrutinise as never before the actions of multinational companies and their suppliers and contractors especially those operating in the developing countries. Engineering companies often work directly with project affected communities and those companies seeking to maximise growth in these markets will recognise the importance of a workforce competent in the theory and practice of sustainability and development. Table 1 (overleaf) maps the ways in which climate change, poverty and globalisation define the context of global engineering and how engineering impacts on this context.

The global dimension can be addressed through a variety of lenes and perspectives. Within the context of engineering education, four perspectives and approaches are suggested as ways to examine what the global dimension looks like. They are a futures perspectives because of the key role universities and engineering plays within technological development. Secondly a business case that recognises areas such as corporate social responsibility and its social role in the economies of the twenty first century. Thirdly a critical perspective because unless engineers recognise there are no simple or easy solutions and that our actions have social consequences, we are not equipping graduates for dealing with complexity and uncertainty. This links with the final perspec-

tive proposed which is a whole systems approach that recognises the interconnectedness of actions both social and economic.

A futures perspective

"At no point in our whole history has the speed and scale of technological change been so fast and pervasive."

Gordon Brown speaking at the Trades Union Congress 2005 conference

The need to adapt and refine curriculum to keep pace with and anticipate the changing global market place for engineering graduates is widely recognised by government, business, engineering institutions, accrediting bodies and the universities themselves. As markets become increasingly global, knowledge and innovation driven and defined by environmental and social constraints, universities will need to keep abreast of changing employer requirements and anticipate the future, something which is recognised by universities themselves. The adjacent table lists some resources for identifying and tracking global futures.

Table 1:
Simple map of the global context showing the linkages and impacts of climate change, poverty, globalisation and engineering upon each other

Climate change linkages and impacts	Impact of climate change on poverty • Poor hit earliest and hardest with the least capacity to adapt. Climate change may led to: • Loss of habitats & biodiversity, • Loss of livelihoods / new opportunities, Increased frequency / severity of natural disasters, flooding and extreme weather, • Water scarcity & desertification, • Conflict, civil unrest and migration, • Health impacts & food insecurity. • Complex trade-offs: e.g. biofuels could boost or undermine livelihoods of poor, carbon markets could reduce or entrench poverty.	Impact of climate change on globalisation • The impacts of carbon trading and the shift towards a low carbon economy especially in energy, transport, foodstuffs, manufacturing, construction & tourism markets, • Localisation of supply chains & markets due to higher transport costs, • Increased risk, uncertainty & market volatility, Disruption to agriculture & infrastructure, • Failure to address climate change undermines global economy and support for globalisation processes.	Impact of climate change on engineering • New markets and opportunities in renewable energy, alternative fuels, energy conservation & waste reduction, • New research / innovation opportunities, • Disaster preparedness and relief and post-disaster reconstruction, • Low carbon economy especially in energy, infrastructure & construction markets.
Impact of poverty on climate change • Farming, energy, transport, urbanisation and development choices of developing nations are critical if global CO2 reduction targets are to be met especially in rapidly industrialising economies (Brazil, Russia, India & China). • Global carbon trading and emissions targets must recognise the needs and rights of the poor and the obligations of industrialised nations.	**Poverty linkages and impacts**	Impact of poverty on globalisation • The responsibility to act ethically, contribute to poverty reduction and involve poor in decision making is becoming recognised by global corporations, • Failure to act responsibly or to address poverty undermines support for (current models of) globalisation. • Globalisation criticised by international development & trade reformers.	Impact of poverty on engineering • Requires low cost solutions that are appropriate to cultural, political, social and economic environment, • Requires participation of the poor and local knowledge, • Developing countries are often high risk / high return markets.
Impact of globalisation on climate change • International supply chains increase energy and transport impacts, • Reduced production costs increase waste and consumerism fuelling carbon emissions • Environmental impacts displaced to less developed country (LDC) production centres.	Impact of globalisation on poverty • Social, legal & environmental safeguards often lower in less developed countries (LDCs), • Offers economic opportunities esp. in natural resources & agriculture, tourism, manufacturing and fair-trade goods, • LDC economies vulnerable to capital flight and brain drain, trade rules disadvantage LDCs and undermine national sovereignty.	**Globalisation linkages and impact**	Impact of globalisation on engineering • Growth in LDC markets esp. in utilities, infrastructure & the extractive industries, • International supply chains promote technology transfer & standardised systems, • Growth in labour mobility, access to knowledge.
Impact of engineering on climate change • Transport, energy, agriculture, infrastructure and manufacturing choices determine impacts, • Engineering and innovation key to mitigation and adaptation, • Engineering key to disaster preparedness and reconstruction.	Impact of engineering on poverty • Engineering key to providing pro-poor energy, transport, shelter, health and water products and services, • Platform infrastructure and technologies provide an enabling environment for growth, • Engineering supply chains and technology transfer offer poverty reduction opportunities.	Impact of engineering on globalisation • Engineering knowledge and innovation especially in transport, energy, manufacturing and ICT are the drivers behind economic integration and globalisation, • Sustainability and climate change will force a revised model of engineering and globalisation.	**Engineering linkages and impacts**

RESOURCES FOR THE ANALYSIS OF FUTURE AND GLOBAL TRENDS

UK HEIs seeking to be internationally competitive in a rapidly changing world will need to anticipate and adapt to change and embed global thinking across the university and curricula.

UN Millennium Project State of the Future programme
DFID 2006 White Paper incl. the speeches of Hilary Benn
DFID Drivers of Change programme
Prime Minister's Strategy Unit
UK Government's Foresight and Sigmascan projects
Deltascan, Stanford University
UK Sustainable Development strategies and priorities

Common features of these futures studies include:

- The unprecedented nature of global challenges and opportunities.
- The increasing speed of change.
- The interdependency and convergence of issues.
- The high degree of complexity and uncertainty especially in global systems such as the climate or economics.
- The key role of science, engineering, technology and innovation (SETI) driving forward and adapting to change.

Engineers are in the business of anticipating and planning for the future. This is especially true in civil engineering which relies on accurate design assumptions of future population, demand, technology and environmental extremes. The trend within engineering is towards long-term business models such as Private Finance Initiatives, Build Operate Train and Transfer Projects and Public-Private Partnerships and this requires engineers to take a long term perspective including change within the local social and political context. Engineers will need to factor in the impacts of climate change in infrastructure design assumptions. These features of change have important implications for educators. The challenge is not only to update the curricula to reflect today's world but to prepare students with the skills and know-how they will need in 10 or 20 years time. Prof. David Hicks, Director of Centre for Global and Futures Education at Bath Spa University has been a leading advocate of the need for a futures dimension in education and its linkages with the global dimension. Hicks defines futures education as the term used internationally to describe a form of education which helps students think more critically and creatively about the future. In more detail it:

- Enables students to understand the links between their own lives in the present and those of others in the past and future.
- Increases understanding of the economic, social, political and cultural influences which shape people's perceptions of personal, local and global futures.
- Develops the skills, attitudes and values which encourage foresight and enable students to identify both probable and preferable futures.
- Works towards achieving a more just and sustainable future in which the welfare of both people and planet are of equal importance.[7]

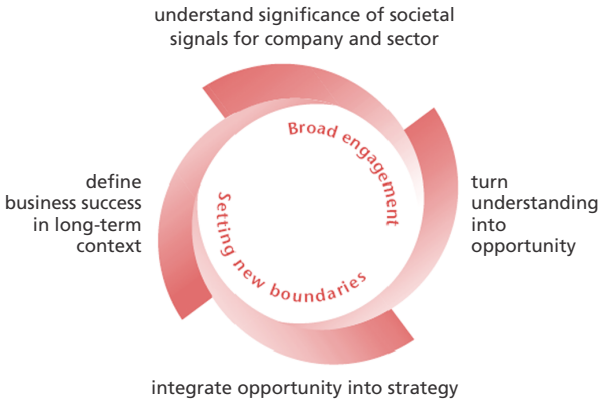
A business perspective

An industry study by the Royal Academy of Engineering states 'UK engineering degree courses must recognise the changing requirements of industry'. The study further stresses the importance of business, enterprise and innovation skills, work placements and stronger linkages with industry and there is a growing demand from students and employers alike for the global dimension and global skills to be embedded across higher education. However in seeking to meet industry requirements, universities should guard against perpetuating business models and technologies which are unsustainable or socially irresponsible. If engineering courses are to prepare graduates to work in a global industry and for a future defined by globalisation and the twin challenges of poverty and sustainability, it is essential courses reflect society's needs and the needs of future generations and not merely 'the requirements of industry' which may or may not be attuned to societal signals.

The business community is increasingly aware and supportive of its responsibility to wider society and protection of the environment. Polls of the business community continue to document rising interest in corporate social responsibility (CSR). Unfortunately, they also reveal significant lags in implementing commitment to CSR.[8] A recent McKinsey global survey of business leaders suggests that few business leaders believe that they yet do this well.[9] The key to translating CSR commitment into business practice and opportunity is making CSR practically relevant to the business and this means aligning CSR with core business operations and strategy.[10]

As Björn Stigson, President, World Business Council for Sustainable Development (WBCSD) argues *"[Business] must address major social and environmental issues as part of [its] business strategies because ultimately it makes good business sense. A business's long-term competitiveness – its license to operate, innovate, and grow – will increasingly depend on how it embraces societal challenges."* CSR has evolved: broadened, deepened and become more aligned

A model for tomorrow's global business



with core business functions. The contribution of business to pro-poor growth and poverty reduction is recognised as increasingly important, especially in global industries such as engineering and extractive industries. The more global issues such as sustainability and poverty reduction are seen to be pivotal to business strategy, public policy and market regulation, the easier it is to make a clear case both to universities and business to invest in global skills. The WBCSD model taken from its publication, 'From Challenge to Opportunity: The role of business in tomorrow's society' (2006)[11], shows the importance of understanding societal signals, integrating these drivers into business strategy and translating them into opportunites. This is reflected in the growing interest in enterprise solutions to poverty[12] and 'base of the pyramid' models.

A critical perspective

'Business as usual' is not sustainable. Poverty and climate change are symptomatic of long term market and regulatory failures. A key issue is to debate why these market failures have occurred and how global markets and regulations could be reformed to incentivise engineering businesses to take a more long term view that addresses the challenges of poverty and climate change. Indeed it is only through a deep rethinking of what a sustainable, people-centred global economy and society would look like that a new model of engineering practice can emerge. Critical analysis which allows learners to challenge their assumptions and the assumptions of others, to analyse a problem from a range of perspectives and to hear voices they would otherwise not be exposed to, is essential to understanding and exploring these complex issues. Research shows that a common explanation of why engineering projects are unsustainable or have unintended negative impacts is a failure to adequately understand the local context and the needs and constraints of local stakeholders.[13] Engineers with critical thinking skills are more liable to question design assumptions and understand and value local knowledge. Critical thinking can be promoted by providing space for dialogue and exchange within the learning environment (through seminars, multi-disciplinary projects and active learning pedagogies, for example) to explore contentious and controversial aspects of engineering. This is a particular challenge for engineering education with its grounding in western, empirical, scientific methods and where learners are often uncomfortable with ambiguity and the subjective analysis of the social sciences. This is something which, in large part, explains the disconnect between the physical and social sciences.

