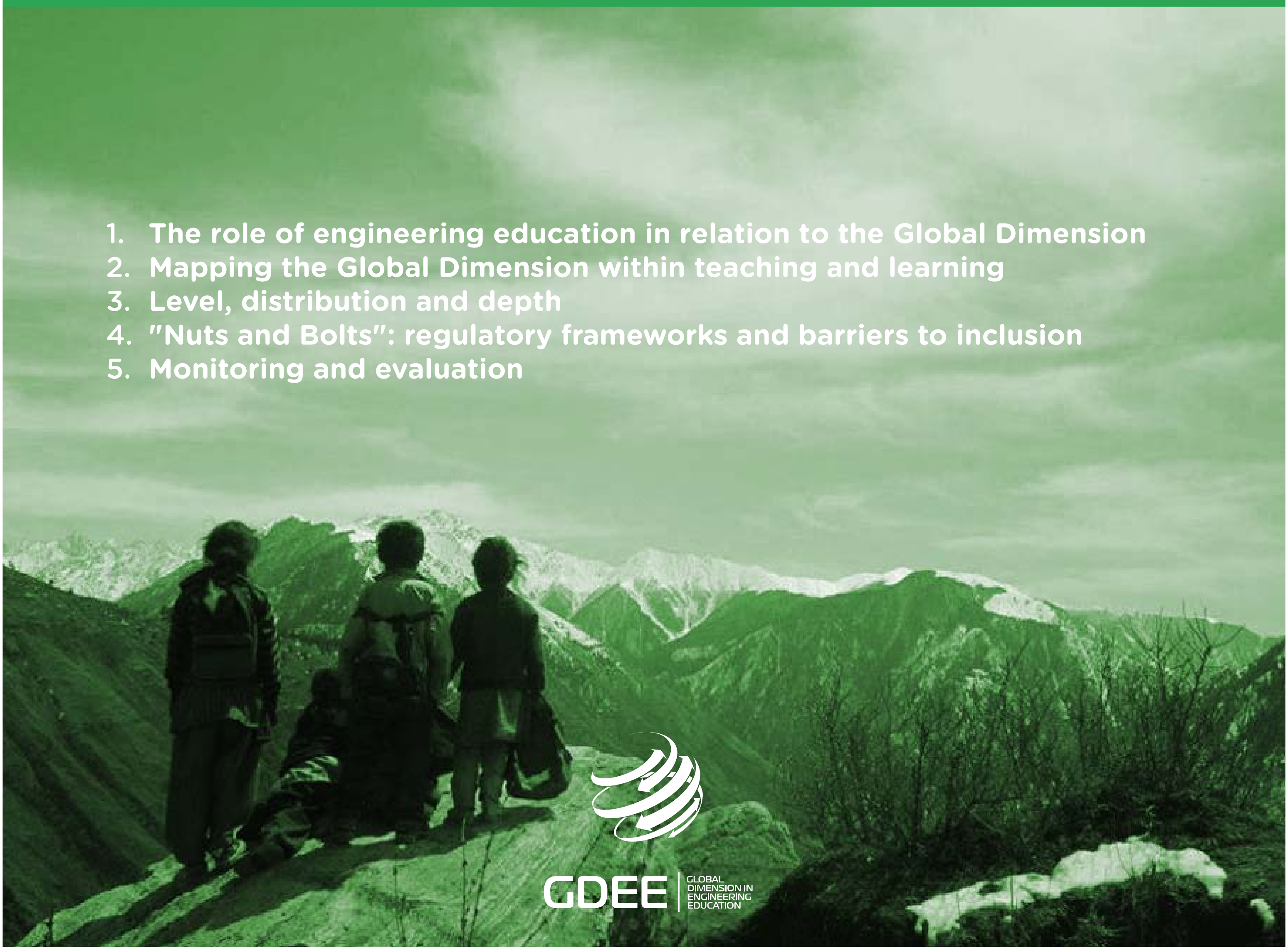
Block C

INTEGRATING GDE INTO TEACHING AND RESEARCH

C.7

Integrating GDE into the Academia



1. The role of engineering education in relation to the Global Dimension
2. Mapping the Global Dimension within teaching and learning
3. Level, distribution and depth
4. "Nuts and Bolts": regulatory frameworks and barriers to inclusion
5. Monitoring and evaluation

GDEE GLOBAL DIMENSION IN ENGINEERING EDUCATION

C.7 Integrating GDE into the Academia

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PHOTO: James Mercer leads a workshop on building batteries. A. Elias

CHAPTER 1

The role of engineering education in relation to the Global Dimension

1

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1 THE ROLE OF ENGINEERING EDUCATION IN RELATION TO THE GLOBAL DIMENSION

Cathryn Gathercole, Director, Tide global learning

EXECUTIVE SUMMARY

The relationship between engineering and human development is well established; it covers all aspects of life and is integral to economic power and influence. As our world changes we face new challenges and need new solutions. Engineering must respond to this changing context, and engineering education is at the heart of this response. Incorporating a global dimension within engineering education will be an integral part of this change.

In this chapter we will explore the relationship between engineering education and the Global Dimension within the context of international development. By reviewing the current agenda for international development and considering what the next global goals will be, we will identify the key global challenges for the next period and the role that engineers will play in responding to these. From this we will consider a proposed framework of knowledge, skills and dispositions which make up the Global Dimension, and we will explore opportunities and challenges for introducing these into engineering courses.

The Global Dimension in education does not exist in isolation and it is helpful to look at related educational agendas, such as environmental education and education for human rights. Many of the lessons from the integration of Engineering for Sustainable Development are relevant when considering the Global Dimension, and can help in identifying possible approaches. This is particularly the case when considering challenges around the role of the educator and intercultural understanding which may be uncomfortable and difficult.

The benefits of the Global Dimension to engineering education are twofold. Making the links to the real world and emphasising the role that engineering plays in addressing agendas such as poverty reduction, human rights and conflict appeals to a wider demographic than is

currently the case. Encouraging a more diverse student base into engineering will address the need for an increased supply of graduate engineers which an economy requires. At the same time the emphasis on global themes, skills and knowledge will produce graduates with the attributes desired by employers. A bonus is that a more diverse student body will inspire greater creativity and innovation: essential in addressing the global challenges we face.

The timing is right for engineering education to embrace the Global Dimension. This chapter provides justification, Context and examples that will help make this a reality.

LEARNING OUTCOMES

After you actively engage in the learning experiences in this module, you should be able to:

- Explain the role that Global Dimension plays in engineering education.
- Understand how the Global Dimension relates to other education agendas.
- Understand the impact of engineering education on global development.

KEY CONCEPTS

These concepts will help you better understand the content in this session:

- How engineering education benefits from the Global Dimension
- Engineering education paradigms similar to the Global Dimension
- The synergies between the Global Dimension, engineering education and international development

GUIDING QUESTIONS

Develop your answers to the following guiding questions while completing the readings and working through the session:

- How can engineering education prepare student engineers to address the key global challenges of climate change, food security, access to water, population growth and use of natural resources over the next 50 years?
- How can the Global Dimension support excellent engineering education?
- What are the challenges and opportunities for the Global Dimension in engineering education?

INTRODUCTION

The world as we know it has been shaped by engineers past and present. The impact of engineering on our world is illustrated by considering the contribution of those who make medical prosthetics and ensure precious drugs are transported at the correct temperature to our health and wellbeing; to those researching ever more efficient and speedy methods of transport and sustainable energy; to those at work on increasingly sophisticated special effects and modes of communication in leisure and entertainment. Engineering is integral to economic growth through the extraction and processing of natural resources in manufacturing and in providing energy. It touches every aspect of our lives, and connects us through a series of complex links to people and places we will never meet or visit. Understanding and implementing the relationship between the Global Dimension and engineering education is not optional; it is a reality. Without it, graduate engineers will be ill-prepared for the world in which they will operate. Increasingly employers are looking for evidence of skills and dispositions which incorporating a Global Dimension into engineering education courses will develop.

This chapter will explore how engineering education can prepare future generations of engineers to tackle the key challenges facing the global community by considering the synergy between the Global Dimension, international development and engineering education. By looking back at the Millennium Development Goals, and looking ahead to the Sustainable Development Goals, we will consider key global priorities and examine the role of engineers in addressing them. We will then look at the major challenges for engineering in the UK, and how the Global Dimension can help to address them. In the final section, we will look at the challenges and opportunities for the global dimension in engineering education, by firstly considering the relationship with ‘adjectival’ educations; then exploring a framework for the global dimension comprising generic themes, skills and dispositions; touching on the challenges of intercultural communication and learning lessons from the history and implementation of Engineering for Sustainable Development.

HOW CAN ENGINEERING EDUCATION PREPARE STUDENT ENGINEERS TO ADDRESS GLOBAL CHALLENGES?

The world is constantly changing. In the last 10 years the global population has increased by 1 billion to 7 billion, more than 50% of whom now live in urban environments. Farmland is being lost to degradation at a rate of 1 football pitch every 7 seconds, and the returns from the remaining productive land are diminishing (Land Commodities). The impact of climate change has led simultaneously to flooding and water shortages, resulting in damage to agricultural land and humanitarian crises. The change in balance of global economic power signals the opening up of new markets particularly in China and India, and with it new consumer demands and increased consumption. In the world of science and technology the invention of the microchip along with the emergence of genetic engineering and biotechnology have been revolutionary, and are seen by many as providing solutions.

Globally, different aspects of our lives are linked through a series of economic and political alliances that affect how and what we consume, where we work, and our values systems. These connections are key to understanding the actions of politicians, and the exercise of power and influence on the international stage. The development and use of engineering is integral to this process. Globally many of the biggest, most powerful companies – such as Apple, Exxon Mobil, General Electric, Pfizer, Samsung – have a technological focus, built on engineering, and as such they wield a great deal of influence.

The pervasiveness of communication technology challenges our understanding of privacy, security, and national boundaries, while it is simultaneously a significant tool for 'citizen reporters' telling the stories of those involved in war and humanitarian crises. An analysis of major global conflicts identifies the control and access to resources – from water, to land to minerals – as a root cause in many cases; while surveillance and communication technology is a significant tool for all those involved in conflict, whether it be organising democracy demonstrations in Egypt or the use of drones in Afghanistan. These examples demonstrate the interdependent nature of our world, and they highlight the impacts that people we will never meet, and places we will never visit, have on our daily lives.

The Millennium Development Goals (MDGs) agreed by representatives from all member countries at the Millennium Summit of the United Nations in 2000 identified eight key goals to be achieved by 2015. These ranged from halving extreme poverty, to promoting gender equality, improving health, promoting environmental sustainability and providing universal primary education. Analysis of progress towards these targets has shown a mixed picture, with meaningful progress made on some targets in some parts of the world (notably East Asia and North Africa), while there have been insufficient improvements overall. Significantly those with a gender dimension such as female empowerment and maternal health are least likely to be reached (UN-DESA, 2014).

The next 50 years will see further changes. The Sustainable Development Goals (SDGs) set out the international development agenda until 2030. They recognise that the new targets should be universally applicable, in light of the need for equity between and within countries.

Table 1 *The proposed Sustainable Development goals are* (United Nations):

No.	GOAL
1	End poverty in all its forms everywhere.
2	End hunger, achieve food security and improved nutrition, and promote sustainable agriculture.
3	Ensure healthy lives and promote well-being for all at all ages.
4	Ensure inclusive and equitable quality education and promote life-long learning opportunities for all.
5	Achieve gender equality and empower all women and girls.
6	Ensure availability and sustainable management of water and sanitation for all.
7	Ensure access to affordable, reliable, sustainable, and modern energy for all.
8	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.
9	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.
10	Reduce inequality within and among countries.
11	Make cities and human settlements inclusive, safe, resilient and sustainable.
12	Ensure sustainable consumption and production patterns.
13	Take urgent action to combat climate change and its impacts.
14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development.
15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.
16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.
17	Strengthen the means of implementation and revitalize the global partnership for sustainable development.

Together these ambitious goals set out a challenging agenda for international development for the next period. They highlight the interdependent nature of our world and recognise that sustainable development is a challenge for everyone wherever they are, not just those living in 'other' countries. It is this framework that will shape the environment in which the engineers in training today will operate.

From this we can identify a number of key challenges facing the global community. Most pressing for engineers is how we can provide enough of everything for an increasing population, given finite resources. Simply put, we have to come up with more creative ways to do more with less. We will ask questions such as:

- How do we feed the global population?
- How can we cope with the effects of climate change?
- How do we combat diseases?
- How do we respond to the growing demand for energy?
- How can we supply sufficient water?

Trying to find the solutions to these questions is already the focus of activity across public, private and academic institutions around the world, reaching across subject disciplines and geographical borders. The global community expects engineers to be at the forefront of this activity. Engineers beginning their training now will devote their careers to answering these questions, from junior researcher to regulator to manager to Chief Executive. The challenge for engineering education is how can the training that these young engineers receive prepare them for this future?

The core business of engineering education is to educate engineers; that is, to furnish them with the depth of knowledge and level of technical skills required to perform their role. How successful they are as engineers will be measured in part by their ability to apply their knowledge and skills to a particular task. Increasingly, those tasks will have more than just a technological dimension but one which encompasses an understanding of the global context and an ability to use this understanding when considering a solution. The Henley Report 'Educating Engineers in the 21st Century: the Industry View' stated (Henley, 2006):

> "*…engineering firms look for skills and attributes in two broad areas. The first is a set of defining skills that are unique to the engineer and which encompass the domain of technical skills. These include a sound knowledge of the engineering fundamentals within their discipline, built on a solid base of mathematics. Other highly sought-after attributes in this domain are creativity and innovation plus the ability to apply theory in practice. The second skill set includes the social and interpersonal skills and attributes that enable the engineer to operate in a commercial working environment. These include communication skills, team-*

working skills, and business skills, which for entry-level graduates primarily mean awareness of the commercial implications of engineering decisions.”

This means that a core part of the training must be to help students develop the ability to think beyond the immediate technological problem, and outside of the known cultural norms to identify a more nuanced, more complex context. It challenges the idea that engineering education is only about technical knowledge, but brings in wider considerations, including concepts of uncertainty, and social and environmental factors. This, in turn, provides a more challenging learning environment that encourages creative and original thinking.

So we could ask ourselves the same questions as above once again, but this time we can consider them in their more complex contexts:

- How do we feed the global population… sustainably, to reduce malnutrition, improve standards of health and take account of local resources, knowledge and customs?
- How can we cope with the effects of climate change… both in mitigating against the impact on lives and livelihoods and also in adapting to new approaches which will not worsen the impact on the most vulnerable populations and harm valuable ecosystems?
- How do we combat diseases… and when considering methods to combat disease, how much do we consider the local context and facilities? What are the factors that influence decisions around which diseases are prioritised for research and development? How can we support research into diseases which predominantly affect poorer people such as the Ebola virus?
- How do we respond to the growing demand for energy… recognising current unequal but changing patterns of consumption and finite resources?
- How can we supply sufficient water… that is easily accessible and clean to ensure high health standards for everyone? How do we address competing demands on water from health, manufacturing and agriculture?

These examples start to show how encouraging an approach which includes a global dimension can enable engineering education to prepare students to address the key global challenges.

WHAT ARE THE CHALLENGES AND OPPORTUNITIES FOR THE GLOBAL DIMENSION IN ENGINEERING EDUCATION?

The Global Dimension does not stand alone within the traditions of engineering education. There are obvious relationships to other agendas such as sustainability, humanitarian engineering and ethics, all of which are established features of engineering courses. Within broader education there are strong traditions of 'adjectival' approaches, including environment, human rights, peace, gender, citizenship, development, multicultural and anti-racist. Different institutions will have different relationships with each of these approaches – depending on their unique history – and this will be a factor for engineering departments in determining their starting point when considering how they can further develop the Global Dimension within engineering.

It is useful to consider common features of some of these 'adjectival' educations to better understand how they can support the global dimension.

Table 2 *Descriptions of 'adjectival' educations* (DEC Birmingham & 80:20, 1999):

APPROACH	DESCRIPTION
Development education	An explicit concern about the nature of development and under-development: how these are defined and measured; debates about human development, gender, culture and environment and how these relate to traditional understandings of economic development; the challenge of pro-poor growth.
Human rights education	An explicit concern with human rights, their definition, origins and implementation: exploring debates about the relationship between economic, political, social and cultural rights as well as those between rights and responsibilities; the role of governments and civil society; how and where rights are abused or denied.
Environmental & Sustainable Development education	An explicit concern with issues relating to environment and to the interface between the bio-physical and social worlds; it emphasises the environmental costs of much of modern economic development and its legacy for the future; it challenges models and strategies which highlight the human dimension only.
Peace education	An explicit focus on issues of peace and conflict: the root causes of conflict; the nature and impact of different types of conflict; strategies and experiences for promoting peace and reconciliation; comparative experiences of both peace and conflict.

Multicultural education	An explicit focus on issues of culture and cultural identity: recognising the centrality of culture as a key lens through which development is interpreted and pursued by different cultures; challenging the 'Eurocentric' or 'Economistic' models of development; exploring and respecting local identity and culture in an age of internationalism.
Gender education	An explicit focus on issues of gender and how these manifest themselves at a variety of levels within society; definitions and debates on the meaning of sexuality and its influence on other issues.
Anti-racist education	An explicit commitment to understanding issues of race, difference and commonality: exploring definitions and debates around issues of race; exploring the histories of different races and how they have become intertwined; challenging attitudes and theories of racial superiority and inferiority; challenging racist behaviours and prompting attitudes and structures to sustain tolerance.

The Global Dimension draws on many of the features highlighted above to incorporate an understanding of international development and human rights, along with equality issues such as gender and racism, and bound by the relationship with the environment and sustainable development.

So what might the Global Dimension in engineering education look like? A research project carried out by Engineers Against Poverty and the Institute of Education drew on dialogue with a range of UK universities and key stakeholders in engineering education to draw up the following framework for the Global Dimension within the engineering profession.

Table 3 *Framework for the Global Dimension in the engineering profession* (Engineers Against Poverty & Institute of Education, 2008):

AREA	ATTRIBUTE
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

It is difficult to argue against any of these generic themes, skills and dispositions as requirements not only for developing good engineers, but also good citizens; indeed they chime with the Henley Report. However, there are implications for the Engineering Educator who may not feel competent in developing a curriculum which addresses these areas, and may in fact feel that these are a distraction from the main focus of technical competence. The publication further identifies that in order to be able to incorporate these aspects in engineering education, some fundamental shifts in course content and delivery need to occur, as characterised by the following table.

Table 4 *Changes in content and delivery needed for the Global Dimension in engineering education* (Engineers Against Poverty & Institute of Education, 2008):

MOVING FROM	MOVING TOWARDS
Fixed content and skills to conform to a pre-determined 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.

These changes represent a challenge to traditional roles of teaching and learning as they suggest that the teacher must take on the role of learner in a shared journey of discovery, recognising that accepted knowledge and practice will be challenged. While some academics will relish this role, others will feel uncomfortable, feeling threatened by new approaches, and unfamiliar with the required knowledge, which in turn will be a barrier to enacting change.

A further challenge goes much deeper, and is related to the accepted cultural and value based norms within which engineering education is grounded; norms that are based on western, empirical, scientific methodologies. This approach does not sit comfortably with a more ambiguous, subjective approach that dominates in different parts of the world. Questions of values and cultural norms are deeply embedded within an individuals' view of the world, and influence all aspects of behaviour and understanding.

A useful way to understand the concept of culture is to consider the visible and invisible components. The anthropologist Edward T Hall used the image of an iceberg to illustrate this, with the majority 'invisible' aspects hidden below the surface.

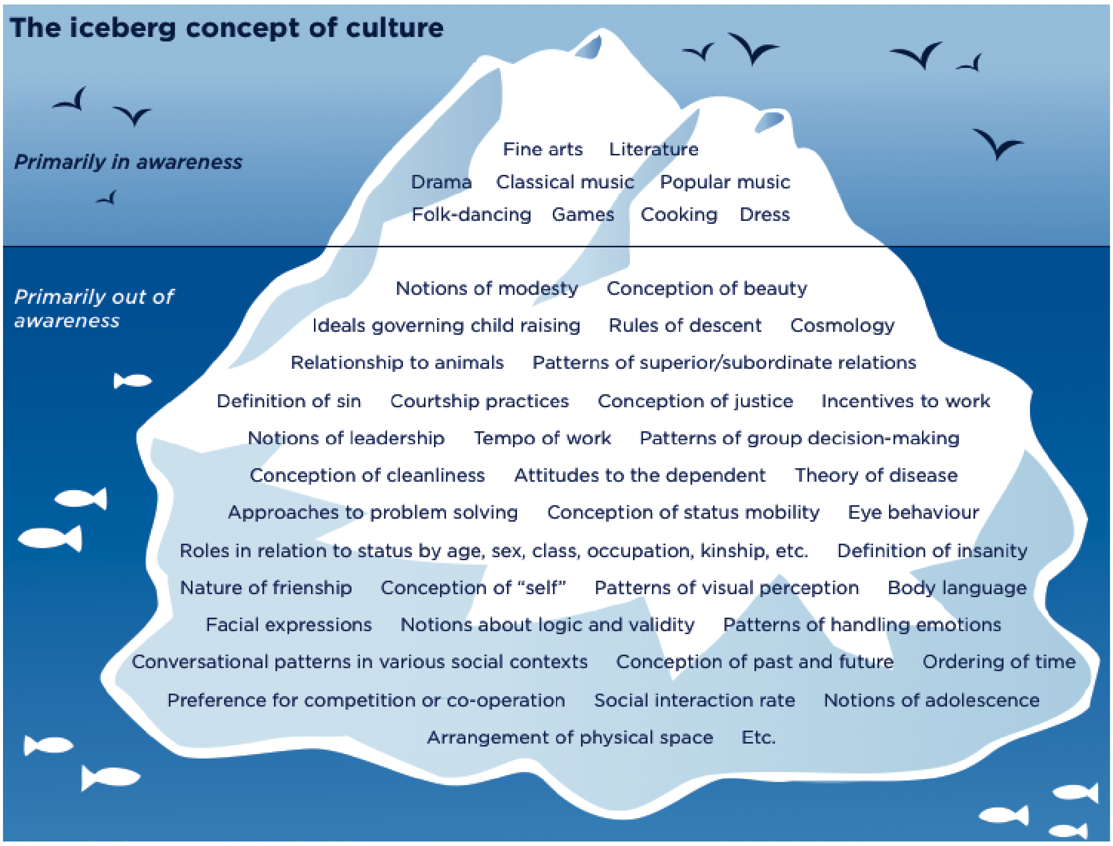

Figure 1 *Edward Hall's iceberg concept of culture*

Figure 1 illustrates why intercultural communication is so challenging, and goes some way towards explaining why working within different values systems and cultural practices can be a disorientating and uncomfortable experience. Possibly one of the most challenging concepts for engineers is the idea that notions of logic and validity can be culturally based. However, if we consider how our values systems determine how we measure success – and therefore how we set goals for a particular activity – this starts to become clearer. For example, a culture which values monetary success highly would have a different objective when conducting an activity to a culture where the success was measured in environmental terms – which in turn would influence the design, methodology and approach taken. These values are deeply embedded, and assumed to be universal unless explicitly questioned.

Someone who has only lived and worked in a predominantly mono-cultural environment – and therefore not questioned their own values or logic – will find this particularly challenging. The Global Dimension encourages engagement with and acknowledgement of multiple perspectives, and so helps to develop better intercultural communication. This is more likely to happen within a diverse group or setting, which is a strong argument for encouraging wider diversity amongst professional engineers. Greater diversity among engineers will also bring other benefits to engineering:

> "*Diverse workforces better understand and respond to the needs of a wide range of customers, and better interact with a broad client base. There is also growing evidence that increased workforce diversity leads to greater creativity and innovation.*" (Education for Engineering, 2013)

We will return to this issue of diversity later in this chapter.

THE EXAMPLE OF ENGINEERING FOR SUSTAINABLE DEVELOPMENT IN THE UK

In order to consider how the challenges to the Global Dimension in engineering might be overcome, it is useful to examine the related case whereby Engineering for Sustainable Development (EngSD) became an accepted part of the role of an engineer.

The history of EngSD goes back many decades and draws on a range of environmental and social movements. In 1987, the World Commission on Environment and Development published ‘Our Common Future’ (known as the ‘Brundtland Report’) which gave the following definition of sustainable development:

> “*Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.*” (Brundtland Commission, 1987)

It further went on to say:

> “*[Sustainable Development] contains within it two key concepts: the concept of needs, in particular the essential needs of the world's poor, to which overriding priority should be given; and the idea of limitations imposed by the state of technology and social organisation on the environment's ability to meet present and future needs.*” (Brundtland Commission, 1987)

This definition still resonates today, and is widely used by different groups.