A systems perspective

The nature of engineering is changing. Engineering consultancies are becoming multi-disciplinary and global in their reach. Traditional boundaries between disciplines in science (chemistry, biology and physics) and disciplines within engineering (civil, mechanical, electrical, etc.) are breaking down. Systems engineering and whole life analysis is increasingly common especially in complex systems. Holistic thinking not only requires understanding complexities within engineering systems but also the relationship between engineering systems and their context. Prof. Paul Jowitt (chair of the Institution of Civil Engineers' Joint Board of Moderators Task Group to embed sustainable development into engineering curricula and professional development) states "a more holistic/systems view of the world is now required - one in which engineers need to be more fully aware of the economic, social and environmental dimensions of their activities and more skilled in meeting their objectives."[14]

Systems thinking is, in essence, the ability to see a problem or situation holistically, from a multitude of perspectives and understand the relationships, interconnections and complexity between the different parts that make up the whole. This approach was originally popularised as chaos or Gaian theory and has been applied across all disciplines including the physical and social sciences (box opposite). Seeing how human systems such as engineering mimic the complexity of natural systems has led several influential writers to draw comparisons with how nature can provide lessons for human systems: a field known as biomimicry.[15]

SYSTEMS THINKING IN OTHER DISCIPLINES

In international development

Schumacher College short course programme and MSc in Holistic Sciences; CDRA's writings on NGOs as learning organisations and capacity building – shifting the paradigms of practice; Gaian Democracies: Redefining globalisation and people power, Roy Madron and John Joplin

In spirituality and new sciences

Conscious evolution; Brian Godwin, From Control to Participation; Contributors to the 'What the Bleep' film and Bethechange conferences

In the natural sciences

Big picture clips on Interconnectedness, Elisabet Sahtouris, (2), Satish Kumar and of the lecturers at Schumacher College

In agriculture and energy

ISIS Dream Farm model, Permaculture models

In business and organisational learning

Frank Dixon on Total corporate responsibility and global system change, (2); Peter Senge on Learning Organisations

What are the key drivers for increasing the global dimension across higher education?

Having explored why the global dimension is so crucial to the future of engineering education, it is also helpful to identify the drivers for increasing the global dimension across higher education in general. These can be summarised in terms of the following:

- Strategies and initiatives on sustainable development including HEFCE's Strategy on Sustainable Development, the work of the Higher Education Academy including

subject centres, Universities UK's report on 'Green Spires" and the work of bodies such as Environmental Association for Universities and Colleges.

- International strategies of universities based around securing more international students, export of courses and expertise and a wider appreciation of the importance of internationalisation and promoting concept of graduates as global citizens. Key to this area has been the government's strategy on Putting the World into World Class Education and follow up initiatives by the Higher Education Academy, bodies such as the DEA and their publication on The Global University and the work of the British Council.
- Impact of globalisation and the need to upskill the UK workforce so that it is more globally competitive. The main driver in this area has been the recommendations of the Leitch Review on Skills.
- Finally and perhaps least known is the Department for International Development (DFID) strategy for Building Support for Development (1998) which has resulted in a plethora of initiatives and projects around the UK within all sectors of education linked to the importance of promoting recognition that we live in an interdependent world and the need to move beyond a 'charitable mentality' towards the developing world.

There is evidence from a number of initiatives within engineering education of engagement with these agendas. For example, UK Standard for Professional Engineering Competence (the UK SPEC)[16] produced by the Engineering Council UK, requires that all UK engineering courses deliver an *"understanding of the requirement for engineering activities to promote sustainable development"* and the Joint Board of Moderators believes *"sustainable development should be integrated … and ideally should be pervasive throughout engineering education."*[17]

University business drivers

There are also a number of external and internal business drivers for the inclusion of global perspectives within higher education, including: encouraging widening-participation, embracing diversity, broadening internationalisation, taking positive steps to demonstrate equal treatment with regard to race, and seeking to ensure universities' own work contributes to a more sustainable future.[18] A major driver for embedding the global dimension and international development within the curriculum is the internationalization of higher education and the growth of overseas students studying in the UK which has doubled since 1998 to a record 157,000 in 2006, contributing almost £8.5bn a year to the economy according a Home Office study. A third of overseas students were from China (52,000), followed by India (16,000) and the US (14,000) with engineering and technology being the second most popular subject behind business among students from abroad. *"It is therefore vital for our universities and the economy that the UK continues to offer a truly welcoming and supportive environment for international students and academics."*[19]

A number of universities such as Bournemouth, Leeds Metropolitan, University College London, Birmingham and Salford are recognising that internationalisation, sustainable development and global perspectives need to be seen in a holistic form.[20] Globally orientated courses are also more likely to attract (i) students from diverse and under represented groups such as women, (ii) international students to UK universities and (iii) international students to the overseas campuses of UK universities.[21] Research shows that students and employers consistently value courses which incorporate opportunities to volunteer both in the UK and internationally, which incorporate international exchanges, business/ employer secondments and internships and which give students practical experience and accredit this experience.[22]

University business strategies are strongly driven by the research assessment exercise. Research funding can act as a driver for embedding the global dimension. There is some evidence that some research councils are seeking to increase their support of research that addresses aspects of the global dimension including (1) cross-disciplinary collaboration, (2) inter-university collaboration and research consortia including international partnerships, (3) partnerships with business and business schools including commercialisation of intellectual property and (4) research addressing the key global challenges such as low-carbon technologies and sustainable energy.[23] By strengthening the linkages between teaching and research, the under-graduate curriculum learning can benefit from the global understanding and capacity that exists amongst graduate schools and post-graduates and build on the courses, partnerships and business linkages that graduate schools establish.[24] However as the recent HEFCE review of sustainable development in higher education found, *"Sustainable development research will not increase further without a further increase in the funds devoted to it. It is not clear that the Research Councils are currently committed to such an increase."*[25]

Students as drivers

Increasingly UK universities are operating in a global market place and attracting students from around the world. This coupled with the large expansion of higher education over the past 10 years has resulted in a far more diverse, multi-cultural student population. As well as being an asset and a resource that enriches university life, this transition in the student population makes decisions about course content more complicated and forces universities to take a more global perspective.

There is evidence from Cambridge University and Imperial College which suggests students who are motivated to engage in global issues secure better degrees and more high profile posts within companies relative to their peers who lack this motivation.[26] There is further evidence from a number of universities and student organizations suggesting students are increasingly demanding more courses and debates on global issues and sustainable development.[27] For example a number of student organisations such as People and Planet and Engineers without Borders-UK (EWB-UK), have come together to produce a briefing document on the

theme of 'Students as Global Citizens'. People and Planet (2006) suggest that:

'Awareness of the world has heightened the curiosity of students about their role in global society. They travel across the world, absorb news from across the world and communicate with people from across the world. Unless students find themselves roles to play, there is a risk of disenfranchisement or of disillusionment: that they are aware of global issues but do nothing about them'.

Research at Bournemouth University (BU) highlights that BU students welcome the opportunity to engage in debate about global issues and global processes and that while UK students may not necessarily feel adequately prepared to be global citizens, they share the same 'top three' personal global concerns as students from other countries (Environment, War, Poverty). 80% of students surveyed saw global perspectives as relevant to their lives and would like more opportunity to develop 'broader global perspectives' while studying at university. Research by StudentForce for Sustainability for the Higher Education Academy found students were concerned about the preparation for their employment provided by universities and believed that sustainable development and CSR should be taught more at universities. University careers staff confirmed a growing trend for students and employers to consider the employer's social and environmental responsibility.[28]

Partly in response to this student demand, some universities, such as Bournemouth, University College London, Leicester and Leeds Metropolitan, market themselves as global citizens and have sought to embed sustainability and global ethics and dimensions across their marketing, business development and course development strategies as a means of differentiating themselves from other UK universities. Engineers Without Borders – UK is a student-led charity that focuses on removing barriers to development using engineering with groups in over 14 UK universities. Its rapid growth is testament to the interest in development amongst engineering students. The charity works in 6 areas: placements, bursaries, research, training, outreach and education. Its education programme works with teaching staff to identify opportunities for the wider inclusion of international development in the engineering curriculum.

Employers as drivers

'Growing numbers of employers want employees who can practice and promote sustainability.'[29] Universities are always conscious of employability of their graduates. In an increasingly global society and economy therefore, graduates need to be equipped to understand and engage in the wider world in order to have successful careers as active global citizens.[30] Added to this, organisations are increasingly finding that they have to confront sustainable development issues, thus, graduates who acquire the knowledge, skills and attributes to address sustainable development, will be valued in the economy.

It is therefore suggested that the inclusion of global perspectives enhances the education of students as global citizens and provides them with skills appropriate for global employment.[31] It is also suggested that a global perspective aligns with the development of 'critical beings' (in the sense used by Barnett 1997) who are able to cope with 'super-complexity'.[32] Through open minded learning, students will develop the skills demanded by today's employers thus, maximising their employment prospects.

A global perspective also aligns well with the need to develop professional skills and furthermore, enhances that development, facilitating the development of students who are:

- Self Reliant global awareness heightens self awareness, confidence, the ability to respond positively and pro actively to personal and professional change in today's globalised world. A sense of empowerment and ability to bring about change are developed through a global perspective approach.
- Connected global citizens work well as part of a team, recognising the value and role of each member, inspiring others and developing cross-cultural capability and sensitivity to others.
- Well rounded a graduate's range of skills can only be considered as well-rounded when they reflect the global environment in which we all operate.
- Critical reflectors – a global perspective requires a student to challenge knowledge, reflect on the economic, social and political contexts that shape experience and adopt a critical perspective in analysis and decision-making, reflecting on self and others.
- Specialist knowledge is invaluable in a competitive, specialised context. A degree programme that includes the global perspective offers the students a 'subject knowledge-plus' approach. Broadening a subject to include the global perspective provides a wider context for subject knowledge where the student explores issues of sustainability and ethics in the context of their subject and their professional development.

Evidence suggests that a global perspective is increasingly compatible with employability. Archer (2005)[33] from a recruitment consultant perspective stresses that, *'to understand the world we live in we must experience it in the widest sense'* and that 'understanding the global context and the 'connected' world is essential' in the context of employment. He reinforces that *'The skills that most employers look for are most evident in graduates who have studied internationally' and that 'much more can be done to enhance the multicultural experience of education and through this, the employability of graduates.'*

There is evidence from the research of Bourn and Sharma[34] that more and more engineering employers are recognizing the importance of these more generic skills and ability to work within an environment that includes people from a wide range of social and cultural backgrounds. This means that to be effective team players and leaders, it is vital that graduates are able to communicate effectively across cultures and have a good understanding of others' perspectives. Graduates also need to understand the "world in its global context" and to "see the global in the local".

Understanding how they interrelate (the local/global) and being able to adapt well to diverse situations and perceptions (multi-cultural), is to have a 'global perspective' in the workplace.

Examples of professional skills sought by global employers

Price Waterhouse Coopers

PwC run a professional development programme, Ulysses, with strong emphasis on global reasoning and positive world change.[35] Their work increasingly includes international development, CSR and sustainability. *"PwC's young people will have to take on some very complex global challenges in the years to come, and they will need more than just business skills and an MBA – they will also have to be socially aware; possess wide intercultural communication skills; be thoughtful; committed to accountability; and, above all, compassionate."*

Voluntary Service Overseas (VSO)[36]

VSO seeks the following qualities in those it employs overseas:

- self-assurance
- flexibility and adaptability
- a flair for solving problems
- ability to work in a team
- sensitivity to the needs of others
- a desire to learn and help others learn
- a positive and realistic commitment to volunteering

What do global skills look like? Differing interpretations of global skills

The case for embedding global skills and the global dimension across engineering education is made and accepted very widely. However, as the authors' dialogue with academics and stakeholders demonstrated, there is a wide range of interpretations as to what global skills actually look like. This section discusses some of these differing interpretations. There is a range of initiatives within higher education which are relevant to the global skills debate such as:

- Education for sustainable development (ESD) agenda.
- Widening access to higher education.
- Developing 'corporate social responsibility' skills.
- Teaching of ethics and human rights.
- Developing entrepreneurial skills and social enterprise.
- Developing students as global citizens.
- Developing professional skills.
- Promoting multi-disciplinary learning.
- Promoting science, technology, engineering and maths (STEM).
- Promoting vocational learning, internships and work experience placements.
- Promoting closer university-business linkages especially in science and innovation.
- Internationalisation of higher education and attracting foreign students to UK universities.
- Developing the capacity of higher education institutions in developing countries.