In 1992 the United Nations Conference on Environment and Development held in Rio de Janeiro (the first ‘Earth Summit’) resulted in ‘Agenda 21’, which is a voluntary action agenda for international and national organisations around the world. Subsequent global meetings have updated the original document – in 1997, 2002 and most recently in 2012 when leaders from 180 countries contributed to an outcome document ‘The Future We Want’. This contains the statement:

> “*The United Nations is working with governments, civil society and other partners to shape an ambitious sustainable development framework to meet the needs of both people and planet, providing economic transformation and opportunity to lift people out of poverty, advancing social justice and protecting the environment.*” (United Nations Commission on Sustainable Development, 2012)

The United Nations General Assembly declared 2005-2014 the United Nations Decade of Education for Sustainable Development and many governments around the world commissioned work to deliver on its agenda. The response in the UK included:

- **Policy response:** The UK government's response included a report called 'Securing the Future: Delivering UK Sustainable Development Strategy' that was published in 2005, which included as a key commitment 'to support education and training in sustainable development'.
- **Academia response:** Within the British engineering community, responses included the Royal Academy of Engineering's Visiting Professor Scheme and the Higher Education Partnership for Sustainability, which raised awareness and helped to spread good practice
- **Teaching response:** One publication, called 'An Introduction to Sustainable Development in the Engineering Curriculum' (and its related Engineering Subject Centre guide), gives a more detailed insight to the development of EngSD and highlights research into its benefits. It links to many valuable resources and case studies, along with information on different approaches such as embedding EngSD within the curriculum or teaching it as a discrete topic. It identified participatory, self-directed learning as especially suitable for developing the skills and attributes needed in EngSD, again emphasising that this required the educator to adopt different approaches which put them in the role of facilitator rather than teacher (Steiner & Penlington, 2010).
- **Accreditation response:** The UK Engineering Council is the official body for certifying engineering education and professionals. Its response to these changes included a commitment for engineers to 'undertake engineering activities in a way which contributes to sustainable development' within its standards, as defined by the following principles (Engineering Council, 2013):
    - Contribute to building a sustainable society present and future.
    - Use professional and responsible judgement and take a leadership role.
    - Do more than just comply with legislation and codes.
    - Use resources efficiently and effectively.
    - Seek multiple views to sole sustainability challenges.
    - Manage risk to minimise adverse impact on people or environment.
- **Student response:** Changing expectations and awareness among young people also had an impact. Student-led initiatives such as the establishment and growth of Engineers Without Borders UK since 2001 highlighted the demand from students for international development experience, and the integration of sustainable development into their academic study.

Overall in the United Kingdom, this combination of an international focus on education for sustainable development, supported by a national policy framework, along with a series of committed academics and students was successful in bringing about changes. The key elements were political pressure, reputable research, production of good quality resources, timely initiatives, successful leadership and opportunities to share good practice. Being honest about the challenges and willing to make the most of the opportunities meant that those who were leading the changes were well placed to be able to address them, and learn from other situations. While there is still further work to be done in integrating EngSD across all academic courses and engineering practice in the UK, there exists a solid foundation for future activity.

The Global Dimension complements EngSD, and will benefit from the successes in this area, while also learning valuable lessons from its history and implementation so far.

In 2014 the international community considered the successor to the Millennium Development Goals and the list of proposed Sustainable Development Goals included:

> "*Target 4.7: By 2030 ensure all learners acquire knowledge and skills needed to promote sustainable development, including among others through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship, and appreciation of cultural diversity and of culture's contribution to sustainable development.*" (United Nations)

When the final goals are agreed in 2015, they will set the agenda for the international community for the next phase of development. Target 4.7 gives both legitimacy and context for incorporating the Global Dimension into engineering education, and a timescale to work towards. The challenge for those who believe in this vision will be to achieve it.

HOW THE GLOBAL DIMENSION SUPPORTS EXCELLENT ENGINEERING EDUCATION

In the sections above we have looked at some of the challenges for engineering education in helping engineering graduates address the key global challenges; and also the challenges and opportunities for incorporating the Global Dimension in engineering education. Together these provide the background for understanding how the Global Dimension can support excellent engineering education.

We must first identify the challenges facing engineering, and then consider how the Global Dimension can help to address these challenges. Below we will explore issues related to the supply of engineers, and secondly how those engineers fit the profile required by employers.

In many countries, successive reports into the state of engineering over a number of years have warned that the demand for graduate engineers exceeds supply and that this will have a negative impact on economic growth. Most recently from the United Kingdom:

> "*There is good econometric evidence from the Royal Academy of Engineering jobs and growth report that the demand for graduate engineers exceeds supply and the demand is pervasive across all sectors of the economy.*" (Royal Academy of Engineering, 2013)

The analysis suggests that there are a number of challenges in being able to address this issue, including how to attract, recruit and retain students to professional engineering courses, and subsequently to engineering careers. Evidence from some Western countries shows that the traditional demographic for engineers is getting smaller as a proportion of overall populations (Education for Engineering, 2013). This means that in order to meet the demand from employers, engineering education must draw from more diverse demographics in future, looking to women, members minority ethnic communities and disabled people. Given that these groups are so far under-represented in engineering, it suggests that a change in approach and profile of engineering is needed.

There is evidence that including a Global Dimension in engineering courses would make them more attractive to a wider audience. As part of the London Engineering Project, three London Universities developed a three-year degree course called 'Engineering for Society' which brought together engineering, development and environmental issues; this course attracted twice as many female applicants as traditional engineering courses (Education for Engineering, 2013). The Global Dimension as outlined above – covering global themes, emphasising 'soft' skills such as communication and holistic thinking, and explicitly highlighting a disposition supportive of social justice and driven by values – is likely to be more attractive to a non-traditional engineering demographic and so help with recruitment and retention on university courses.

Another challenge for engineering education is the changing expectations of graduate engineers by employers. In 2006, the Henley Report identified two broad areas which engineering firms look for in their employees: technical engineering skills; and social and interpersonal skills and attributes, including communication and team working skills (Henley, 2006). This builds on the statements in the Egan Review in 2004:

> "*We believe that it is the generic skills, behaviour and knowledge that will make the difference between successful delivery and failure. Skills such as the ability to create a vision, leadership to achieve buy-in to the vision, communication, team-working, project management, process re-engineering, understanding sustainable development, effective financial management, understanding the economics of development and the processes of local democracy.*" (Egan, 2004)

Including a Global Dimension in engineering education courses would support the development of these skills and dispositions among graduate engineers.

Taken together, these two ideas represent the throughput of engineering education: attracting recruits to study in the first place (supply), and providing the skilled professionals required by employers at the end of the process (demand). The Global Dimension supports both of these objectives, and will add value to engineering courses as a result.

This conclusion is further backed up by research that identified key 'learning habits of mind' which describe the ways engineers think and act (Centre for Real-World Learning & Royal Academy of Engineering, 2014), as illustrated in this diagram:

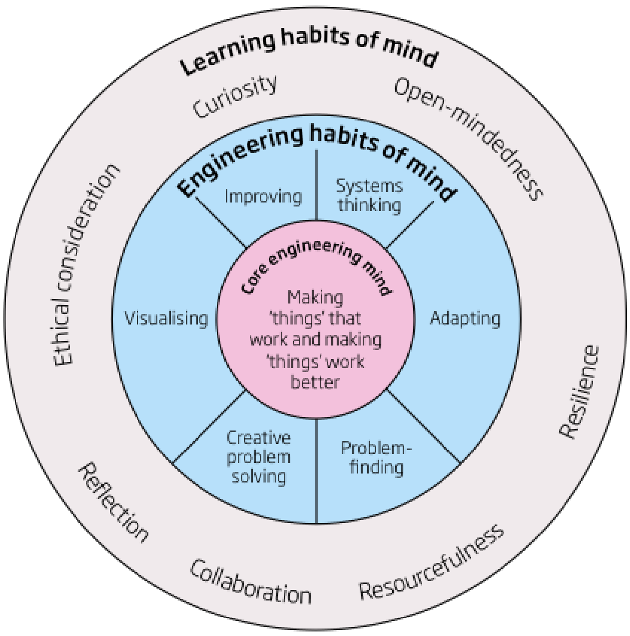

Figure 2 *Learning habits of mind and engineering habits of mind*

The report goes on to identify how these learning habits of mind can be developed using activities and pedagogies which use…

> "*… problem/project based learning with real world projects supported by employers; active learning that fosters systems thinking and engineering design; peer learning fostering collaboration… across the engineering curriculum.*" (Centre for Real-World Learning & Royal Academy of Engineering, 2014)

Providing excellent and accessible real life material could help to introduce real life situations with a Global Dimension into engineering education (such as the case studies provided by this Global Dimension in Engineering Education project). As the report goes on to argue, there are a number of implications for adopting this problem/project based learning approach in terms of the role of the teacher, pedagogical methodologies and content – many of which mirror those identified above related to the Global Dimension. It also indicates that a one-off or short-term experience is far less valuable than one which is consistently embedded across the whole learning experience. The Global Dimension is the perfect vehicle to support and develop all of these aspects, and if applied consistently throughout engineering education courses would greatly enhance the quality of education the participants received.

CONCLUSION

Engineering touches every aspect of life from basic needs such as health and nutrition, to lifestyle and quality of life. The application of engineering is essential to understanding power and influence globally, both now and in the future. Given this context, engineers are at the forefront of responding to the global challenges as set out in the Millennium Development Goals and the Sustainable Development Goals. Incorporating a Global Dimension in engineering education is not optional: it is a requirement if we want the next generation of engineers to have the necessary knowledge, skills and dispositions to respond to these challenges.

Engineering faces two key challenges: how to increase the supply of graduate engineers to meet demand; and secondly how to ensure those graduates have the necessary skills and understandings that employers want. Incorporating the Global Dimension in engineering education addresses both of these challenges. By making explicit the links with the real world – and emphasising the contribution to aspects such as social justice and poverty reduction – engineering courses will appeal to a wider demographic, and so increase the supply of graduate engineers. The Global Dimension will further support the development of attributes such as holistic thinking, intercultural communication and active learning, so addressing the needs of employers.

The Global Dimension does not stand alone within education. It builds on traditions such as human rights education, education for sustainable development, ethics and peace education. We can identify generic themes, skills and dispositions which would constitute the Global Dimension in engineering, however incorporation into engineering courses will also require a fundamental shift in course content and delivery, and include an examination of intercultural communication. This will be difficult and uncomfortable for some educators, but there are useful lessons to be learnt from examining the development and integration of Engineering for Sustainable Development over a number of years. This highlighted the roles of: international bodies in providing a framework; national government support for institutional initiatives; production of useful, high quality resources highlighting best practice and research; and academics and students willing to take on the roles of champions. The proposed Sustainable Development Goals and in particular Target 4.7 provide an international framework for the Global Dimension as an entitlement for all learners. This provides both the context and the legitimacy for embedding the Global Dimension in engineering education.

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PHOTO: Practical Action

CHAPTER 2

Mapping the Global Dimension within teaching and learning

2

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2 MAPPING THE GLOBAL DIMENSION WITHIN TEACHING AND LEARNING

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EXECUTIVE SUMMARY

This chapter attempts to map the Global Dimension of engineering within the academic setting and hence provide some pointers as to how academics can incorporate Global Dimension perspectives and capacities into engineering programmes. It takes its cue (both in terms of defining the Global Dimension and in framing the problem of Global Dimension incorporation) from the Engineers Against Poverty publication “The Global Engineer: Incorporating global skills within UK higher education of engineers” (Bourne and Neal, 2008), and proceeds to propose some possible interventions. For this reason, this chapter should be read in conjunction with the above mentioned publication, which is available online.

LEARNING OUTCOMES

After you actively engage in the learning experiences in this module, you should have developed the following:

- Capacity to map the Global Dimension onto existing educational contexts and engineering practices, including both content and the relevant regulatory frameworks.
- Awareness of specific opportunities incorporation of Global Dimension related initiatives and perspectives within teaching and research programmes.

KEY CONCEPTS

These concepts will help you better understand the content in this session:

- The mapping process; how to explicitly develop links between the Global Dimension and engineering education programmes.
- Mapping against regulatory frameworks.
- How to identify opportunities for integration of Global Dimension related perspectives and capacities into engineering education programmes.

GUIDING QUESTIONS

The guiding questions for this chapter relate to how the Global Dimension and its related perspectives and capacities can relate to and be successfully incorporated into engineering education programmes. The aim here is not to consider the Global Dimension as additional material which is simply added to an already overburdened programme in addition to 'core material'. Rather, the aim is that Global Dimension perspectives and capacities would be seen as a model or vehicle for enhancing existing engineering programmes in such a way that will enable them be both relevant and fit-for-purpose in facilitating the education of engineers for our contemporary world and society.