Underlying the range of issues and approaches raised in this publication is the need for greater recognition of the interconnectedness of these perspectives. It is not suggested here that there is one way of seeing global skills or global perspectives, more a recognition of different approaches and noting how they could potentially come closer together. Recognition of the need to bring these agendas closer together has recently been recognised within the curriculum for schools in England and Wales.

A review of recent policy studies shows a high degree of alignment between different skills frameworks that address the global dimension. For example: the transferable skills and competencies identified as being relevant for sustainable development are very similar to the professional skills demanded generically by business and the CSR Academy's skills framework. The question is how to get these different initiatives and drivers for global skills to tie together whilst ensuring that critical thinking skills and recognition of multiple perspectives is not lost within the debate. This means the inclusion of 'soft' professional skills that are generically needed by employers such as communication, presentation and interpersonal skills, critical and analytical skills, creativity, innovation and adaptability.

Concepts related to the global dimension

Sustainability	Cross-cultural capability
Development education	Diversity
Global ethics	Inclusivity
Human rights	Gender/Race/Ethnicity/
International relations	Nationality/Disability
Political analysis	Business responsibility
Justice and equality	Citizenship

Skills Frameworks relevant to the global dimension

- Global Citizenship secondary school map, National Assembly of Wales,[37]
- Development Education Association's framework,[38]
- Learning and skills for sustainable development, (HEPS and Forum for the Future: 2004),[39]
- ICE Joint Board of Moderators framework on Sustainability and Design,[40]
- The DFES framework, Putting the World in to World Class Education[41] and
- The CSR academy's Making CSR Happen: the contribution of people management.[42]

In recognition of these complex agendas it is suggested here that some form of framework of learning is necessary to ensure that engineering educators are able to take forward this array of approaches and perspectives within a coherent form. The following themes, skills and dispositions are suggested as a starting point:

A framework for the global dimension within the engineering profession[43]

Generic Themes:

- understanding of the major global challenges
- commitment to democracy and the social contract between government, business and the citizen
- corporate responsibility debates and solutions
- sustainable development debates and solutions
- global development and poverty reduction debates and solutions
- corruption, conflict and ethical debates and solutions
- global interdependence and the connections between local and global

Generic Skills:

- holistic thinking, critical enquiry, analysis and reflection
- active learning and practical application
- self awareness and empathy
- strong communication and listening skills

Generic Dispositions:

- commitment to promoting social justice and responsibility
- appropriate values and informed perceptions
- integrity and trustworthiness
- continuous learner

The Leitch Review[44] emphasises the need for 'world class skills'. A key component of these skills for engineers has to be to understand and engage with the wider world. But as suggested already, this is not merely knowledge about countries and global processes, important as they are, but the skills necessary to make sense of globalisation and its impact on peoples' everyday lives and to respond to global challenges and opportunities.

Global skills could be defined as merely about skills to engage with economies and markets. This, for example, is the perspective of major US consultancy company, World-View:[45]

Global Skills are foundational business skills for companies seeking to enhance their global competitiveness, and which focus on acquiring the necessary local country knowledge as it pertains to communication, relationship-building and problem-solving skills. Global Skills play a key role between the interplay of economics, politics, culture, technology and the environment, and reflect the forward thinking of companies who desire to work effectively across borders while respecting local values.

However this perspective wholly exists within the prevalent global business model and fails to acknowledge the legitimate criticisms of this business model. The danger is that such an approach is liable to perpetuate 'business as usual' attitudes, entrench existing inequalities and power structures and leave unsustainable and unethical practice unchallenged. As the Development Education Association (DEA) has observed unless global skills includes essential skills in critical engagement and also leads to the adoption of impact-oriented behaviours, learning will be ineffectual.[46]

It is suggested here that the key to understanding global skills recognising the following:

- The value of critical thinking
- The complex nature of the world in which we are living.
- The increasingly vulnerability of economies and societies to global shocks.
- That the future is uncertain and there are not necessarily a series of easily identifiable solutions.

In response, education needs to prepare students for life-long learning in a globalised society which enables them to cope with and adapt to this complexity, uncertainty and vulnerability. This involves fundamental shifts in course content and delivery…

Moving from	Moving towards
Fixed content and skills to conform to a predetermined idea of society and the future	Concepts and strategies to address complexity, difference and uncertainty
Absorbing information, reproducing received knowledge and accepting and adapting to existing structures and models of thinking, knowing and being.	Assessing, interrogating and connecting information, generating knowledge, living with difference and conflict and shifting positions and perspectives according to contexts.
Structured, ordered and stable, predictable, comprehensible as a whole, universal meanings and interpretations	Complex and changing, uncertain, multifaceted and interconnected, different meanings and interpretation

This approach reinforces the importance of transferable professional skills including awareness of emerging global risks and opportunities and cross-cultural capability outlined in the Henley report.[47] The Henley report describes the shift in emphasis within engineering education away from imparting knowledge, towards developing the underpinning skills required to find, analyse and apply knowledge in ways which are appropriate and sensitive to the local context and culture and appropriate attitudes and personal qualities to do this with humility and empathy.

How does international development fit within the global dimension?

The UK is one of the leading providers in the world of undergraduate and post-graduate degree programmes tackling international development. There are a number of specialist 'development engineering' degrees and masters programmes, that is programmes specifically aimed at engineering in an international development and humanitarian relief context. Working in developing countries raises some very specific issues and complexities that engineers working in the UK are unlikely to have encountered and 'development engineering' courses play an important role in preparing engineers unfamiliar with these challenges for work in international development and humanitarian sectors. However, there is a danger that universities will see such specialist courses or elective modules as an adequate response to global dimension and fail to acknowledge that (1) all engineering students need exposure to the global dimension and (2) the skills, lessons and approaches which underpin 'development engineering' have universal relevance.

Dialogue with academics from Cambridge and the Open University (OU) with considerable experience in 'development engineering' education confirmed this danger. They recalled the perception of some colleagues that sustainable development is only concerned with poverty reduction in developing countries or with the environmental impacts of engineering. The danger in developing a specialist centre or provision for development engineering within an engineering department is that these issues and thinking may be marginalised: partitioned in a corner, while 'proper engineering' gets on with what it does. However there is counter evidence that suggests

"The presence of …… a specialist sustainable development (SD) delivery unit has proved an important driver in some cases. Wolverhampton, for example, has long had its internationally recognised Centre for International Development and Training (CIDT), which has been a niche player in the SD space within the university for many years. As HEIs develop a more institutional approach to SD such units can have an important catalyst role in advancing SD adoption."[48]

Whilst there will continue to be demand for specialist post graduate courses preparing engineers for work in the relief and development sectors, the challenge is to ensure that the global dimension is central to the thinking across the whole faculty and embedded within all engineering courses. The lack of an explicit poverty reduction dimension within HEFCE's recently launched resource centre on sustainable development education[49] perhaps illustrates the difficulties and confusion arising from different understandings and definitions of the global dimension or sustainable development and the danger that the poverty dimension is excluded from this agenda.

A strategy identified to reduce this risk of marginalisation is to demonstrate the relevance of 'international development' thinking to engineering in 'developed' countries. Engineering and related services impact on the lives of the global poor whether those activities are in the UK or overseas. Most engineers working in the developing countries do not work for aid agencies nor on aid-funded projects and few will have an educational background in development or development engineering. It follows that if the engineers of tomorrow are to have skills, knowledge and attitude to be able to respond to global challenges and complexities, then the global dimension needs to be embedded across all engineering courses. In doing so, adequate attention to development and poverty reduction is needed.

In considering how engineering can best minimise its harmful social and environmental impacts and maximise its positive contribution to society, the same issues and the same skill sets arose whether UK or international case studies were used. The importance of local context and stakeholder engagement can as well be demonstrated by studying the Mersey barrage or terminal 5 as the Pergau dam. Bill Kennedy of the Open University stated his belief that courses should instil graduates with the confidence, adaptability, skills and breadth of perspective to work anywhere. In the past, there was talk of knowledge sharing between the global North and the South. It is suggested that now and for the future the emphasis should be much more on recognising the complex linkages between local and global and that what happens in one part of the world has a direct impact on another.

The principle finding and recommendation arising from this study is that champions of 'education for sustainable development' and 'development education' should seek to place sustainability and poverty reduction at the centre of the global dimension of education. This understanding of the global dimension should be at the heart of the curriculum and pedagogy change; a multi-faceted, cross cutting agenda that is entwined throughout the course and flowing between its individual components. The global dimension should be at the heart of the university life: its brand, strategy, structures, values and culture. The market for engineering services is increasingly global in nature and engineering is both affecting and being affected by the major global crises. Whilst these issues are particularly relevant to civil engineers and engineers working in developing countries, they affect all engineers to a greater or lesser extent. This is something that is increasingly recognised by engineering institutions.

What are the key barriers and constraints and how can these be overcome?

Alongside the drivers for the global dimension it is equally important to recognise, explore and identify strategies that address barriers and constraints to change. These barriers will vary between universities, however discussions identified common constraints linked to space and time in the curriculum, skills and expertise, resources, research agendas and support from senior management.

Curriculum content management

The Bologna Process promotes harmonisation of engineering qualifications across Europe. In mainland Europe, courses are typically 5 years in duration, whilst in the UK 4 years is

the norm. The RAEng study proposes an output competencies approach which would ensure Bologna compatability whilst preserving UK degrees in their current form. In the absence of a funding increase to enable course expansion, it is unlikely universities will support any extension to course length and that space within the engineering curriculum will continue to be pressured. The study further concludes:

'Universities must continue to teach 'core engineering' and not dilute course content with peripheral subject matter. Industry's top priorities for engineering graduate skills are practical application, theoretical understanding, creativity and innovation. Whilst broader technological understanding is also important it should not be at the expense of understanding the fundamentals. It is important that courses are not overloaded with technical content: the emphasis should be on the ability to understand and apply theory to real problems. There is a limited requirement for training in key business skills, envisaged primarily as commercial awareness - an understanding of how businesses work and the importance of the customer – combined with the basic principles of project management.' (RAEng 2007)[50]

This conclusion was echoed in the findings from this study's dialogue. Respondents felt this defense of 'core engineering' is in part driven:

- By staff wishing to focus on teaching 'core engineering' topics of which they are familiar and confident with and avoid teaching broader issues of which they are less familiar.
- By the tension between depth and breadth, with the desire to cover topics in greater depth reducing opportunities to include a greater breadth material within the curriculum.
- By resistance amongst senior staff and researchers whose careers, funding and prestige are closely linked to excellence in leading edge engineering research as opposed to teaching the global dimension.
- By the perception amongst senior teaching staff that projects addressing social and environmental dimensions of engineering are less academically rigorous and favoured by less able students as an easy option.
- By silo or mono-disciplinary thinking, academic conservatism and resistance to disruption that change inevitably involves.

Whilst the need for a global dimension was universally acknowledged, there would be strong resistance within faculties if additional content displaced 'core engineering' content. Following on from this, the consensus was not to develop new modules, but to embed the global dimension within existing courses through the use of globally relevant case studies, research projects, dissertations and team projects.

Limited staff time, skills, knowledge and capacity

Academic staff are recruited on a wide range of criteria: research experience and interests, previous work experience, the depth and range of knowledge, an ability to attract new funding and business and teaching ability. As a result, it is unusual to find engineering teaching staff who also have practical experience of international development or of working in developing countries. This lack of development experience and knowledge may constrain the capacity of engineering departments to teach and embed international development within the curriculum and bring the global dimension to life.

There are a range of strategies that departments could adopt to compensate for this gap including:

1. Recognising the existence and implications of this gap.
2. Mapping and tapping into the expertise that does exist both within engineering and in other faculties.
3. Building active, long-term relationships with international development non-government organizations (NGOs) especially those with expertise in development engineering and development education. Such partnerships could mirror initiatives with business and include NGO staff sitting on course advisory boards, providing visiting professors and 'employer' tutors, offering project topics and teaching resources and offering student placements: see partnership section.
4. Supporting the provision of appropriate professional development for teaching staff, including linkages and staff exchange programmes with developing country universities.
5. Utilising the skills and experience that international staff and visiting fellows bring.

Limited funding

'Engineering courses at UK universities are now seriously under-funded' concludes the Royal Academy of Engineering. 'Engineering is an intrinsically expensive subject to teach well because of the demands it makes for small group work in design and build projects, specialist laboratory equipment and technician support. These elements of the learning experience are cited as critical by both recent graduates and employers in developing innovative, entrepreneurial graduates who can tackle open-ended problems. In the context of the current funding formula this requires an increased level of support of the order of 2.5 to three times the basic unit of resource (compared to the current allocation of 1.7)' (see endnote 1)

Despite a considerable expansion of overall funding and access to higher education over the past 10 years, funding for teaching per student has fallen and engineering has suffered disproportionately. This has led to a reduction in opportunities for relatively expensive practical and project work. It is one thing to identify the need for more participatory, practical and active learning and greater investment in course review and design processes, but without the necessary funding, engineering education reform is likely to be slow and inadequate.

Engineering faculties need to come together with professional engineering and education bodies to lobby the government to increase funding for both course development and delivery. In addition to this, universities should

explore how partnerships with business, NGOs and other universities offer opportunities to increase funding and share costs.

Research focus

'The funding and ranking-driven focus on research in many universities is constraining the development of innovative learning and teaching in engineering' (RAEng, 2007). A Cambridge professor stated there is little financial and career incentive to develop more practical and participatory pedagogies such as role plays. This is true not just for engineering or for Cambridge but across academia. The importance of the Research Assessment Exercise has left teaching feeling like a 'poor relation' in terms of competition for staff time and commitment in our leading universities according to the Royal Academy of Engineering. Within the research framework there is the perception that research councils prioritise hard specialist, scientific and engineering research over multi-disciplinary research looking at the wider sustainability and development context. Whilst teaching staff are also motivated by professionalism and the desire to make courses interesting and relevant, one way universities can redress this imbalance, the academy suggest, is to "recognise the importance of excellent and innovative course design and delivery through promotion criteria and reward" for teaching staff. Professional engineering and education bodies also have an important role in influencing the research councils and higher education funding.

Senior management support

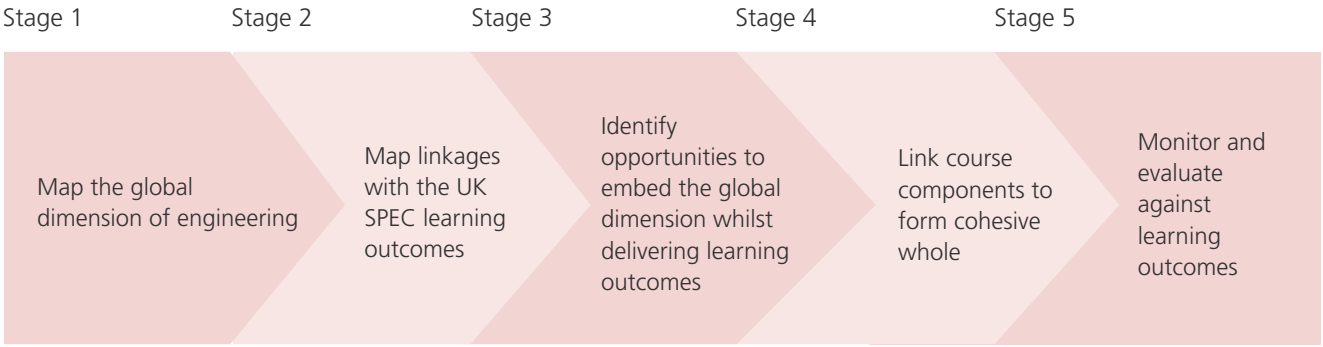
As with any process of institutional change support for change from senior management is essential. In order to make rapid change on the global agenda, senior management need to be convinced and supportive of the idea that global issues and sustainable development are the key drivers for HEIs in the UK and these issues should be at the heart of their institutional strategies and thinking. Senior management support is vital at both the faculty and university levels. A key strategy to win this support is to demonstrate the strong business case for a greater global dimension in teaching and the strong alignment between the global dimension and many other drivers of change within higher education and engineering.

Part 2: Incorporating the global dimension within learning

Having explored why the global dimension is so critical to engineering education and what the global dimension looks like, this second part of the publication aims now to consider how the global dimension can be embedded by looking at a range of strategies and approaches currently being adopted by UK universities. The Joint Board of Moderators advises that the best way to embed sustainable development (which as previously noted is closely allied with the global dimension) is by a teaching and learning process that:

- Provides an interdisciplinary perspective on the problems that engineers will tackle in practice
- Develops an understanding of the interaction between engineering, the environment and society
- Develops an ability to use technical engineering knowledge to help solve complex problems as described above

Designing courses which incorporate these features whilst maintaining the integrity of core engineering is a complex trade off and the solutions which best suit each faculty and university will be different. The approaches outlined in stage 3 are in current practice and many of the examples and comments were gathered during the seminars and interviews. One of the principle findings to arise from the research and dialogue with academics for this publication was the value staff place on mechanisms to share lessons and experience with other universities and within their own universities. This is one area where national stakeholders such as government, the professional institutions and the Higher Education Academy have a vital role to play. As a contribution to this, Engineers Against Poverty have compiled a directory of engineering education initiatives and contacts.[51] Although far from exhaustive, it illustrates the range and creativity of what exists. The framework of approaches breaks down into curriculum, partnerships and extra-curricula learning approaches which can be adopted at the course or faculty level as well as university-wide, national and international approaches to embedding the global dimension.



Towards a five stage framework for embedding the global dimension

Course and faculty leaders who are convinced of the case to embed the global dimension within the curriculum are advised to

Stage 1: Develop their own understanding of the global dimension of engineering by mapping the issues and skills which have a global dimension (see table below) and which are relevant to their courses and to map how these issues and skills are currently address within the curriculum. **Stage 2:** Understand how, by addressing these issues and skills, many of the Engineering Council's UK SPEC learning outcomes are also addressed

Stage 3: Identify and prioritise opportunities to embed these issues and skills within the curriculum as well as extra-curricular activities. Develop and pilot new course material, methodologies and approaches

Stage 4: Seek opportunities to link course components together so that learning builds upon prior learning and so that cross cutting themes such as ethics, business responsibility and sustainability become integrated throughout.

Stage 5: Pilot, monitor and evaluate the course innovations introduced and measure their effectiveness against course learning outcomes. Ensure staff have adequate time to monitor and evaluate course innovations and to reflect on and share this learning with colleagues as well as investing in additional professional development of teaching staff and in course assessment and development if appropriate.

Stage 1: Mapping the key issues and skills which define the global dimension of engineering

Social

- Poverty reduction
  - Enterprise solutions to poverty
  - Emerging business opportunities in developing countries
  - Challenges of working in developing countries
  - Working in fragile, conflict and crisis prone regions
  - Engaging marginalized and disadvantaged groups
  - Engineering and humanitarian relief
- Stakeholder analysis and dialogue and public engagement
- International politics and political analysis
- Science and engineering in society and social impacts of engineering

Environmental

- Sustainable development
- Climate change
- Soil and water management
- Flooding
- Bio-diversity
- Energy security and 'peak oil'
- Barriers to sustainable development
- Operation and maintenance
- Recycling, waste management and resource optimisation

Professional and management skills

- Contextual analysis (STEEP: social, technical, economic, environment and political)
- Needs assessment and feasibility studies
- Design and project management skills
- Systems thinking and systems engineering
- Full life-cycle analysis
- Communication skills
- Team working skills
- Critical thinking skills
- Creativity and conception skills
- Cultural sensitivity and adaptability

Business and enterprise skills

- Business ethics: governance, human rights, transparency, accountability and corruption
- Corporate responsibility: social and environmental impacts of business, impacts and trends of globalization, 'socially responsible investment', fair and ethical trade
- Aligning shareholder and social value
- Conflict sensitive business practice
- Innovation and enterprise: emerging technologies and their application to global challenges
- Emerging ethical issues arising from emerging technologies
- Emerging markets in low-carbon economy and growth in developing country investment

Stage 2: Mapping the linkages between the UK SPEC learning outcomes for engineering courses and the global dimension of engineering education	
UK SPEC learning outcome	The global dimension
Appreciate the social, environmental, ethical, economic and commercial considerations affecting the exercise of their engineering judgment.	Opportunity to illustrate how these considerations vary greatly from place to place by using a wide range of examples and case studies from around the world
Demonstrate creative and innovative ability in the synthesis of solutions and in formulating designs	Opportunity to show the importance of creativity and innovation in addressing global challenges and adapting solutions to a developing country context
Able to comprehend the broad picture and thus work with an appropriate level of detail	Exploring the global dimension of engineering is essential for this comprehension
Possess practical engineering skills acquired through, for example, …. work experience; in individual and group project work and in design work	The global dimension can be woven into project and design work, UK and international volunteering and work placements with international engineering companies
Transferable skills and include problem solving, communication, and working with others. They also include planning self-learning and improving performance	Design and research projects especially multi-discipline and team based exercises present excellent opportunities to incorporate the global dimension and develop these transferable skills
Understanding of and ability to apply a systems approach to engineering problems	Systems thinking ranges from understanding how the components of engineering systems relate and impact on each other and whole life analysis to understanding complexity in human, natural and economic systems. The global dimension encourages students to place engineering within its widest context and understand global – local and engineering – society linkages.
Investigate and define a problem and identify constraints including environmental and sustainability limitations, health and safety and risk assessment issues	The global dimension promotes understanding of these constraints, their complexity and how they vary according to the local context as well as appropriate tools to investigate and define a problem such as risk and needs assessment and social and environmental impact assessment
Understand customer and user needs	Global case studies illustrate the importance and challenges of identifying end-user needs in unfamiliar contexts
Ensure fitness for purpose for all aspects of the problem including production, operation, maintenance and disposal	Ensuring that all aspects of sustainability (such as operation and maintenance capacity) are built into problem solving is a key aspect of the global dimension
Knowledge and understanding of commercial and economic context of engineering processes	The global dimension deepens understanding of how this context varies greatly according to locality
Knowledge of management techniques which may be used to achieve engineering objectives within that context	Management tools for environmental, social and ethical issues provide an opportunity to explore the global dimension
Understanding of the requirement for engineering activities to promote sustainable development	The global dimension is essential to fully understand the contribution of engineering to sustainable development
The ability to develop, monitor and update a plan, to reflect a changing operating environment	The global dimension enhances understanding of how the operating environment varies considerably according to location and over time
Ability to use fundamental knowledge to investigate new and emerging technologies	The global dimension is essential to assess the suitability and sustainability of new and emerging technologies in different contexts
Awareness of the framework of relevant legal requirements governing engineering activities, including personnel, health, safety, and risk (including environmental risk) issues	The legal framework and its enforcement differs greatly between countries and sector. Global examples will help illustrate this
Understanding of the need for a high level of professional and ethical conduct in engineering.	The global dimension is essential to fully understand the range of ethical issues engineers face
The ability to learn new theories, concepts, methods etc in unfamiliar situations.	The global dimension emphasizes the need to adapt and modify approaches in unfamiliar situations and to value new approaches and perspectives
Ability to use appropriate codes of practice and industry standards.	Global case studies will illustrate how codes of practice and industry standards vary internationally