The approach is therefore critical of current pedagogical approaches ("*We are not equipping graduates for dealing with complexity and uncertainty.*" (Bourne and Neal, 2008)), while it views Global Dimension initiatives as being orthogonal to 'core material' so that Global Dimension issues permeate right through a programme. It does not so much require extra material, but a different perspective on how programmes are constructed and delivered. This is of course based on an understanding of engineering as a normative endeavour, i.e. that engineering has an ethical responsibility: "*the overall mission of the profession as* *contributing to human welfare*" (Colby and Sullivan, 2008). This goes against the opposing conception, which is rooted in the belief that "*the profession is 'value neutral' [and] that we are all but 'guns for hire'*" (Bucciarelli, 2008). Indeed it is this latter vision, Bucciarelli (2008) argues, which remains "*implicit in all of our teaching in the core of our disciplines*". This however, he argues is simply irresponsible of engineering educators:

> "*While teaching the 'fundamentals' of science and mathematics, and the engineering sciences remains necessary, we must do so in more authentic contexts, showing how social and political interests contribute in important ways to the forms of technologies we produce. We ought not as faculty imply as we do, that solving single answer problems or finding optimum designs alone, uncontaminated by the legitimate interests of others is what engineers do all of the time. This is irresponsible.*" (Bucciarelli, 2008)

This chapter concurs with Bucciarelli's basic thesis, as well as that of the late educationalist Paulo Frieire who reflected that "*it seems fundamental to me to clarify at the beginning that a neutral, uncommitted and apolitical education practice does not exist*" (Shaughnessy et al., 2008). This also coheres with the concept of the 'new engineer', as articulated by Sharon Beder (1998), which essentially describes an engineer who "*recognises that values and ethics pervade all engineering practice, leaves hubristic illusions of control aside and embraces context, complexity, inherent uncertainty and risk*" (Byrne and Mullally, 2014).

INTRODUCTION

The 21st Century contemporary world and society we inhabit presents a range of unprecedented interconnected meta-trends which have emerged as part of the ongoing evolution of our global (ecological, social and techno-economic) system. These include:

- Unprecedented rates of anthropogenically induced climate change
- Unprecedented levels of ecological destruction
- An anthropogenically induced Halocene extinction event, culminating in the current elevated levels of species extinction rate
- Unprecedented human global population
- Unprecedented levels of (absolute and per capita) human consumption rates and appropriation of materials and energy
- Access to unprecedented scientific knowledge and capacity
- Unprecedented levels of technological ascendancy, complexity, prowess and technological encroachment on people's lives
- Unprecedented levels of human connectedness at the global level and an increasingly globalised world
- Unprecedented levels of disconnect and isolation between humans/human society and our environment/the natural world

Added to these is an economic system characterised by boom-bust cycles which both requires continual economic growth to maintain itself and which tends to promote increasing levels of wealth concentration and economic inequality (Jackson, 2009). Such a system is unsustainable (Morgan, 2013). In addition, there are associated significant health and social problems globally such as elevated levels of unemployment, anxiety, isolation, violence, depression and issues associated with unprecedented levels of obesity.

These issues, it has been argued, represent symptoms which are the inevitable culmination of a modern conception of progress which envisions progress as a linear determinate pathway towards increased ascendancy, complexity, control and certainty (Wright, 2005; Ehrenfeld, 2008; Ulanowicz, 2009; Kauffman, 2010, Ehrenfeld and Hoffman, 2013). Regardless of how one envisages the diagnosis, the issues outlined above are very real and will impact greatly upon the professional and personal lives of engineers practicing through the 21st Century as well as that of society and our world more generally. It therefore behoves the community of engineering educators and associated stakeholders to seriously consider how these issues should impact on, and influence the education of contemporary engineers so as to enable them to be fit-for-purpose in understanding and addressing these interconnected issues. Introducing a Global Dimension to engineering education can help facilitate this.

INTRODUCTION TO INTEGRATION OF THE GLOBAL DIMENSION INTO PROGRAMMES

Bourne and Neal (2008) in their Global Engineer publication make the argument that:

> "*Higher education needs to prepare engineers of the future with the skills and knowhow 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.*"

They also state that within the Education for Sustainable Development (EngSD) realm, the focus has traditionally been on "*environmental rather than social and political dimensions*", which is a claim substantiated by the leaders in the field of Engineering Education for Sustainable Development (EESD) (Segalàs et al, 2012; Desha and Hargroves, 2014).

Conlon (2008) expresses concern that an overly instrumentalist and technological approach taken by engineering at the expense of broader humanitarian and social issues not only does reputational damage to the profession but also helps facilitate continued gender imbalance in the profession, and suggest that "*to attract women, the humanitarian role of engineering should be highlighted including the role of engineering in promoting sustainable development*".

This appears to be backed up by research, such as for example evidence that female engineers are particularly attracted to a profession which can enable them "*make a [positive] difference to the world*" (Alpay et al, 2008) as well as to programmes which are "*more interdisciplinary, contextualised*" and which require "*a complex understanding of technological knowledge and student-centred learning*" (Du and Kolmos, 2009). This points to a need for a broader self-perception of the engineer as one which will not just provide instrumental 'value free' design and analysis, but as Bourne and Neal (2008) put it, are also adept at "*recognising the contribution engineering can make to securing economic and social change*".

This in turn raises a couple of key questions:

- How, for example, might engineers be equipped to understand the context that surrounds their practice?
- If engineers are to be part of a process of socio-economic economic change (as opposed to playing a disinterested technocratic role) then in what direction should this be directed?

There is general consensus around the answers to these questions, certainly among Global Dimension and EngSD education practitioners and researchers. In response to the first question, Bourne and Neal (2008) contend that ‘global skills’ incorporate competencies in areas 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*”. Furthermore, they identify the following Global Dimension related concepts:

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

Bourne and Neal (2008) then proceed to cite the “*framework for the global dimension within the engineering profession*” under three generic headings: Themes, Skills and Dispositions (see Table 3 in Chapter 1).

Drawing from an earlier publication by the Development Education Association (McCollum and Bourne, 2001), Bourne and Neal (2008) point out that the upshot of all this is that for them to be effectual, ‘global skills’ must include “*essential skills in critical engagement*”, which means that their “*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*”, and this demands “*fundamental shifts in course content and delivery*”. This means they propose, that (engineering) graduates must be educated to recognise (and consequently handle):

- 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.

To accomplish this, Bourne and Neal (2008) propose the following four perspectives and approaches within the context of engineering education:

- A futures perspective.
- A business case (recognising the social role of business in the 21st Century and corporate social responsibility).

- A critical perspective (recognising engineers actions have social consequences and equipping graduates to recognise and handle complexity and uncertainty).
- A whole systems approach (recognises the interconnectedness of actions; social and economic).

These perspectives can be represented by a worldview which aligns with the concept of the new engineer (Beder, 1998), and more broadly with what other conceptions of reality such as ‘complexity thought’ (Morin, 2008), ‘new era thinking’ (Gidley, 2013) and approaches to transdisciplinarity (Nicolescu, 2008). It is also informed by well-established approaches to science and reality including the concepts of post-normal science (Funtowicz and Ravetz, 1993), mode II science (Gibbons et al, 1994), wicked problems (Rittel and Webber, 1973), integral and postformal studies (Gidley, 2013), the ‘new science of complexity’ (Jörg, 2011), the ‘end of certainty’ (Prigogine, 1997) and a ‘third window’ on the world (Ulanowicz, 2009).

Embracing the above approaches, including developing futures, critical and whole systems approaches, facilitates the comprehensive formulation of an answer to the second question regarding what direction engineering practice should take. This is an unapologetically normative construction of the engineer as one who is a co-creating participatory agent for positive change (alongside fellow professionals, other disciplinary experts, stakeholders and publics alike); an engineer who is working towards a progressive society and world where we collectively steer away from the unprecedented mega-trends discussed earlier, which can, in this context, be regarded as mere representations of the interconnected symptoms of an unsustainable societal construct.

The upshot is a radically transformative way not simply of ‘doing’ engineering but of fundamentally ‘viewing’ it (Byrne & Fitzpatrick, 2009), consistent with “*a new Enlightenment, to redefine our notion of progress*” (ICEE, 2007). Academically, in terms of programme construction and delivery, it requires that programmes incorporate the Global Dimension and its accompanying ethic throughout. As Bucciarelli (2008) argues:

> “*If we, as engineering faculty, still claim that it is our job and responsibility to teach ‘the fundamentals’, it’s time explicitly to recognise that what is fundamental to engineering practice goes beyond scientific, instrumental rationality; I hold that failure to acknowledge this fact is ‘just about unethical’*.”

DEVELOPING LINKS BETWEEN GLOBAL DIMENSION PERSPECTIVES AND CAPACITIES IN ENGINEERING PROGRAMMES

There is strong overlap between Global Dimension related perspectives and capacities in engineering programmes (Bourne and Neal, 2008) and those articulated in the EngSD literature (Lourdel et al, 2007, Segalàs et al, 2010; Byrne et al, 2013). Thus the model proposed by Bourne and Neal (2008) in relation to the application of Global Dimension to engineering education (as outlined above) is adopted here.

One modification here though is that the order of the four perspectives is changed: it is deemed that three of the perspectives are fundamental (and deeply interconnected): the critical perspective; the whole systems approach, and; the futures perspective. Meanwhile the business case emerges as a practical and pragmatic approach which requires the previous three perspectives to be successful.

Each of the perspectives are discussed and elaborated upon in Bourne and Neal (2008; pp. 6-8) and so won't be repeated here. However, the business case is revealed as problematic as constituted within the framework because it does not, generally in practice, either recognise or act consistently with the other three perspectives.

For example, Bourne and Neal (2008) point out that "*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*" including:

- Investment in oil, gas and mining with over $600bn projected expenditure over the next 10 years in Africa alone.
- Opportunities arising from the global application of emerging computing, energy, nano- and bio-science technologies.

Developments in the fields of fossil fuel and mineral resource exploitation and the application of emerging technologies do not, of course, proceed within a technological vacuum or closed system. In fact, the technological aspects (particularly for engineers) typically represent the easy part to solve for any larger problem!

The reality is that technological innovation and resource exploitation do not simply proceed along one way streets, leading to progress through realising simple end game 'solutions' (in the guises of GDP increase, economic growth and 'lifting all boats') that act as all-round unproblematic goods. Questions of power, decision making processes, rights of local and indigenous communities, patchy environmental laws and their enforcement – if considered and viewed from Global Dimension perspectives – may lead to alternative framings and possible outcomes (including ruling out or constraining the techno-economic developments).

Example of a Global Dimension change in perspective: global food supply and demand

Engineers play a key role at many levels and stages in the production of food. The dominant narrative dictates that – with a global population growing and predicted to reach 8 to 10 billion by 2050 – food production will need to increase by about 70% by 2050 (FAO, 2009). This would be done courtesy of a (techno-optimistic) projection of the green revolution, employing a number of productivist measures.

These measures would include raising the efficiency of production (e.g. "*yield improvements, adoption of improved production technologies, including improved seed varieties*" (G8 New Alliance for Food Security, 2012)) and related technological initiatives (including biotechnology, genetic modification, agrochemicals, irrigation, synthetic fertilisers, etc.), along with increased land use and instruments such as liberalised international trade and economies of scale (moving from small subsistence family producers towards agricultural industrialisation). The 'value free' conception of engineering education uncritically adopts the values and ideology inherent in this dominant worldview.

A Global Dimension infused engineering education – which requires the three perspectives of critical thinking, whole systems and the futures perspective – would on the other hand, find this simple 'solution' problematic on a number of levels. The fundamental shortcomings and deeply problematic nature of this approach have been widely articulated (Sage, 2012; Action Aid, 2014; McKeon, 2014) and a number of these are highlighted in Table 1 in terms of the three Global Dimension perspectives.

But we can go further. Elaborating on the point made in Table 1 about the additional energy gained from organic and more labour-intensive modes of agriculture ('pre-industrial') compared with wholly productivist approaches in the production of rice, Table 2 is based on data presented in Ho and Ulanowicz (2005). It shows that, in fact, the ratio of energy output-to-input is far higher in the 'pre-industrial' model. It also shows that similar (and even higher) differences between total energy of agricultural inputs and outputs can be just as good as (and in some cases better) with low intensive methods. Indeed, they conclude that "*there seems to be a plateau of output per hectare around 70–80 GJ regardless of the total input*" (Ho & Ulanowicz, 2005).

An understanding of the Global Dimension perspectives would have caused engineers to raise these questions and to recognise these traditional solutions.

Table 1 *Using Global Dimension perspectives to critique dominant approach to problem of feeding the world.*

Global Dimension Perspective	**Critique the dominant approach to global food problem:** ***"A third more mouths to feed [yet] food production will have to increase by 70%"* (FAO, 2009)**
Critical perspective (recognising social consequences, complexity and uncertainty)	• Inequality is the main driver behind global hunger and food insecurity, not food production or population; there is ample food in the world to feed everybody, even with a larger population; problems of obesity and under nutrition mirror each other globally. • Fails to address problem of (hugely resource intensive) meat production as well as animal welfare issues around intensive agriculture; assumes increased per capita consumption of meat, whereas a reduction would help mitigate problems. • Increased uncertainty and reduced resilience as a result of a globalised productivist model of food production with ever longer and more efficient supply chains. • Most critically, the productivist model fails to recognise finite global limits of land and (material and energy) resources.

Whole systems approach
 	
(recognising interconnectedness)
	• A worldview characterised by reduction and separation ignores or plays down the reality of a multitude of deeply interconnected features which impact on production and consumption levels, and which are exacerbated by an intensive agricultural model 'solution' e.g.
	    • climate change (and associated increase in extreme weather events)
	    • water availability and stresses
	    • energy security and availability
	    • environmental degradation (freshwater resources, desertification, deforestation, soil fertility) and biodiversity loss
	    • monoculture agriculture
	    • effects of overfishing on marine biodiversity (Worm et al, 2006)
	    • corporatisation and rural/agrarian unemployment
	    • transnational and multinational land grabs within a globalised framework alongside displacement of indigenous rights and increased concentration of power and wealth, fuelling increased inequality
	    • disempowering consequences of corporatisation and control of agricultural inputs e.g. through pushing the spread of genetically modified seeds
	    • replacing family farm units with low paid (often migrant) farm workers
	    • social disruption due to reduced viability of small farmholdings (unemployment, depression, suicide)
	• The additional energy provided by food produced from a productivist model of intensive agriculture which employs large energy inputs (e.g. high technology, synthetic fertiliser and pesticides) is no greater than the additional energy provided by low intensive (e.g. more labour intensive, organic fertiliser) cyclical whole system approaches (Ho and Ulanowicz, 2005), though the former results in increased soil depletion and environmental degradation, as well as greater social alienation and unemployment. Moreover, monoculture crop

	models promote increased soil depletion and reduce productivity (Ho & Ulanowicz, 2005). • Would support adopting policy supports for food production methods such as family farm units, organic farming, urban agriculture, grow it yourself, cooperative models of production and distribution/sales, small local retailers and markets as well as support for consumption patterns such as unprocessed, locally produced and vegetarian options. • A circular economy which coheres with social and ecological cycles requires an alternative economics to the linear 'boom-bust' classical model which requires perpetual growth to avoid economic and social hardship (Jackson, 2009; Morgan, 2013; Barry, 2013; Alexander, 2014). Consideration of this, the nature of such a model and its implications for practice may be considered.
Futures perspective	• Economic growth is associated with dietary change, including higher consumption of meat and processed food, as well as rising obesity levels and associated health issues. • Potential for mass social unrest and war fuelled by a growth based intensification model within a finite global (land, material and energy) limits, as these limits (e.g. water, land, energy) are stretched and passed.
Business role	• Taking on board all the above, the case may be made for an alternative business (and perhaps economic) model to emerge; perhaps one based on small localised enterprises within a planetary whole, with an increased respect for the artisan over the mass produced, a transformative shift from the profit and shareholder/share price/quarterly performance driver to a longer term ethos which values the long term sustainability of the enterprise through rooting it in the locality, with local suppliers and customers, empowerment and profit sharing among staff and a recognition of the primacy for care of social and environmental factors. • Engineers may also reflect on and critique the ethical implications of current business and economic constructs, and on their own future career paths and potential contributions.

Table 2 *Comparing energy flow of high and low intensive models of agricultural production* (data from Ulanowicz and Ho, 2006).

Rice fields	# Studies	Fossil fuel input (%)	Human input (%)	Energy Output / Input	Output-Input (per hectare) GJ
'Pre industrial'	8	2-4	35-78	6.9-29.2	2.4-166.9
'Semi industrial'	10	23-93	4-46	2.1-9.7	51.75
'Full industrial'	7	95	0.04-0.2	>~1	65.66

As this example shows, an engineering education which views the profession as ‘value free’ and education in general as ‘neutral, uncommitted and apolitical’ will choose to construct a sanitised (though incomplete and wholly inadequate) version of reality, which excludes all but the utilitarian and narrow ‘scientific’ aspects.

This is essentially an exercise in reductionism par excellence, the ultimate consequence of Cartesian dualism from which has emanated our modern and contemporary ‘age of separation’ (Eisenstein, 2011). It is an ultimately unsustainable and inadequate (world) view of reality based upon reduction and separation/disjunction (Morin, 2008).

A Global Dimension approach, by contrast, would seek to encourage students – with both increased intellectual honesty and reduced hubris – to embrace the messy complexity and indeterminacy that is part of facilitating a better understating of reality, and to competently deal with emergent issues. This requires recognising and considering the underlying context and values that are always part of real world engineering practice.

MAPPING ENGINEERING AGAINST AND ACROSS CONTEMPORARY ISSUES

Bourne and Neal (2008) suggest that in an independent review of strategic global trends to 2036, the UK Government concludes that human activity will be dominated by three pervasive 'ring road' issues which will define contemporary society globally: climate change, inequality and globalisation. These issues frame the environmental, economic and social pillars of sustainable development. In their report on the global engineer, Bourne and Neal (2008) proceed to map out many of the relationships in terms of linkages and impacts between each of these three macro-societal issues and engineering (practice). The useful linkages and impacts matrix that they constructed is reproduced as Table 3.

Bourne and Neal (2008) recognise the interconnected and inherently complex nature of each of the issues as they identify the co-evolutionary nature of each of the respective pillars through binary feedback or causality loops. For example, engineering can impact on poverty through "*providing pro-poor energy, transport, shelter, health and water products*", while poverty impacts on engineering through its requirement for "*low cost solutions that are appropriate to cultural, political, social and economic environment*".

In Table 3, the respective impacts are generally presented in a positive manner as (self-rectifying and largely unproblematic) negative feedback loops. In addition, there is no commentary or proviso presented.

This however is problematic as the table presents a largely idealised version of reality. For example, in reality the current dominant societal model underpins an economics that shows no propensity to produce 'pro-poor' products. (Quite the opposite in fact, as the only products that are promoted are 'pro-market'.) Likewise, in places where widespread and endemic poverty are prevalent – such as throughout much of the global south – this may indeed lead to low-cost (and comparatively low-tech) engineering solutions being chosen where relevant. However this is not the case in ostensibly wealthy parts of the world where there are very high levels of societal inequality. In these places high-cost, high-tech options are generally available to society, though these are unaffordable to those affected by poverty. A closer examination of Table 3 thus facilitates the raising of questions about the problematic nature of these linkages.

In general, a more thorough and critical examination of proposed linkages and impacts in Table 3 can serve to demonstrate how critical, whole systems and futures thinking can lead to alternative conceptions of reality (rather than uncritically accepting the dominant largely unproblematic narrative). It can help develop a broader and radically improved understanding of our interconnected (social, technological, economic, environmental) reality and thus may help reduce risk of system failure, and improve resilience and sustainability.

Table 3 *Mapping three 'ring road' issues with engineering* (taken directly from Bourn and Neal, 2008).

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**

Case study: Globalisation as problematic; alternative visions

A critical, whole systems and futures thinking perspective can also highlight the problematic nature of the phenomenon of market-driven globalisation. Exploration of problematic nature of globalisation as it is currently conceived and practiced and its linkages and impacts on the issues of poverty and climate change respectively – and how these can in turn relate to engineering practice – can yield potentially productive learning opportunities, particularly in terms of developing critical, futures and whole systems thinking skills among engineering students (see, for example, the proposed activity for this chapter).

While Table 3 makes the bold claim that "*sustainability and climate change will force a revised model of engineering and globalisation*", this is a questionable claim – particularly unless a critical approach is taken by the engineering profession as well as by society at large. Indeed the dominant perspective would hold that globalisation is a largely unproblematic good, and (as is claimed in Table 3) fuels "*engineering knowledge and innovation especially in transport, energy, manufacturing and ICT*" which are iteratively "*the drivers behind economic integration and globalisation*" and thus global economic growth.

Again this positive and largely unproblematic framing neglects to critically assess the social and ecological degradation that such a dynamic brings, the centralised ascendant concentration of power and wealth, as well as the ever-longer and more efficient global supply chains that facilitate separation of producers from consumers. While globalisation (as it is currently constituted) results in the emergence of new types of jobs, these are often of a lower paid or less secure nature, and often involve displacement to locations where social and environmental protections are weak and/or laws are poorly enforced. This benefits neither citizens of the north nor south.

Moreover, the overall result is the displacement of human jobs by technology. Given that the energy inherent in one barrel oil is equal to approximately ten years human labour, the economic 'value set' which dictates that human labour is worth several orders of magnitude less than oil means that the system is blind to the physical reality of material and energy limits necessary for sustainable long term flourishing of human society and its environment. MIT chemical engineering emeritus professor John Ehrenfeld (2014) identifies the intersection between the effects of globalisation and the importance of critical thinking (and a concomitant comfort with inherent uncertainty and indeterminacy) to engineers:

> "*You may say 'Why are your children being less exposed to critical thinking by the growing emphasis on the so-called STEM curriculum (science, technology, engineering and math)'… These are the very subjects that are assumed to be the basis of the improvements in efficiency that will cost some of these very students their jobs in the future. When that happens and someone says to them 'Sorry, but it's a fact of life that with more efficiency comes fewer jobs' they will not have the tools to dig down to discover the arbitrariness behind that 'truth'. And without that ability, they can do very little about the quality of their lives. Vaclav Havel, the intellectual liberator and President of Czechoslovakia, wrote 'Keep the company of those who seek the truth, and run from those who have found it'.*"

Picking up on the wisdom of Havel, the former Czech leader suggested that "*the time has come for people who feel a responsibility for the future of humankind on this planet*" to envision a globalisation of a different type, namely a "*globalisation of good*" (Havel, 2001). This would displace the emerging globalisation of ascendancy and control that marked both the failed totalitarian reductionist ideology of 20th Century communism as well as the analogous, and similarly flawed, totalitarianism that an ideology of globalised unfettered markets creates. Both seek to deny the humanity through control and the reification of an empty materialism (Havel, 2004):

> "*I believe that every kind of centralisation is dangerous... it is quite possible that some of us will live in countries where the gross domestic product is growing by leaps and bounds, where everything is flourishing, the superstores are full of goods, the roads are teeming with lorries, energy is getting cheaper all the time, there is more and more construction, more and more industrial zones, bigger and bigger multiplexes, and more and more persuasive advertisements assail us from all sides – and yet everything is somehow dull, desolate, empty, soulless, ugly and, in spite of its pretence of diversity, infinitely uniform. And people are more and more nervous, disenchanted, lonely and sad.*"

Havel summed up his alternative vision as follows (Havel, 2001a):

> "*It seems to me that the global world which we are entering - the globe enveloped in one single interconnected civilisation - must grow from mutual respect for various identities, various cultures and various instances of otherness and from a commitment to the principle of equality of all these cultures.*"

This 'globalisation of good' has been articulated by others under different formulations including as the new 'planetary première' involving emerging efforts "*by those who are in the process of constructing a future of solidarity and sustainability*" as a counterbalance to the 'Men of Davos' (Petrella et al, 2000). Earlier echoes are obvious in Teilhard de Chardin's original concept of 'planetisation' – one based on the emergence of an unprecedented global human consciousness or 'noosphere' i.e. the "*thinking envelope of the Earth*" in the wake of unparalleled interconnectedness and complexity on our finite planet (Chardin, 1959). These developments are often posited around the process of human self-realisation and our place within a larger emergent 'big history' of cosmic evolution (Chaisson, 2009). The related socio-geologic terms of 'anthropocene' (Crutzen and Stoermer, 2000; Crutzen, 2002), 'Gaia' (Lovelock, 2007) and of the unified planetary consciousness inherent in 'homeland earth' (Morin, 1999) serves to reflect our recent self-awareness as interpenetrating and interdependent collaborators in global socio-environmental change.

MAPPING AGAINST REGULATORY FRAMEWORKS

Bourne and Neal (2008, p.16) proposed a five-stage framework for embedding the Global Dimension in engineering programmes. The following steps are proposed for academics and course leaders interested in embedding the Global Dimension into their programmes:

- **Stage 1:** Develop their own understanding of the Global Dimension of engineering by mapping the issues and skills which have a Global Dimension 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 accreditation-required 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.

Stages 1-3 are complemented by tables in Bourne and Neal (2008, pp.16-18).