Stage 3: Identifying opportunities to embed the global dimension	
Embedding within the undergraduate curriculum	Ethos and core values Core and elective lectures and modules Visiting lectureships Feasibility and design projects Dissertations and research projects Management, business, innovation and enterprise skills Innovative pedagogies and team based working
Partnerships	Linkages between engineering schools and other faculties and graduate and research centres Partnerships with business Partnerships with development and community organisations Partnerships with overseas campuses and universities based in developing countries
Extra-curricula learning	Informal learning events
University level strategies	Post graduate and short course training Careers advice Professional development Curriculum review processes
Inter-university, national and international	Sharing good practice Education centres Course accreditation processes National and international collaboration, debate and policy initiatives

Embedding within the undergraduate curriculum

"In our view the greatest contribution higher education has to make to sustainable development is by enabling students to develop new values, skills and knowledge. The main (though not the only) way to make this happen is through developments in curricula and pedagogy." HEFCE

The following section identifies some of the ways in which global issues and thinking have been embedded within curricula and pedogogy.

Ethos and core values

The shifts described earlier towards embracing complexity, uncertainty, diversity of perspectives, critical analysis, change and interconnection and inter-disciplinary thinking could be said to run counter to engineering culture with its foundations set in empirical certainties and scientific method. Grappling with messy global problems and complex contexts is unfamiliar territory for much of engineering education. However, it is very much part of modern engineering. Change has been a constant feature of higher education especially in recent times. For engineering education in particular and higher education in general, the challenge of embedding the global dimension especially sustainability and development is a difficult one which for some universities will represent considerable change in the culture, ethos and values. However in a global knowledge economy, HEIs are obliged to embrace the global if they are to remain relevant. The examples given under university wide strategies show how some universities are embracing this agenda and placing the global dimension at the heart of their ethos, values and corporate strateg

Core and elective lectures and modules

One of the key strategies the authors propose for embedding the global dimension is to map how the global dimension can be aligned with other learning outcomes specified under by the Engineering Council's UK Standard for Professional Engineering Competence: The Accreditation of Higher Education Programmes[52]. The global dimension is most readily incorporated into modules addressing business, enterprise and project management, design and feasibility studies, environmental sustainability, science and society and human rights and ethics. One of the keenest debates in engineering education is the balance between depth and breadth when addressing the global dimension and how best to embed these issues.

Should the global dimension be taught through separate modules (such as at the Sustainable Development module at Imperial College or the 'Making a difference: global social responsibility' module at Leeds Metropolitan) or embedded across existing modules and in project and design elements or a combination of both? Should climate change, sustain-

ability or poverty reduction be discrete modules? If so should they be core or elective modules? How is it best to impart problem solving or team skills, cultural awareness or critical thinking? Can these skills be taught or is the role of the 'lecturer' to provide opportunities for students to acquire them? What is the balance between addressing the global dimension within undergraduate courses and more specialist post-graduate courses? Does engineering in the international development or humanitarian relief sectors require such a distinct skill and knowledge set that they should be taught separately from traditional civil engineering degrees?

Visiting lectureships

Since 1998 The Royal Academy of Engineering has run a visiting professorships programme in engineering design for sustainable development.[54] This programme gives selected universities access to specialist expertise from academia and business and supports sharing of teaching resources. This is valued by universities but is insufficient to meet the scale of the demand and many lecturers supported the creation of a register of suitable guest lecturers which all universities could tap into. Beyond national programmes, universities should look to expand guest lectureships, drawing on expertise from within the university, from other universities and from NGOs and business. 'Guest lectureships' are a common feature of masters and CPD courses. Greater use of outside lecturers who can provide a range of perspectives and practical experience should be actively promoted by faculties embracing the global agenda, although care is required to ensure the content of guest lectures fits within the overall course structure and is 'owned' by the course leader. Guest lectures require careful introduction to avoid the impression amongst students that such lectures are optional additions to the core course lectures.

Feasibility, design and research projects

The Engineering Council UK SPEC requires courses to *"investigate and define a problem and identify constraints including environmental and sustainability limitations, health and safety and risk assessment issues"* and give students *"[an] ability to apply a systems approach to engineering problems ...."* and to *"understand customer and user needs"*[55] Feasibility and design projects are common to all engineering courses and represent a principle way to deliver the learning outcomes set out in the UK SPEC and one of the main opportunities to address the global dimension.

Design modules are an excellent way to bring sustainable development into the curriculum especially when combined with international partnerships with universities and NGOs in the developing countries or undertaken as multi-disciplinary projects. One constraint is the need for design courses to maintain a strong engineering rather than 'social science' focus. Even subtle changes, such as using examples from around the world or conducting tests on materials other than concrete and steel, send important signals.

Many courses include research projects and dissertations and these also provide opportunities to learn about the global dimension. One example is the Appropriate Technology Research Programme at Nottingham University, which has won awards for embedding sustainability within the curriculum. The projects were sourced from around the world through NGOs (Tearfund, EWB-UK and Practical Action) and by direct advertising and allow 3rd and 4th year students to learn about engineering problem solving in a development context and become involved in global design problems. They are popular with students and have raised the profile of appropriate technology within the department and beyond.[56] Another example is Developing Technologies: a programme of staff led research projects at Imperial College which

Case study

The Centre for Sustainable Development (CSD) at Cambridge University Engineering Department[53]

Established in 1998, the Centre aims to be the dedicated centre for sustainable development within Cambridge's engineering department. The centre supports the wider faculty helping to deliver classes: for example a 4th Year (MEng) option module: Engineering Design for Sustainable Development, 3rd year modules on Technology, Work and Environment and Environmental Engineering and a compulsory 1st year class: Engineers in Society, as well as providing case studies and supporting relevant MEng projects. These modules are well received and attract positive feedback from students.

The Centre also runs an MPhil programme for engineers wanting to focus on engineering for sustainable development. With the exception of Centre for Sustainable Development (CSD), engineering courses at Cambridge have a strong mathematical and technical focus especially in years 1-3. Only in the 4th year does the curriculum widen and include topics on sustainability, globalisation, watsan, energy and environment and responses to climate change. Traditionalists within the faculty view the CSD with some suspicion wary of the lack of 'second order differential equations'.

The CSD curriculum focuses a lot on context setting such as energy security and developing country dimensions. The Centre uses a lot of active learning pedagogies such as role plays, facilitated discussions, distinguished lecture series and staged 'select committee' inquiries into sustainable development issues The distinguished lecture series is open to the public and is one of the most effective ways of raising awareness of SD issues in the wider academic community. Initially some students, more familiar with 'chalk and talk' teaching methods, struggle with the centre's approach. However the course continues to be popular, growing year on year and attracting a high proportion of women, foreign and mature students relative to undergraduate courses, many with work experience with international NGOs and business: A resource that undergraduate course leaders could potentially tap.

"works in partnership with development agencies, aid workers and indigenous communities to provide engineering design and training in appropriate technologies" and provides 3rd and 4th year students with research projects.[57]

Design projects offer opportunities for multidisciplinary team working, problem solving and project planning and placing engineering within a wider context: These are all skills which support the global dimension. One example of this in practice is Imperial Racing Green[58], a cross-faculty project where students from Aeronautics, Chemical Engineering, Electrical and Electronic Engineering, Earth Science Engineering, Materials and Mechanical Engineering are supported by staff to design, build and race a zero-emission electric hybrid fuel cell racing cart. A similar example is provided by mechanical engineering students at Queen's University Belfast entering the annual Formula Student competition. The endeavour is undertaken in a similar manner to running an engineering business, with the students undertaking the full range of technical and managerial roles necessary to complete the project successfully and providing opportunities to develop key skills through an authentic design-build project.[59]

There are other design competitions open to engineering and built environment students such as the 2005 Sustainable Construction Centre Architecture Design Competition and Ecohouse student design competition[60] and the Royal Academy of Engineering's Sustainable Engineering Design competition, this year won by students from Loughborough.[61] Loughborough University has created a 'toolbox' for other lecturers in engineering and design who recognise the importance of including Sustainable Design in undergraduate and postgraduate courses.[62]

Management, business, innovation and enterprise skills

Where project management and business skills are included in the curriculum, there is an opportunity to develop transferable skills and explore global issues such as:

- Global skills required by employers.
- The impact of globalisation on engineering employment.
- Global business drivers (such as innovation, poverty reduction and climate change).
- Global futures in the engineering sector.
- The importance of multi-disciplinary, team working in engineering.
- The importance of understanding the social, economic, environmental, cultural and political context.
- Global business ethics and corporate responsibility.

The Applied Ethics programme at Leeds University CETL organized a conference on Engineering Ethics in 2006.[63] Leading on from this, where enterprise and innovation are included in the curriculum, there is opportunity to explore the important role of innovation, enterprise and technology has to play in addressing climate change and poverty. The use of diverse case studies, active learning methodologies and working with other faculties and schools within the university such as business, politics and development can all help incorporate social and environmental dimensions within the business and enterprise education of engineering students. One area students, academics and employers agree upon is the need for courses to be more practically relevant and to develop the practical, problem-solving and creative skills.[64] Work placements are vital in giving students practical experience. By offering a broad range of placements - especially with employers who work internationally such as international development NGOs, students can gain a more global perspective on engineering (see partnerships with business).

Innovative pedagogies and team based working

Despite the constraints identified earlier, there is evidence of growing support and interest amongst undergraduate teaching staff in teaching methods which enable students to participate and engage in learning, rather than acting as passive sponges of received wisdom. In core engineering (mathematics and engineering science), lecture based learning is often the most appropriate and preferred teaching method. However such teaching methods provide little or no opportunity for group working, critical reflection, discourse and examination of contested and complex issues and do nothing to develop transferable skills such as team working, communication skills or the ability to think 'outside the box'.

Role play, simulation and action learning in general (as popularised by educationalists such as Paulo Friere[65] and Robert Chambers) are one of the most useful ways to bring out learning in development processes. Not only do they provide the space and opportunity to explore complex issues in imaginative ways which actively involve learners, they can also be used to introduce students to the application and value of participatory learning techniques within both international development and organisational learning and management. Participatory techniques such as participatory rural appraisal and participatory action and learning have become highly influential across development thinking. They also have wider application in business management and developing transferable skills. Similar approaches to learning are found in the worlds of business or change/management consultancy, for example Peter Senge's work on Learning Organisations[67] and any number of management textbooks. The use of role play and simulations is common to many disciplines. For example, in medicine, with actors role playing patients and in law with actors role playing clients in court room exchanges.