Stage 2 involves a mapping exercise whereby facets of the Global Dimension are mapped against the UK SPEC learning outcome requirements (the formal requirements for professional accreditation of programmes by UK engineering bodies). The applicable learning outcomes used were from the then applicable requirements.

A more recent edition of the requirements published in 2014 (UK SPEC 2014) had the effect of strengthening many of the Global Dimension attributes (such as the ethical dimension and critical thinking) (Engineering Council, 2014). This follows a trend that has been common to engineering accreditation guidelines globally over the past few decades (Byrne et al., 2012). Table 4 maps the required learning outcomes for an Integrated Masters (MEng) degree programme (UK SPEC, 2014) against the relevant aspects that the Global Dimension can enhance. In total, a comprehensive application of Global Dimension perspectives and capacities can potentially facilitate the accomplishment of *over half* the total number of UK-SPEC learning outcome requirements (Table 4 includes 24 of 42 learning outcome areas).

Table 4 *Mapping the linkages between the UK SPEC learning outcomes for engineering courses* (3rd ed., 2014) *and the Global Dimension of engineering education*.

Science and mathematics	
Understanding of concepts from a range of areas including some outside engineering, and the ability to evaluate them critically and to apply them effectively in engineering projects.	The Global Dimension is essential to help develop critical thinking and helps facilitate contextualisation of engineering practice, including understanding areas outside traditional narrow engineering competences and working with people from various backgrounds.
Engineering analysis	
Understanding of engineering principles and the ability to apply them to undertake critical analysis of key engineering processes.	The Global Dimension is essential to help develop critical thinking and apply critical analysis throughout and across engineering practice.
Understanding of, and the ability to apply, an integrated or systems approach to solving complex engineering problems.	Systems thinking and its resultant approaches 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.
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.
Design	
Understand and evaluate business, customer and user needs, including considerations such as the wider engineering context, public perception and aesthetics.	Global case studies illustrate the importance and challenges of identifying end-user needs in unfamiliar contexts as well as the wider engineering and societal context.
Investigate and define the problem, identifying any constraints including environmental and sustainability limitations; ethical, health, safety, security and risk issues; intellectual property; codes of practice, standards.	The Global Dimension promotes understanding of relevant constraints, their complexity and how they vary according to the local context including environmental and sustainability issues; ethical, health, safety, security, risk and intellectual property issues, as well as appropriate implementation of relevant codes of practice and standards.
Work with information that may be incomplete or uncertain, quantify the effect of this on the design and, where appropriate, use theory or experimental research to mitigate deficiencies.	The Global Dimension is essential to help understanding of the nature of incomplete information and uncertainty and how to address it appropriately.

Apply advanced problem-solving skills, technical knowledge and understanding to establish rigorous and creative solutions that are fit for purpose for all aspects of the problem including production, operation, maintenance and disposal.	Ensuring that all aspects of sustainability (including production, operation, maintenance and disposal) are built into problem solving is a key aspect of the Global Dimension as is creativity.
Communicate their work to technical and non-technical audiences.	The Global Dimension helps facilitate and realise the necessity for two-way communication with a broad range of stakeholders in the work of the engineer, both technical and non-technical.
Demonstrate the ability to generate an innovative design for products, systems, components or processes to fulfil new needs.	Opportunity to show the importance of creativity and innovation in addressing global challenges and adapting solutions, including via appropriate (product, system, component, process) design, in particular to a developing country context.
Economic, legal, social, ethical and environmental context	
Understanding of the need for a high level of professional and ethical conduct in engineering, a knowledge of professional codes of conduct and how ethical dilemmas can arise.	The Global Dimension is essential in helping to understand the fundamental importance of ethics and values that underpins all engineering practice.
Knowledge and understanding of the commercial, economic and social context of engineering processes.	The Global Dimension can facilitate an understanding of the social context of engineering practice as well as providing the 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.
Knowledge and understanding of management techniques, including project and change management that may be used to achieve engineering objectives, their limitations and how they may be applied appropriately.	Management techniques and 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 and ability to apply quantitative techniques where appropriate.	The Global Dimension is essential to fully understand the contribution of engineering to issues of sustainability and sustainable development.
Awareness of relevant legal requirements governing engineering activities, including personnel, health & safety, contracts, intellectual property rights, product safety and liability issues, and an awareness that these may differ internationally.	The legal framework and its enforcement differs greatly between countries and sectors. Global examples can help illustrate this.

Knowledge and understanding of risk issues, including health & safety, environmental and commercial risk, risk assessment and risk management techniques and an ability to evaluate commercial risk.	The Global Dimension is essential to help understanding of the nature of risk and uncertainty and how to address it appropriately.
Engineering practice	
Understanding of contexts in which engineering knowledge can be applied (eg operations and management, application and development of technology, etc) .	The Global Dimension is essential to help facilitate critical contextualisation of engineering practice and in considering the relationships between development of technology and broader social issues and implications.
Understanding of appropriate codes of practice and industry standards.	Global case studies will illustrate how codes of practice and industry standards vary internationally.
Ability to work with technical uncertainty.	The Global Dimension is essential to help understanding of the nature of uncertainty including technical uncertainty and how best to incorporate this into context appropriate practice in various situations and locations.
A thorough understanding of current practice and its limitations, and some appreciation of likely new developments.	The Global Dimension emphasises the need to adapt and modify approaches in unfamiliar situations and to value new approaches and perspectives as well as to understand the context and drivers around current practice.
Understanding of different roles within an engineering team and the ability to exercise initiative and personal responsibility, which may be as a team member or leader.	The Global Dimension can be woven into project and design work, including within different roles through local, national and international volunteering and work placements with international engineering companies.
Additional general skills	
Apply their skills in problem solving, communication, working with others, information retrieval and the effective use of general IT facilities.	Design and research projects especially multi-discipline and team based exercises present excellent opportunities to incorporate the Global Dimension and develop these transferable skills.
Plan self-learning and improve performance, as the foundation for lifelong learning/CPD.	The Global Dimension facilitates the development of a lifelong learning approach to education, and to the development of lifelong/CPD skills and attributes such as critical thinking, understanding and dealing with uncertainty and risk, valuing and integrating knowledge from different sources and team working and communication skills.
Exercise initiative and personal responsibility, which may be as a team member or leader.	The Global Dimension facilitates the development of team-working, communication and leadership skills in the context of an uncertain and diverse global world.

Of course the Global Dimension can be mapped against other national or professional organisations accreditation/learning outcomes requirements. It can also be mapped against, for example, the UK Higher Education Academy's 'Aspects of Employability' criteria for graduates (Yorke and Knight, 2006; Byrne, 2012). In each case, to a greater or lesser extent, there is a requirement to incorporate some degree of competency in issues relating to the Global Dimension such as handling uncertainty and complexity, employing critical thinking, sustainability and ethics. (Byrne et al, 2010).

OPPORTUNITIES TO INTEGRATE GLOBAL DIMENSION IN ENGINEERING EDUCATION

Stage 3 of the five-stage framework of Bourne and Neal (2008) presents opportunities for the integration of the Global Dimension in engineering education. This is shown in Table 5.

Table 5 *Opportunities to embed the Global Dimension* (Stage 3, Bourne and Neal, 2008).

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-curricular 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

The following initiatives and interventions in the curriculum are proposed in the context of the generic themes, skills and dispositions associated with the Global Dimension (as outlined in the introduction) as well as the corresponding four Global Dimension perspectives (of critical, whole systems, futures and business). These are by no means exhaustive nor definitive but simply represent a range of the types of initiatives that can facilitate the development of a fit-for-purpose accredited programme through the provision of Global Dimension perspectives and capacities. Many of the particular initiatives cited here represent some tried-and-tested approaches used by the author in his teaching as a means of attempting to develop Global Dimension perspectives among students. However the type and number of appropriate initiatives for incorporating Global Dimension perspectives are bounded only by imagination.

Support and encourage relevant curricular and extra-curricular global activities

The Global Dimension can be incorporated explicitly into programmes through the formal inclusion of projects, assignments, field trips, exchanges, communication link ups, etc, which deal directly with global and international issues (and in particular those relating to developing countries). These can be facilitated in association with local Engineers Without Borders groups and the wider Engineers Without Borders community. Formal programme-based initiatives can be supplemented by informal and extra-curricular activities through local Engineers Without Borders groups, which are often student led.

Active learning

A Global Dimension ethos incorporates ways of learning that facilitate active engagement. Among the Global Dimension generic skills listed by Bourne and Neal (2008) are "*active learning and practical application*". An approach to teaching which facilitates and encourages active learning can also facilitate the development of other Global Dimension related generic skills such as "*holistic thinking, critical enquiry, analysis and reflection*" (Bourne and Neal, 2008). There are many examples of active learning techniques available in the engineering education literature such as, for example, those proposed by Richard Felder (Felder and Brent, 2003, 2009; Bullard and Felder, 2007)

Problem Based Learning

Problem Based Learning is a popular and effective means of facilitating student engagement through some hands-on practical learning and is particularly suited to being employed as a means of explicitly incorporating elements of the Global Dimension (Lehmann et al, 2008; Du and Kolmos, 2009; Guerra and Holgaard, 2013).

Peer learning (Example 1)

Peer learning is a form of active learning which helps empower students with their own learning and facilitates cooperative and collaborative approaches to student learning. It can be facilitated through a wide range of techniques and formats. The physicist Eric Mazur is a proponent of an effective form of classroom based interactive peer learning involving clickers (Mazur, 1997; 2009). This can also be employed just as effectively on a more low tech easy to use basis by employing laminated coloured 'flashcards' (Lasry, 2008). It works by incorporating a series of overhead slides during the designated lecture session (as an alternative to the 'traditional' lecture). Each slide includes a question as well as four (judiciously chosen) possible multiple choice answers (see Figure 1).

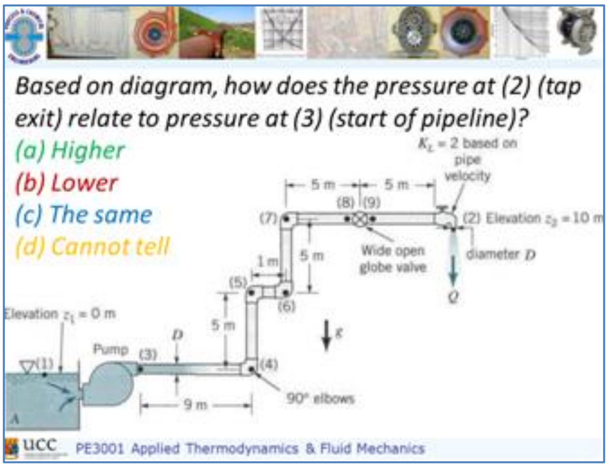

Figure 1 *Multiple choice question used to facilitate active and peer learning*

Students are then invited to individually reflect on the question and its possible answers before 'voting' on their chosen answer by selecting their choice either via a remote hand held clicker device or by holding up their coloured cards. If virtually all select the correct response the lecturer briefly discusses the item before quickly moving on to the next topic/slide. If however, there is a range of responses, students are asked to find a colleague sitting close or adjacent to them who has selected a different option, and to then confer/discuss/argue/debate the problem with them. After conferring, they are then asked to vote again. In many instances students tend to converge around the correct answer (Mazur, 1997).

However, and most importantly, each student will have reflected upon, actively engaged with and ultimately developed a better understanding of the topic at hand. Mazur makes a convincing argument that suggests that evangelical students learn better directly from each other (peer learning) i.e. from a fellow student who has just engaged with and developed an understanding of the topic from the first time, rather than from a professor (perhaps over twice their age and who is less able to envisage the difficulties and potential mental roadblocks surrounding learning some new concept).

In the experience of the author, this approach is much appreciated by students. On a fluid mechanics module that it was employed on, some 86% of respondents agreed that the approach of the lecturer in facilitating learning was 'excellent' while a similar proportion agreed that the stimulation to their thinking provided by the lecturer for this module was 'excellent'. The following is typical of the qualitative feedback received on the initiative: "*The* *approach taken by the lecturer e.g. coloured flash cards and engaging the students to think about and answer questions rather than reciting notes, like most lecturers, is very effective*".

The approach moreover can equally be used on either deterministic technical subjects or more open ended and qualitative subjects, such as sustainability and ethics for example, as a useful means of promoting active student engagement and in developing critical thinking.

Peer learning (Example 2)

Another example of peer learning which also helps develop critical thinking skills might involve group assignments requiring, for example, a design exercise such as the design of a biopharmaceutical facility involving process and chemical engineers. The design exercise might require the compilation and submission of a formal report. The lecturer takes the submitted reports and redistributes then among the various project groups, asking each group to critique the report they have received with a 1-2 page assessment. A week later, having forwarded their completed critiques to the lecturer, the respective design groups are then required to make a synopsis presentation on their respective designs to all of their peers and the lecturer in a formal setting. Following each presentation, the critiquing group are invited to question the presenters (in 'Dragon's Den' style) drawing from their short critique document as well as from the presentation just given. The lecturer then grades each component of the exercise (including the design report, critique, presentation, and how each group addresses questions from their peers). From experience and feedback, this works very well among students who acknowledge that the process really helps them engage with the material and develop their critical thinking skills through the respective modules.

Wicked problems

The term 'wicked problems' was coined in a seminal paper by Horst Rittel and Melvin Webber (Rittel and Webber, 1973). It relates to complex and messy real-world problems to which not only is there no definitive nor determinate 'solution', but whose very framing is contested; there can be wide disagreement on what the problem actually is.

They thus summarise that "*it makes no sense to talk about 'optimal solutions*" and indeed "*there are no 'solutions' in the sense of definitive and objective answers*". Nor can there be any a-priori test to the 'solution' to a wicked problem, except through a pragmatic approach where options are tried and experiential knowledge is gained.

Wicked problems therefore go beyond purely technical problems with defined and closed system boundaries; they involve some societal aspect or interaction with people. Values and ethics are inherent in describing and in tackling such problems. Socio-economic and policy/value based approaches are inevitably required in addressing wicked problems alongside any technical or technological initiatives. Resolutions of wicked problems thus never come from simple answers or simple thinking.

Assignments can be set up and framed as bespoke wicked problems, as part of for example, ethics or sustainability related modules (Byrne, 2012a, Byrne and Mullally, 2014). Alternatively, the wicked nature of broader design considerations can be emphasised for the final year capstone design project (and incorporated in the framing and grading of assessment descriptions) to enable and encourage students to frame the design problems beyond narrow (largely black-and-white) technical limits. This helps to contextualise and posit the design in the real world; to incorporate messy social, ethical and environmental considerations.

Inter- and trans-disciplinary projects

Inter- and trans-disciplinary interactions and projects can act as very useful platforms for developing Global Dimension perspectives and capacities. For example, one initiative undertaken by the author has involved working with an academic colleague in sociology to facilitate the bringing together of two groups of students from different modules (though each is in the area of sustainability) for a number of collaborative workshops. This involved watching a documentary (which critically reflects on issues of social and ecological degradation in the global south as a result of interventions from the global north, as a consequence of the market driven model of globalisation) as well as a number of sessions whereby students were matched up into groups and asked to articulate, consider and ultimately present on some aspect of sustainability. This exercise incorporated part of the assessment for each of the modules. The general response from students (both engineers and sociologists) was overwhelmingly positive, not least as it gave each of them the opportunity to engage with, challenge, understand and reflect on very different perspectives and methods, including their conceptions and epistemological frameworks common to their own respective disciplines.

Ethics

Modules dealing with ethics are an ideal platform upon which to incorporate the Global Dimension. Projects, assignments and teaching and learning strategies such as those outlined above can be readily, imaginatively and productively incorporated onto ethics modules, thus bringing them to life and transforming the ethics class from a turgid box ticking exercise (typically involving some individualistic micro-ethical dilemma which requires students to answer to ‘What would you do if…?’) into an opportunity for insightful and reflective student learning dealing with broader macro-ethical one (e.g. around issues of sustainability and societal, organisational and professional norms) (Herkert, 2000, 2005; Bucciarelli, 2010; Conlon, 2010; Conlon and Zandvoort, 2012; Byrne, 2012a).

Final Year Capstone/Project

Final year design projects and other such capstone courses provide an ideal platform for exploring and integrating Global Dimension perspectives, for example through broadening the scope of the assignment to incorporate issues around ethics, sustainability and effects and appropriate considerations with respect to the developing world. Ultimately this implies a broader (re)conception of the role and nature of design "*towards a reflective, creative practice*" to the point where engineers would "*view design as a reflected social practice ideal for open, complex problems at the intersection with other professional fields*" (Petersen, 2013).

The role that the above-mentioned initiatives can play in meeting accreditation criteria are highlighted in Table 6, in relation to how they can be applied to meeting the core requirements of 'basic' engineering (scientific and mathematical, computational and modelled design) and 'embedded' material (sustainability, ethics, safety, uncertainty, risk, social, environmental, contextualised design decisions) learning outcomes as well as those relating to 'transferable' (communications, team-working, knowledge sharing) skills.

Table 6 *Some initiatives which promote Global Dimension perspectives and their respective accreditation requirements.*

Initiative	Basic	Embedded	Transferable
Supporting and encouraging relevant curricular and extra-curricular global activities		✓	✓
Problem Based Learning	✓	✓	✓
Active learning	✓		
Peer learning	✓		
Problem framing			✓
Wicked problems		✓	✓
Inter- and trans-disciplinary projects		✓	
Ethics		✓	
Final Year Project	✓	✓	✓

The initiatives described above present only a small subset of possible initiatives that can be undertaken to incorporate Global Dimension and Global Dimension perspectives/capacities into engineering programmes. Indeed, imagination is the only limit to the possibilities. Various constraints (times, resources, etc) will always apply, and not every initiative will meet with immediate (or eventual) success. The key ingredient required, however, is an aspiration to enable and empower learners to meet their full potential by developing the necessary skills and aptitudes (critical, reflective and complex thinking, self-awareness and empathy, teamwork, listening and communication skills) to be fit-for-purpose in addressing the complex issues around (un)sustainability and human flourishing in a contemporary, globalised 21st Century society. Once this aspiration remains the driver, all manner of creative possibilities can emerge.

CONCLUSION

The current chapter had described a framework for the Global Dimension in engineering education which builds on contemporary state of the art (re)sources on this area. It has proposed a number of (inexhaustive) possible initiatives that can facilitate the incorporation of the Global Dimension and Global Dimension perspectives that can also help meet contemporary and emerging programme accreditation requirements. It is suggested that an enthusiasm for incorporation of Global Dimension perspectives by relevant actors and academics – coupled with appropriate programme-level and module-level experimentation – can go a long way in helping precipitating the necessary transformational change to develop engineering programmes and graduates that are fit-for-purpose in addressing contemporary societal issues.

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CHAPTER 3

Level, distribution and depth

PHOTO: A Child Works With Her Mother in a Water Powered Flour Mill, Dhorpatan, Western Nepal. D. Narayanan

3

CHAPTER 3. Level, distribution and depth

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3 LEVEL, DISTRIBUTION AND DEPTH

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EXECUTIVE SUMMARY

The Global Dimension can be integrated into the different levels of academia in a variety of ways, and with different breadth and depth. This chapter uses real examples to present and discuss methods for introducing the Global Dimension. In particular, it uses examples of Service Learning to show how the Global Dimension can be integrated at levels ranging from undergraduate modules to post-graduate research.

This chapter introduces ideas that can be used to stimulate student learning by presenting innovative modules and case studies of Service Learning such as: community-based projects; multi-disciplinary projects; partnerships with NGOs for students to work in developing countries as part of their degree programme, and; multi-disciplinary teams to support PhD students in addressing community needs.

By considering the advantages and disadvantages of each method – and the contexts in which they can be used – the chapter demonstrates how the right method for introducing the Global Dimension can be selected for the right context. By taking examples from the National University of Ireland, Galway in Ireland, this chapter gives a sense of the level, distribution and depth that can be achieved when Global Dimension is taken into the core of academia through the lens of Service Learning. Key success factors of embedding Service Learning in curricula are summarised.

LEARNING OUTCOMES

After you actively engage in the learning experiences in this module, you should be able to:

- Describe different ways the Global Dimension can manifest in the curriculum in a practical way that fits the stakeholders' needs, capabilities and capacities.
- Recognise and explain the advantages / disadvantages of each manifestation.
- Select the most appropriate method of integration for a variety of situations.

KEY CONCEPTS

These concepts will help you better understand the content in this session:

- Project-based Learning and Service Learning
- Community engagement
- Self-guided learning
- Academics as facilitators

GUIDING QUESTIONS

Develop your answers to the following guiding questions while completing the readings and working through the session:

- How would this work at my university, and what would need to change in terms of culture and support?
- What student/ group/ class projects exist in my university that could be adapted to take a Service Learning approach, whilst not diminishing engineering content?
- Are my students ready for this? And am I ready for this?

INTRODUCTION

The Global Dimension can be integrated into academia in a variety of methods. For example, the 'Global Engineer' is a concept developed by Bourn and Neal (2008) that steers engineering education in 'global' directions (in response to a combination of global challenges such as sustainable development and poverty reduction) and highlights the need to foster 'global skills' and incorporate new methodologies that enhance student learning.

The overall context for the Global Engineer is one that is both challenging and promising. Taking the example of Ireland, Bourn (2009) notes some interesting priorities and trends. Firstly, there is evidence of a more 'ethical-based approach to engineering', as reflected in the Institution of Engineers Ireland Code of Ethics and the presence of linkages between engineering and development ((Bourn 2009), citing Institute [sic] of Engineers in Ireland 2003 & Institution of Engineers in Ireland 2004). However, Bourn's report (Bourn 2009) also finds that sustainable development does not appear to have a high profile in Irish engineering education in comparison to, say, the United Kingdom or Germany.

This chapter presents ways in which the Global Dimension has been implemented in engineering education in tertiary-level institutions in Ireland. 'Soft skills' and new teaching and learning approaches are core to the Global Dimension agenda and core to its framework of generic themes, skills and dispositions. Within National University of Ireland (NUI) in Galway, we identify civic engagement and social responsibility to be the principal lens through which the Global Dimension is taking root and developing. Service Learning (also known as Community-Based Learning) as a pedagogical tool provides a means of connecting students' academic study with the context of community and society, with the explicit intention of promoting active and responsible citizenship (Bringle & Hatcher, 1996; Furco & Holland, 2004; Zlotkowski, 2007). Since 2003, Service Learning has been used as a pedagogical tool in the College of Engineering & Informatics at the NUI Galway. All students undertaking engineering degree programmes at NUI Galway (as well as some postgraduate Engineering students) complete at least one Service Learning project during their course. This means more than 200 students complete these projects each year (see Table 1 and the next section for further details). These projects are framed by a research orientation, commitments to civic engagement and building university-community partnerships, city-university partnerships and partnerships with other official agencies. Such framing means that community users can provide real learning problems and contexts for students, and researchers can benefit from the results.

This chapter will explore Service Learning as a pedagogy tool for the Global Dimension across engineering education, by presenting details of its implementation at NUI Galway. It will highlight how the approaches outlined fit well with the ideas of engaged scholarship (Boyer, 1996) and civic professionalism (Sullivan, 2005). The evaluation of Service Learning modules in engineering at NUI Galway highlighted that the students come to value consulting the end-users of their designs and recognise the long-term value of engaging with community partners. This is also connected with a new understanding of their future role in the community as engineers, reinforcing the idea that their work can respond – and should respond – directly to real needs in the community.

WHY EMBRACE THE GLOBAL DIMENSION IN ENGINEERING EDUCATION?

Recent research and reports (Royal Academy of Engineering, 2007; Jamieson & Lohmann, 2009; Sheppard et al, 2009; Atman et al, 2010) have shown that there is a critical need to provide students with a deeper understanding of the general concepts and principles of engineering, and to provide them with the means to meet the challenges of the 21st Century. One such report by the Royal Academy of Engineering (2007) highlighted the need for "*university courses to provide more experience in applying theoretical understanding to real problems*".

Service Learning provides such an opportunity. The project modules are based around the student groups developing innovative technology for real-world problems. They use a design process that involves close interaction with end-users to understand their needs and to repeatedly get feedback on the suitability and usability of their design concepts.

Evidence has been collected from the aforementioned projects at NUI Galway which shows that, by creating Service Learning, the students' energy in learning can have a positive impact on the community and the students. Their energy and enthusiasm can be better utilised (and increased) by setting assignments as real community-based projects. The students get a sense of pride and satisfaction out of the knowledge that their work may be helping communities (and that learning is not just to get marks to pass the exam!). The projects can increase the students' sense of ownership of their own learning. Learners are more motivated when they can see the usefulness of what they are learning, and when they can use that information to do something that has an impact on others (Bransford et al, 2000 and Goggins, 2012). The projects allow the students to achieve all of the programme outcomes that the engineering professional body has specified for an accredited engineering degree (College of Engineering & Informatics, 2012). Furthermore, there is evidence to show that such engagement can lead to a widening of participation to include greater numbers of women and minorities in both engineering education and the engineering profession (Oakes, 2008).

As seen from Table 1, and highlighted further in the following sections, the College of Engineering & Informatics at NUI Galway has embedded civic engagement across all its undergraduate programmes through local and international community-based engineering projects.