Innovative learning encourages more critical and independent thinking and awareness of context. Lecturers can gain further guidance through dedicated centres which promote innovation in teaching and participatory or creative learning, such as: the Centre for Educational Development at Imperial College[68], Open Spaces for Dialogue and Enquiry[69] and Promoting Enhanced Student Learning[70] at Nottingham University and the HEFCE funded Centres for Excellence in Teaching and Learning (CETLs)[71] and amongst facilitators and trainers within the NGO and business training world. However not all students welcome such approaches.

Student surveys at Imperial College show some engineering students, particularly those who excel at maths and science, struggle with non-technical subjects and non-lecture based learning. These students mark down such modules which they perceive to be more difficult, despite many acknowledging the value of such non-technical content later in their courses.

Web-based learning is increasingly popular within higher education especially among foreign students unable or unwilling to study in the UK with all the additional costs this entails: Examples include (1) WEDC[72] (e.g. WEDC's new Infrastructure in Emergencies) and the Open University distance learning courses; (2) The Observatory on Borderless Higher Education[73], a joint initiative of the Association of Commonwealth Universities and Universities UK and (3) the Einstein Network which shows how distance learning can be applied to professional development of engineers[74] and which HEIs could adapt and learn from.

Closely linked to innovative learning pedagogies is the introduction of innovative assessment methodologies. These are especially relevant in assessing less tangible learning outcomes such as the assessment of team and group work, the assessment of sustainable design and sustainability and the assessment of creativity in design. EC UK, the Engineering Professors Council and the Engineering Subject Centre have recently formed an Assessment of Learning Outcomes Working Group (ALOE) which aims to provide support to the engineering community to enhance the process of assessing learning outcomes. An ALOE case study, 'Preparing students for the world of work',[75] describes how Prof. Clarke of Newcastle University has sought to embed issues relevant to the global dimension such as enterprise skills and skills needed for sustainable communities within the course. Other examples of innovative assessment methods include (1) conducting and accrediting mock 'professional reviews' on sustainable development similar to those required by professional institutions in order to gain chartered status[76] and (2) staging student-led inquiries and debates.

Partnerships

As already identified a lack of relevant experience, skills and resources can significantly constrain the capacity of faculties to incorporate global and development perspectives. Innovative partnerships with a whole range of employers and stakeholders can help bridge these gaps and expose teaching staff and students to a wider range of perspectives. Many of the initiatives and approaches identified rely on working with others from outside the engineering faculty and university, building long-term mutually beneficial partnerships and counteracting knowledge silos and fragmentation of learning that exist within universities.

Linkages between engineering schools and other faculties and graduate and research centres

Higher education funders are increasingly seeking to support partnerships that bring together different disciplines both within and beyond science and engineering and which promote partnerships between UK universities and between UK and overseas universities. In addition, professional and academic research networks promote dialogue and shared learning across disciplines. The opportunity is to build on these existing collaborations and networks as a way of bringing a wider range of perspectives to undergraduate teaching and bridge gaps in internal capacity. At the University of Bath, there is collaboration between engineering and economics/international development programmes. It is suggested that engineering schools learn from the experience of other disciplines, such as sociology or tourism, in incorporating the global dimension.[77] One constraint to increasing collaboration is incompatible course timetables. In an effort to promote inter-school linkages, Imperial College has recently introduced 'flexy Friday' that enables students greater flexibility in choosing options from other schools.

Partnerships with business

At the post-graduate level, engineering schools have long recognised the value of working with business to develop and commercialise innovation and research. If tomorrow's engineers are to rise to global challenges, they need business awareness and the confidence to marry engineering, innovation and enterprise. Alliances between engineering related graduate schools, business schools, enterprise development agencies and business are common place especially at Russell Group universities and the UK government is especially interested in promoting innovation, enterprise and business skills across higher education. Several universities, such as Surrey and Loughborough, incorporate industrial placements of up to a year within their courses.

Within the international development community, there is growing interest in enterprise, growth and market-based solutions to poverty and the role of partnerships in mobilising the private sector in poverty reduction. One example of this approach is given by Professor Hopper of Cambridge University. Having established a record of successful business start-ups he is now focusing on the application of information and communication technologies for development.[78] Another example is Red Button Design and their reverse osmosis sanitation system (ROSS). The design was originally developed by students from Glasgow University as multi-disciplinary research project. It was featured recently on the BBC's Dragon's Den and has won several awards for innovation.[79]

The challenge and opportunity for undergraduate course leaders is to tap into these partnerships and bring this knowledge into the curriculum. There are many ways which have already been noted in which business can support engineering education including:

- Seconding staff to course development panels and accreditation boards.
- Seconding staff for guest lectures and extra-curricula talks.
- Business placements and internships (such as the Year in Industry programme).

- Topics and support for under-graduate projects and research/dissertation.
- Supporting education centres such as the constructionarium or partnering in knowledge portals.
- Sharing professional development training resources with academic partners.
- Joint ventures on research and business start-ups and incubators.

Partnerships with development and community support organisations

In terms of promoting the global dimension, the opportunity is twofold: (1) Encouraging UK and international student volunteering as a central part of an active global citizenship programme and (2) Embedding volunteering within the curriculum, recognising and accrediting the learning and linking volunteering to design and practical course elements. A few UK development agencies offer internships and volunteering opportunities for undergraduate students. This can provide valuable work experience and understanding of international development as well as supporting the work of the NGOs. To date, this experience is largely extra-curricula and not accredited within courses, although there is growing interest in recognising and incorporating it within the curriculum. For example, Heriot Watt University has teamed up with Challenges Worldwide[80] to incorporate international volunteering within courses with 5th year return volunteer students giving talks to 3rd students about their experiences, an example of peer learning.

Further examples from Nottingham and Developing Technologies work at Imperial College show the advantages of active staff support in identifying suitable 'projects' and overseas partners. Feedback from academics suggests volunteering can be a life changing and rewarding experience which is popular with students and motivates a wider awareness of the world and their place within it. Engineers Without Borders-UK recently won support from DFID for a 3 year programme promoting research and UK and overseas volunteering partnerships between engineering departments and NGOs. As well as internships and research projects, NGOs offer valuable experience and knowledge in applying engineering in the developing countries and the value of participatory methodologies in both development and learning (e.g. ICA-UK and INTRAC). They can also be a rich source of case studies and learning resources in global development issues (e.g. Practical Action, VSO and RedR) and guest lecturers. Partnerships with Diaspora and organisations serving minority and disadvantaged communities such as the Refugee Council offer student volunteering opportunities and allow an insight into cross-cultural working and empowering disadvantaged groups. The 1997 White Paper calls for DFID to *"build on the skills and talents of migrants and other members of ethnic minorities within the UK to promote development…"* and Engaging Diasporas produced by Oxfam UK explores this approach further.[81]

The growth of commercial and not-for-profit international volunteering agencies (see box) demonstrates the demand from young people to experience life and work overseas, especially in developing countries. In its 2006 White Paper, DFID committed to, "expand opportunities for young people … to volunteer in developing countries".. There is a wealth of experience in international volunteering from organisations such as VSO and Skillshare International. Although the majority of volunteering opportunities offered by VSO are open to professionals with a minimum of 3 years professional experience, there is renewed interest from DFID in promoting youth and student volunteering.[82] Overseas student volunteering offers many benefits to volunteers including developing problem-solving, team working and project skills, developing awareness of the complexities and challenges of working in the developing countries and the importance of context to engineering projects and personal development and awareness of other cultures. This is clearly a potential growth area but the evidence suggests there is a need for a careful regulation of this area and realistic expectations of the benefits for the host community or project are required.[83] UK volunteers should work alongside and be supervised by experienced local development workers. Poorly conceived and managed projects will impact negatively on the host community and the students' learning.

Volunteering agencies

Architects for Aid
Co-Plan
Challenges Worldwide
Engineers Without Borders
i-to-i
Habitat for Humanity
Raleigh International
SAFAD - Silsoe Aid for Appropriate Development
Shelter Centre
Skillshare International
VSO
Voluntary Design and Build
Volunteer Africa
Youth Action for Peace UK

Partnerships with overseas campuses and universities based in developing countries

International linkages can include visiting professorships, collaboration on research projects, field trips, student and staff exchanges and participating in international knowledge consortia such as DFID's Technology, Infrastructure and Urban Planning Resource Centre.[84] The internationalisation of higher education has led to fierce competition between universities to attract overseas students onto UK courses and led to a growing number of partnerships with academics and universities based in the developing countries. Nottingham University, for example, has established campuses in China and Malaysia. This raises important questions on adapting the curricula to the changing student demographic.

Extra-curricula learning

Informal learning events

At every university there is a wide range of extra-curricula activities, societies, student groups, conferences, talks and networks. Through these events opportunities arise to promote cross-disciplinary learning and debate on global

issues and sustainable development. The Distinguished Lecture Series held by The Centre for Sustainable Development at Cambridge[85] and Engineers without Borders (EWB-UK) talks[86] are two such examples. Student-led development organisations such as people and planet, EWB-UK, Architects sans Frontiers, the El-Salvador project (Imperial) and SAFAD (Cranfield) have a range of roles: campaigning, talks, training, summer gatherings, research, overseas and UK volunteering, influencing engineering education and so forth. These organisations can make a significant contribution to student learning and promoting global citizenship, a theme explored at conferences on "graduates as global citizens".[87] Universities looking to support global citizenship as a strategy to deliver the global dimension should explore the experience of other universities such as UCL's 'Global Citizenship' programme and Bournemouth University's Global Perspectives Project, as well as 'U8 Global Student Partnership for Development'[88] which promotes international collaboration between student development groups.

University level strategies

The university workshops stressed the importance of working at all levels (national, university, departmental and course levels) to drive change forward. Many examples were found of individual champions being able to drive forward change within their own courses from the bottom up even in the absence of support from senior staff. However, it is where university leaders (Council, Senate, Pro-Vice chancellors) and Deans and Heads of Department are explicitly and fully supportive of the global dimension and incorporate this agenda across their strategic thinking, policies and practice that the greatest opportunity arises. The model below is taken from the HEFCE strategic review of sustainable development in higher education in England.[89] The model is equally relevant to show the phases of adoption of the global dimension.

As the HEFCE strategic review of sustainable development in higher education in England illustrates, curriculum review is only one area in which sustainable development applies to universities: other areas include research, marketing, estate management and procurement. Universities wishing to embrace the global dimension are advised here to map how the global dimension and related agendas are currently addressed across existing strategies, policies and curriculum. Strategies need to cascade from university wide policies down to faculty, department and course levels.

A similar process of curriculum mapping is set out by the Royal Academy of Engineering's Teaching of Engineering Ethics Working Group in 'An engineering ethics curriculum map'.[90] This process needs to be holistic and lead to a long term implementation plan. It is advised that each depart-

Four phases of sustainable development (SD) adoption:

Phase one	Phase two	Phase three	Phase four
Grass roots enthusiasts	Early adopters	Getting really serious	Full commitment
■ Confined to individual enthusiasts and small teams, with a bottom-up approach ■ Values-driven ■ Activity principally in teaching and research ■ Often unaware of one another's work, and therefore some duplication of effort ■ Links more likely with other HEIs than internally ■ Sometimes element of counter-culture	■ Senior management involvement (often limited), sometimes on a partly opportunistic basis ■ (Enabling) Steering group set up ■ Largely still (enabled) bottom-up ■ Statement on sustainable development (SD) drafted for HEI's next strategic plan ■ Formulation of initial policy and procedure on SD ■ Staff invited to buy SD, not sold it ■ Setting of first and sometimes quite modest targets, often for baselining purposes, and without clear or compelling sanctions ■ SD has little organisational impact and no operational impact ■ Vice Chancellor (VC) has overall 'watching brief'	■ Significant involvement of senior management by the end of this phase, resulting in a senior sponsor with real ownership ■ VC/governance level active interest ■ Steering group taking firmer directive role (yet still collegial where possible) ■ Small team of SD change agents in place, often at least partly virtual ■ SD playing a significant role in both teaching and research across the HEI, and full SD estates policy and practice in operation ■ SD beginning to be joined-up ■ Extensive use of quantified targets, with an effective system of sanctions ■ SD becoming embedded in human resources	■ VC/governance level ownership ■ Values-driven/woven into fabric ■ HEI is an SD institution in the same way that it might be a research-intensive or widening participation HEI ■ SD is therefore captured in mission and in five-year strategy, and is organisationally and operationally embedded ■ Most activity is sufficiently 'on message' that it is integrated, but there are some who fall at least partly outside the cultural circle ■ Joined-up approach where the 'talk' in research and teaching is where possible 'walked' in estates practice ■ Virtuous circle of enhancement

ment appoints a team of tutors to be responsible and where necessary bring in expertise to advise and train the team and develop learning resources. The process should identify: (1) Short term, quick wins and minor adaptations (such as using a wider range of global case studies) which will promote global perspectives; (2) Wider lessons from other courses and universities and (3) Gaps in knowledge and capacity and external support available to fill these gaps?

Post graduate and short course training

Post-graduate courses represent an invaluable source of experience, teaching resources and lecturers, especially for course leaders lacking the necessary experience. Within engineering, there is a need to distinguish between the bachelors and masters levels. At the undergraduate level, there is a lot of pressure to cover all the "hard science" material within the first 3 years of a bachelors degree which leaves little room for "soft skills" modules. This has led some to suggest that the 4th year (masters level) offers more opportunity to integrate global issues in the curriculum. The past 5 years has seen continued significant growth in post-graduate centres and courses reflecting global issues such as CSR, the environment (especially climate change) and development / poverty reduction. This training includes masters and diploma courses, short courses, seminars, lectures and distance and e-learning including a few specific courses on engineering and development and engineering and humanitarian relief (see box). Post-graduate courses suit those specialising in international development, although this provision does not mitigate the need for the global dimension within undergraduate engineering courses.

Case study

University level programmes case study: Envision 2010, Imperial College[91]

Envision 2010 aims to drive reforms across the engineering faculty: curricula design, buildings, reward and promotion of academic staff, recognition of excellence: all fall within its remit. An extensive survey of students, alumni, industry and academic staff found many graduates were falling down on non-technical skills. The programme aims to update engineering education to reflect the changing needs of employers. Envision seeks to break down departmental knowledge silos by promoting greater cross-department collaboration, shared modules and supporting practical projects like Racing Green, the El Salvador Project[92], Developing Technologies and EWB-UK Imperial branch.

'Engineering and Development' MScs

- Bournemouth
- Cambridge
- Coventry
- Cranfield
- London Metropolitan
- Open University
- WEDC
- Development studies course directory

Further examples of UK universities strongly promoting the global agenda

- Bath University Centre for the study of Education in an International Context (CEIC)
- Bournemouth University: Includes information on the University's Global Perspectives project
- University of Bradford Ecoversity: a programme that aims to embed the principles and practice of sustainable development across the entire institution and all activities.
- University of Bristol Details of the work of the Energy and Environmental Management Unit.
- Chester College: Global Perspective initiative
- University of Glasgow brings together the university's sustainable development policies and initiatives.
- University of Gloucester The first English institution-wide certification to the ISO14001 environmental management standard.
- London South Bank University Education for Sustainability
- Leeds Metropolitan University: Global Perspectives Network linking staff in British universities.
- Middlesex University Global Citizenship and Civil Society through Service Learning
- University College London: 'Global Citizenship' programme

Further examples of UK universities strongly promoting the global agenda

- University of Kingston: Centre for Sustainable Communities Achieved through Integrated Professional Education
- University of Plymouth: Education for Sustainable Development
- East Midlands Regional Centre of Expertise (RCE) in Education for Sustainable Development: Universities in the East Midlands, officially recognised by the UN, one of only 35 RCEs worldwide and the first in the UK
- Engineering Centre for Excellence in Teaching and Learning and Full directory of CETLs
- Higher Education Academy Subject Centres
- Development Education Centre: Global development perspectives in HE 2003, The Global University 2006
- Institute of Education, Development Education Research Centre

Careers advice

EWB-UK survey of engineering students found careers advice focuses on traditional career paths with multi-national companies and management consultancies and those students with an interest in and commitment to poverty reduction and/or working overseas felt poorly served. These students need clear advice and encouragement to consider engineering as a pathway into international relief and development or sectors such as water engineering which make a significant contribution to international development. Often the most direct route for an engineer is to gain a minimum of 2-3 years professional experience with an international engineering company before seeking a role in international development since few agencies will employ staff without this professional experience. Here there is a role for organisations such as the Engineering and Technology Board and Women Into Science, Engineering and Construction (WISE) that are responsible for promoting engineering to prospective students, to work with schools and universities to promote this message and develop their capacity in this area. Careers officers in schools, colleges and universities need support in gathering and giving students access to advice on careers related to development or working internationally. Bristol and Manchester Universities as well as NGOs such as RedR, World Service Enquiry and AidWorkers.net offer such guidance on international development careers and represent a valuable body of knowledge.[93]

Professional development

As mentioned previously, a lack of appropriate skills and knowledge amongst teaching staff and the lack of status of undergraduate teaching in general have been identified as significant constraints in implementing the global dimension within engineering education. The university meetings proposed the following solutions

- Drawing on external expertise such as from the Higher Education Academy Engineering Subject Centre, Visiting professors, NGOs and business
- Investing in professional development and training of teaching staff and staff within accrediting bodies including funding staff time for networking, knowledge sharing and industrial secondments
- Strengthening the capacity of university staff training and development offices and drawing on relevant capacity and experience from other universities (e.g. Leeds Metropolitan University courses)
- Giving teaching ability greater consideration during recruitment and professional reviews of professors and lecturers

Curriculum review processes

'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 …. should actively inform the development of course content to ensure that courses produce graduates that industry will want to employ' (RAEng, 2007).

National accrediting bodies and those organisations which influence and work closely with them (such as the sector skills councils, the Engineering Council, the Engineering Professors Council and the Royal Academy of Engineering) are ideally placed to shape the future of engineering education. This publication makes the business case as to why industry requires the global dimension, sustainability and poverty reduction to be at the heart of engineering education. In seeking to ensure courses meet industry needs, accrediting body guidance should reflect the needs of global society and the world's poor and not just the needs of advanced engineering and UK industry. Their guidance needs to be future proofed and global in perspective. The accreditation and curriculum review process offers one of the greatest opportunities to drive this agenda forward. National accrediting bodies should draw on external expertise to inform their own work as well as making this expertise available to engineering faculties and course review panels during curriculum review. Universities would benefit from greater support in how to structure the process of course evaluation, review and development in order to respond to the global and poverty agendas. One way to redress the imbalance in priorities between research and teaching, especially at the Russell group universities, is to link funding to excellence in teaching much as the Research Assessment Exercise does with research.

Inter-university, national and international strategies

Sharing good practice

The Higher Education Academy (HEA) provides subject-specific support for enhancing the student learning experience through 24 subject centres including engineering and built environment as well as the Centres for Excellence in Teaching and Learning previously referred to. This support includes a database of publications, research, teaching resources, small grant funding, seminars and networks. Both within and between universities, networks and virtual communities of practice keep researchers, post-graduate students and teaching staff in contact and promote multi-disciplinarity: Examples include (1) CAMTools – run by Caret – at Cambridge University, (2) Intute which provides online gateways to education resources including engineering and development[94], (3) Teaching for Learning Network, (4) Collaborative Research Networks at Birmingham University and (5) Engineering Professors Council as well as the engineering institutions.

Education centres

Education centres play a vital role in providing educational field visits, practical demonstrations, design and construction simulations and opportunities for research collaboration as well as developing problem solving, team working and

project skills. All stakeholders recognise the value of practical experience and relating taught theory to real life problems. Education centres provide opportunities for role plays and simulations, team working and action learning (see innovative pedagogies). However, providing such practical experience is expensive. National and regional education centres allow cost sharing and pooling of knowledge amongst HEIs. Examples of education centres relevant to the global dimension of engineering and the built environment include:

- The Centre for Alternative Technology
- The Eden Project and the joint summer schools run with Architects sans Frontiers
- The constructionarium
- Practical short course training run by NGOs such as RedR, Architects sans Frontiers and EWB-UK

National and international collaboration, debate and policy initiatives

An assessment of the Make Poverty History Campaign showed that whilst it raised public awareness and support in the short term, there is little evidence the campaign led to a greater depth of understanding and there is a risk wider public support could quickly dissipate. DFID believe that education in general and HE institutions in particular are increasingly important to building support for development. At the national level, there was a perceived need for greater coherence in government policy on global skills education and DFID increasingly works with other government departments and agencies such as DIUS, the FCO, the British Council, HEFCE and the Research Councils. One example of this is the DELPHE (Development Partnerships in Higher Education) programme.[95]

The debate around the future of engineering education and the need for a greater global and poverty reduction dimension takes place during a period of rapid change and expansion in UK Higher Education and within a wider debate on global education and education for sustainable development and education for global citizenship. Stakeholders within engineering education would benefit from informing and participating in these wider debates both nationally and internationally and forging stronger links with other sectors and key policy formers. As a case in point, engineering and the physical and natural sciences could learn from work on global perspectives within the social sciences such as the DFID funded study by the Royal Geographical Society.[96]

As already noted, whilst there is wide support for the 'global skills' agenda examined by the Leitch Review, there are different interpretations of what the implications are for engineering education. What is the balance between (1) 'core engineering' 'hard skills' and broader professional 'soft skills', between (2) advanced science and engineering and 'intermediate' technologies often more suited to the developing countries and between (3) meeting the current industry needs and anticipating how these needs may

Case study

International Collaboration Case study: CDIO Project[98]

CDIO stands for Conceive - Design - Implement - Operate. CDIO aims to conceive and develop a new vision of engineering Education and is a collaboration of leading engineering schools in the U.S., Europe, Canada, U.K., Asia and New Zealand to ensure engineering education reflects changing real-world demands on engineers. The CDIO website presents a wealth of experience from around the world with particular focus on how practical design projects present students with active and experiential learning opportunities to develop the personal, professional and creative skills referred throughout this publication.

National and international policy frameworks relevant to the global dimension of engineering education

- Putting the World into World-Class Education: DFES, now DIUS
- Education for Sustainable Development and Global Citizenship, ACACC, now the Welsh Assembly's Dept. for Education Lifelong Learning and Skills (DELLS).
- Science in society strategy UK Research council
- Engineering a better world, Engineering and Physical Sciences Research Council
- Sustainable development strategy, Institution of Civil Engineers et al, 2007
- Engineering Subject Centre: Sustainability portal
- Global Sustainability Forum – Imperial College 2007
- Royal Academy of Engineering International Strategy
- Engineers of the 21st century, Forum for the Future
- The environmental association of universities and colleges (EUAC)
- EU Leonardo Project
- Bologna Declaration
- The Observatory: Status of engineering education for sustainable development in European higher education, 2006, Alliance for Global Sustainability
- International Federation of Engineering Education Societies (IFEES) 2008-2012 Strategic Plan
- Alliance for International Education
- Protocol for Engineering a Sustainable Future for the Planet: ICE, ASCE and CSCE memorandum

change radically as the engineering sector changes. How urgent and radical does change need to be? Stakeholders promoting the concept of the global engineer need to work with and lobby appropriate national bodies to ensure development and poverty reduction are integral to these reforms and that the costs of such reform are adequately resourced.

There is also the need to recognise that whilst duplication and fragmentation exists, this is an inevitable consequence of the competitive environment within which universities operate that often results in a reluctance to co-operate. Universities will however respond if there are incentives and there is potential benefit for students in terms of experience and research.

UK universities could also actively learn from innovation in engineering education from other countries. Examples of different approaches include: (1) the tradition of engineers wearing an iron ring depicting the moral responsibilities of engineers in society (Canada)[97]; (2) 5 year instead of 4 year degree programmes, the ability of students to take different modules in different universities, degrees being delivered in "smaller chunks" or modules and close collaboration between universities (continental Europe) and (3) inverting the curriculum. In the UK, years 1 and 2 tend to focus on maths and physics and then move onto practical examples. In the US, courses start with practical examples and work up to the maths. In the US, there is also more private funding, longer courses and more flexibility in terms of subject choosing.

Conclusions

This publication has aimed to demonstrate the need for engineering within higher education to give a higher priority to global and sustainability issues. Engineering does and can play a major role in combating global poverty. Higher education needs to prepare engineers for these challenges but also recognise the increasingly complex and uncertain world within change is taking place.

In addition to addressing the why of the global dimension, this publication has looked at what the challenges mean in terms of the content and focus of engineering education and also how it is implemented. There is evidence from around the UK that more and more HEIs involved in teaching engineering are recognising the importance of the global dimension but in too many cases, it is still seen as a 'bolt-on' and not an essential component of the learning of all engineering graduates.

Key to integrating the global dimension within engineering education is the recognition of the skills graduates will need for the twenty first century. These global skills of critical thinking, multi-discipline, team working, the ability to work across cultures and contexts, systems thinking and strong inter-personal and communication skills will need to an integral part of all engineering education, not just for those working developing countries.

Finally this publication has recognised that these challenges will not be easy to address and will require additional resources and support within universities. There will be a need for an externally supported professional development programme to ensure academics and institutions have the knowledge and skills to embed the 'global engineer' within their courses. However, this publication also illustrates that given this additional support, this change is achievable and commands widespread support from students, employers and academia. The global agenda is here to stay. The issue is now how can the sector best respond to ensure the engineering graduate is equipped to play a positive role in the global economy and society of the future.

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References and endnotes

1 Educating Engineers for the 21st Century, The Royal Academy of Engineering, 2007

2 Ibid

3 Engineering for Sustainable Development: Royal Academy of Engineering, 2006

4 Stern Review Report on the Economics of Climate Change

5 The Strategy Trends Programme of Development, Concepts and Doctrine Centre (DCDC), an independent centre within the Ministry of Defense identifies the paramount importance of globalisation, climate change and global inequalities as drivers of change over next 30 years. The connections between climate change and poverty and the linkages between globalisation and poverty are described in numerous publications such as DFID's Climate Change Keysheets, Chapter 7 of DFID's 2006 White Paper and Chapter 4 of the Stern Review, DFID's Making globalisation work for the world's poor (2000) White Paper. These publications also note the critical linkages with science, engineering, technology and innovation. The linkages between engineering and poverty been to focus of numerous recent studies including Millennium Project Task Force on Science, Technology and Innovation, C Juma (ed), *Going for Growth: Science, technology and innovation in Africa* (The Smith Institute, 2005) and S Jahan and R McCleery Making Infrastructure Work for the Poor, (UNDP 2005)

6 Henry, W P (2004) Engineering Beyond Technology. Inaugural American Society of Civil Engineers (ASCE) Address, Baltimore, Maryland October 2004.

7 Centre for Global and Futures Education, Bath Spa University

8 McKinsey Quarterly January 2006 survey documents increasing executive interest in CSR

9 Trends in CSR, Grayson, 2007

10 Corporate social opportunity, Grayson, 2007

11 From Challenge to Opportunity: The role of business in tomorrow's society, WBCSD, 2006

12 Enterprise Solutions to Poverty, The Shell Foundation, 2005

13 Making Connections, DFID, 2002 (p15: Learning from Past Mistakes)

14 Systems and Sustainability: Sustainable Development, Civil Engineering and the formation of the Civil Engineer Professor Paul W Jowitt 2004

15 Interviews with leading thinkers on biomimicry, Big Picture TV

16 The Accreditation of Higher Education Programmes, Engineering Council UK, UK Standard for Professional Engineering Competence, 2004

17 Annex C- Sustainable Development in degree programmes: Joint Board of Moderators, 2005

18 Page 3, World-Wide Horizon: Cross-Cultural Capability & Global Perspectives, Guidelines for Curriculum Review Killick, D. (2006, b)

19 Overseas students boost UK economy by £8bn a year, The Independent, 2007

20 The Internationalisation of UK Higher Education: a review of selected material, Caruana V & Spurling N. (2007)

21 Teaching International Students, Carroll J & Ryan J (2005) Abingdon, Routledge

22 Caruana V & Spurling N. (2007) and Global and Sustainability Issues Within Engineering Education, Final Report, Bourn, D & Sharma, N (2007) Unpublished paper for Imperial College and Engineers Without Poverty

23 The increased interest of research councils in the Global Dimension is demonstrated by increased funding for research that tackles major international issues as well as numerous specific initiatives such as EPSRC's international strategy and activities, its Energy Research and International Development Scoping Workshop and its Carbon Vision programme,

24 Education for Sustainable Development: Graduates as Global Citizens conference 2007 Bournemouth University,

25 HEFCE strategic review of sustainable development in higher education in England (2008) HEFCE

26 Unpublished research conducted by Engineers Without Borders – UK comparing graduate careers of former EWB and non-EWB members at Imperial and Cambridge

27 Students as Global Citizen? Bourn, D (2007), Unpublished paper presented at Bournemouth University Education for Sustainable Development conference, September 2007

28 Employable Graduates for Responsible Employers: Research on the links between sustainability and employability in the graduate job market in relation to higher education teaching and learning, A Cade (2007) StudentForce for Sustainability

29 Graduate Employability for Sustainability, Cade A & Tennant I (2005) submitted to the Institute of Environmental Management (IEMA) for publication in their December 2005 Issue of the Environmentalist in the Learning Supplement

30 'Internationalisation and Employability' Leggott, D & Stapleford, J (2007) in Jones, E & Brown, S. (2007) eds. Internationalisation in Higher Education, London, Routledge

31 'Global Perspectives and Sustainable Development in the Curriculum: Enhanced Employability, More Thoughtful Society?' Shiel C, Williams A and Mann S (2005) in Enhancing Graduate Employability: The roles of learning, teaching, research and knowledge transfer, Proceedings of the Bournemouth University Learning and Teaching Conference,

32 Realising the University in an age of supercomplexity, Barnett R (2000): Open University/SRHE

33 The Global University: what are employers looking for? Archer W (2005) Presentation at Graduates as Global citizens: Quality Education for the 21st Century, DEA Conference, London

34 Global and Sustainability Issues Within Engineering Education, Final Report, Bourn, D & Sharma, N (2007)

35 PriceWaterhouseCoopers' professional development programme, Ulysses

36 Volunteer Services Overseas assessment process

37 Global Citizenship Secondary School Map - Education for Sustainable Development and Global citizenship: National Assembly for Wales, 2005,

38 Development Education Association

39 Learning and skills for sustainable development, HEPS and Forum for the Future, 2004 and Education for Sustainable Development portal
40 ICE Joint Board of Moderators framework on Sustainability and Design,
41 The DFES framework, Putting the World in to World Class Education
42 The CSR academy's Making CSR Happen: the contribution of people management (see also Ashridge study)
43 A framework for the global dimension within the engineering profession, EAP/DEA, 2006
44 Leitch Review of Skills, Prosperity for all in the global economy - world class skills, 2006
45 WorldWise web page on global skills
46 Measuring Effectiveness in Development Education, McCollum and Bourn, 2001, Development Education Association publications
47 Henley Report Educating Engineers for the 21st Century: The Industry View, Henley Management College, 2006
48 Page 67, HEFCE strategic review of sustainable development in higher education in England (2008) HEFCE
49 Sustainable development in HE resource guide HEFCE, 2007
50 Endnote 1: Educating Engineers for the 21st Century, The Royal Academy of Engineering, 2007
51 Directory of UK engineering education, EAP
52 UK Standard for Professional Engineering Competence, The Accreditation of Higher Education Programmes, the Engineering Council, 2004
53 The Centre for Sustainable Development at Cambridge University Engineering Department
54 Visiting Professors in Engineering Design for Sustainable Development, Royal Academy of Engineering
55 Engineering Council UK, UKSPEC, The Accreditation of Higher Education Programmes 2004
56 Appropriate Technology research at Nottingham University and the work of Mike Clifford (1, 2)
57 Developing Technologies, Imperial College provides engineering design and training in appropriate technologies
58 Imperial Racing Green, Imperial College
59 Formula Student Design case study, Dr G Cunningham (2005), Queen's Belfast University
60 Ecohouse Student Design Competition
61 Royal Academy of Engineering's Sustainable Engineering Design competition
62 Toolbox for Sustainable Design education, Loughborough university
63 Engineering Ethics, 2006 conference, part of Applied Ethics programme at Leeds CETL
64 Placements Work – The Empirical Evidence
65 Paulo Freire Institute, UCLA
66 Robert Chambers, leading thinker on participation in education and development
67 Summary of Peter Senge's work on learning organisations, Infed website
68 Centre for Educational Development at Imperial College
69 Open Spaces for Dialogue and Enquiry, Nottingham University
70 Promoting Enhanced Student Learning, Nottingham University
71 Centres for Excellence in Teaching and Learning (CETLs)
72 Infrastructure in Emergencies, WEDC and distance learning at WEDC
73 The Observatory on Borderless Higher Education
74 The Einstein Network
75 'Preparing students for the world of work' case study, Prof. B Clarke, Newcastle University, (2007)
76 ICE Sustainable Development Professional Review
77 For example, modules on development and globalisation at Northumbria and Anglia Ruskin Universities
78 Prof. Andrew Hopper, Cambridge University
79 Red Button Design's Reverse Osmosis Sanitation System was featured on the BBC's Dragon's Den
80 Challenges Worldwide, Heriot Watt partner
81 Engaging Diasporas, deHaas, Oxfam, 2006
82 DFID and volunteering programme, DFID website, 2007
83 DEA response to DFID's Public Consultation Document on Youth Volunteering, DEA, 2007
84 DFID's Technology, Infrastructure and Urban Planning Resource Centre
85 The Distinguished Lecture Series held by The Centre for Sustainable Development at Cambridge
86 Engineers without Borders talks and seminars
87 Graduates as Global Citizens Conferences 2005 and 2007
88 U8 Global Student Partnership for Development
89 Page 60 of HEFCE strategic review of sustainable development in higher education in England, HEFCE, (2008).
90 'An engineering ethics curriculum map', Royal Academy of Engineering
91 Envision 2010, Imperial College
92 The El Salvador Project, Imperial college
93 Guidance for careers in international development from Bristol and Manchester Universities, RedR and Aidworkers
94 Intute education and research web portal
95 DELPHE (Development Partnerships in Higher Education) programme
96 Global Perspectives in Higher Education, Jenny Lunn, Royal Geographical Society
97 Canadian Iron Ring ceremony,
98 CDIO Project

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