Table 1 *Service Learning initiatives introduced to Engineering & Informatics in NUI Galway:*

Module	Programme	Year	Number of students each year	Number of community partners
CAIRDE (see page 9)	BEng in Biomedical Engineering; BEng in Mechanical Engineering.	3rd	70	> 20
CE226 Principles of Building: community-based engineering project (see page 11)	BEng Civil Engineering; BEng Environmental Engineering; BSc in Project and Construction Management; BEng in Energy Systems Engineering.	2nd	70 to 130	> 25
EE325/EE326 Third Year Project Module (see page 14)	BEng in Electronic and Computing Engineering; BEng in Electrical and Electronic Engineering.	3rd	35	5
Professional Studies in Electronic Engineering and Electronic & Computer	BEng in Electronic Engineering; BEng in Electronic and Computer Engineering.	3rd	12	10
Managing Development (see page 15)	BEng Civil Engineering; BEng Environmental Engineering; BSc in Project and Construction Management; MA in Environmental, Society and Development (Geography).	3rd yr (undergrad Engineering); 1st yr (postgraduate Geography)	170	38
Engineering for Humanity – professional field placements (see page 17)	BEng Civil Engineering; BEng Environmental Engineering; BSc in Project and Construction Management.	3rd yr	8	2
Final year project	BE Civil Engineering; BE Environmental Engineering; BSc in Project and Construction Management.	4th yr	10	2
Information Technology Project	Masters in Information Technology.	MIT	12	8
Engaging with the community: research practice and reflection (see page 19)	Structured PhD in College of Arts, Social Sciences and Celtic Studies; Structured PhD in College of Engineering & Informatics.	MA / MEngSc / MSc / PhD	10	2

COMMUNITY-BASED PROJECTS: A LENS THROUGH WHICH TO IMPLEMENT THE GLOBAL DIMENSION IN ENGINEERING EDUCATION

This section introduces ideas that can be used to stimulate the students learning, by presenting innovative modules and project-based learning case studies such as:

- Community-based projects (also known as Service Learning).
- A multidisciplinary project called 'Managing Development'.
- 'Engineering for Humanity', which is a joint initiative with NGOs to give undergraduate engineering students the opportunity to work in developing countries as part of their degree programme.
- 'Engaging with the Community: Research Practice and Reflection', which is the first module of its type in Ireland and gives PhD students the option of working in small multi-disciplinary teams to address the needs of voluntary or community organisations (a credit-bearing module in a postgraduate research programme).

These initiatives allow students to complete engineering research projects in the community. Students are therefore 'learning by doing'. Some specific examples relating to Service Learning are given in the following subsections.

Moving project modules from a more traditional approach – of projects based solely around an academic's or student's area of interest – to one driven by Service Learning and partnering with community organisations acts to enhance student engagement through the real-world nature of the technical problems being addressed. This is in addition to the opportunity to work with groups that are often excluded from many technology innovations (due to cost or poor design).

The modules are individually tailored for the group of students, taking account of their previous learning experiences, size of group, programme, diversity and so on. The modules are carefully designed to ensure there is no loss in the technology learning outcomes, whilst students gain significantly in terms of: understanding the role of the engineer in society; the need for a tight and inclusive design cycle to address user requirements, and; the importance of cost in terms of adoption of the solution in the target consumer group. Service Learning fits well with the descriptors for the six Programme Areas outlined in the Institution of Engineers Ireland Accreditation Criteria for Engineering Education programmes, including "*responding to real life situations*" and "*developing awareness of the social and commercial context of engineer's work".* The quality and impact of the projects was specifically praised by the accreditation board during their visit in 2012. The College of Engineering & Informatics at NUI Galway was shortlisted for the 'Best in Class' award at Institution of Engineers Ireland Awards in 2013 for work in Service Learning.

1. Community-based projects: University support

Service Learning is currently seen as having priority within higher education in Ireland. According to Byrne & McIlrath (2011), this priority has been prompted by the 'Celtic Tiger' phenomenon where the 1990s brought a profound change and Ireland benefited from an economic boom. Coupled with this wealth was a growing concern over perceived declines in levels of 'social capital'. To counteract this, there was recognition of the potential role that Service Learning (as well as other civic engagement strategies within higher education) could play in redressing the balance (Boland & McIlrath, 2007).

The first formal commitment to increasing social capital through civic engagement came in NUI Galway in 2001. With the support of a number of benefactors (including Atlantic Philanthropies) the 'Community Knowledge Initiative' (CKI) was established within the university. This initiated '*the creation of a radical new approach to the betterment of society through emphasis on three core elements of community-based research, service learning and knowledge-sharing*' (Community Knowledge Initiative, 2001, p2). The CKI was subsequently afforded prominence within the institution's Academic and Strategic Plans (2003-2008 and 2009-2012) (National University of Ireland, Galway, 2002, 2008). This funding allowed the university to employ personnel to work on both mainstreaming civic engagement within the curriculum across the university (Service Learning) and also on encouraging and supporting extracurricular (student volunteering) activities. Each year, the CKI undertakes a community needs analysis whereby the community document their needs related to the disciplines that contain a Service Learning experience. These needs are subsequently mapped to members of faculty and this process ensures that the university is responding to a direct need and not saturating the community sector with an over-abundance of Service Learning students. Since the inception of the CKI, over thirty academic degree programmes have incorporated Service Learning experiences.

Since 2003, Service Learning has been used as a pedagogical tool in the College of Engineering & Informatics at the NUI Galway. For example, in 2003, a Service Learning module was established in a post-graduate degree programme called the Masters in Information Technology (MIT) (Byrne & McIlrath, 2011). In the same year, Service Learning was introduced into the BEng in Mechanical Engineering and BEng in Biomedical Engineering as a required component (called 'CAIRDE') of the mandatory third-year module 'Engineer and Society', which is now also a module also taken by Electronic Engineering students. Wallen and Pandit (2009) outline the benefits of introducing civic engagement into biomedical and mechanical undergraduate programmes at NUI Galway. Since then, the College of Engineering & Informatics at NUI Galway have gone further and implemented a number of initiatives in their civil engineering undergraduate and post-graduate degree programmes to allow students to complete engineering projects in the community.

1(a). Community-based projects: Biomedical and Mechanical Engineering

The Mechanical and Biomedical Engineering degree at NUI Galway has a Service Learning module incorporated into its programme, giving students experiential learning while applying academic knowledge. 'Community Awareness Initiatives Responsibility-Directed by Engineers' (CAIRDE) was designed as a way for students to identify a need in their community and define a project with very distinct goals (Wallen & Pandit, 2009). It brings together subjects such as 'Engineering in Society', ethics and community outreach and involves 18 hours of lectures, 8 hours of tutorials and 16 hours of service over two semesters. It is credit-rated with 6 ECTS.

Extract from Table 1 *Summary of CAIRDE:*

Module	Programme	Year	Number of students each year	Number of community partners
CAIRDE	BEng in Biomedical Engineering; BEng in Mechanical Engineering.	3rd	70	> 20

CAIRDE is a pioneer programme for Service Learning amongst engineering students in Ireland. It has been recognised internationally as an exceptional student community engagement initiative by being awarded a MacJannet Prize in 2010. Since the programme's inception more than 500 students have taken part in Service Learning projects, devoting over 8,000 hours of service to local communities. The students have made tremendous strides in taking an active role in society and have gained strong relationships with their community partners. CAIRDE has enabled students to build a link between the university and community, showing how collaboration between the two can yield positive results that are reciprocally beneficial.

Students of the CAIRDE programme are expected to take on a great deal of responsibility in the facilitation of their Service Learning project. They must develop a project that enables them to utilise their engineering skills to address a real need for an individual or group in the broader community. By putting this knowledge into action, students work directly with the beneficiaries and must ensure that their needs are met through the work conducted. Projects vary in terms of the beneficiaries and type of work students engage in. Some may work with established organisations (such as Enable Ireland, Saint Vincent de Paul, The Simon Community, National Council for the Blind and The GAF youth cafe). Others direct their efforts towards supporting local schools, nursing homes, hospitals, libraries, playgrounds and athletic clubs. Some students choose to address the needs of a specific individual by either contributing to personal care or improving someone's quality of life. The success of these projects has gained CAIRDE such great recognition that the number of community organisations wishing to collaborate with the programme continues to increase.

CAIRDE demonstrates the value of Service Learning, as it requires student participants to use and develop ‘soft skills’ that are invaluable to engineers but often difficult to teach in a traditional classroom setting. These ‘soft skills’ include project management, task analysis and interpersonal skills as well as practicing shared decision-making and being able to reflect on their learning and experiences. Additionally, the students are able to apply knowledge to a specific, real project for the first time, which helps them to view their academic preparation in a new light. All the while, CAIRDE is fostering a greater understanding of community needs and what methods can be taken to address these needs.

CAIRDE places great emphasis on how the students understand their impact on society. Therefore, reflection plays a central role to the Service Learning process. In the reflection process, students tie in what they are learning about the community as well as how they can further develop their engineering skills. Students share this reflection with the greater educational community, building awareness and demonstrating to their peers how they can make a difference in their communities.

1(b). Community-based projects: Civil Engineering

In the second year community-based engineering project, students must form small teams, identify a suitable community partner and sign a ‘learning agreement’ with their community partner. The learning agreement clearly outlines the goals of the project and tasks involved in completing the project, as well as the learning outcomes for the students. The outcome of the project is a written technical report, which is sent to the community partner. The specific aim of the project is to fulfil a real need of the community partner that relates to the associated module taken by the students ‘CE226 Principles of Building’. The project takes about 100 hours over one semester and is credit-rated with 5 ECTS.

Extract from Table 1 *Summary of the community-based engineering project:*

Module	Programme	Year	Number of students each year	Number of community partners
CE226 Principles of Building: community-based engineering project	BEng Civil Engineering; BEng Environmental Engineering; BSc in Project and Construction Management; BEng in Energy Systems Engineering.	2nd	70 to 130	> 25

Some community partners and community-based projects are identified by the instructor. However, the onus is on the students to identify suitable community-based projects. The ‘learning agreement’ must be submitted by the students within 2 weeks of starting the project. In addition to the set learning outcomes for the project, the students must also decide on three additional learning outcomes that relate to this component of year’s work.

Marks are allocated for the technical context and presentation of a written report and oral presentation. Marks are also allocated for the level of engagement with the student’s community partner and for producing a report or outcome that relates directly to a real need in the community. The students must each complete a self-assessment marking sheet at the end of the project, which is marked by a grader (a postgraduate student or lecturer). The criteria in the self-assessment sheet relate to the learning outcomes.

Lectures and workshops are held during the semester on effective communication, facilitated by a consultant in public relations. Postgraduate students act as mentors by hosting weekly drop-in centres for students to give technical and report or presentation advice. Objectives set for the students in the project’s ‘Mini Group Project’ guidelines include (Goggins, 2012):

- Develop engineering skills through a self-directed project.

- Apply knowledge or skills learned in the module (and others) to a real context.
- Develop a sense of commitment to local communities by making a contribution of time and expertise to an individual or community group.
- Learn how engineers make contributions to their communities in their careers.
- Produce a technical engineering report.
- Deliver a high quality oral presentation on a particular subject.

An award has been introduced for the best community-based project. Shortlisted projects are presented by the students to their peers, academics and the wider community. The project judged by those in attendance to be the best receives the award.

Structured community partner feedback was also captured through surveys so as to develop guidance on best practice in community-based engineering projects. For example, in 2012, 17 of around 30 community partners completed the survey and 82% of them were either ‘very satisfied’ or ‘satisfied’ with student compliance to project aims, goals and objectives. Strict adherence to the signed learning agreement was clearly of benefit. Such a ‘contract’ document maintained the link to the initial plan. Additionally, the drop-in clinics were of benefit to students and ensured focus was continually redirected back to the signed learning agreement, as found from student feedback. When asked to rate the usefulness of the student report findings, 92% of community partners selected ‘very satisfied’ or ‘satisfied’ and 94% of surveyed partners said they intended to implement the findings. The surveys demonstrate that the vast majority of the students fulfil the main aim of their project; that is, to identify and satisfy a real engineering need of a community partner. Some of the very positive comments from community partners are also received through these surveys.

Grouped student evaluation surveys in 2011 showed that students liked getting involved with and working for organisations or individuals in the community. Out of 40 groups of students, 21 groups responded that they obtained an increased knowledge and understanding of the project topic, 3 groups thought they gained a better understanding of the overall content of the course and 16 groups said they gained by completing a project on real world applications (the students were asked to document the group’s opinion and consensus in five questions).

Salient features of the set-up of the community-based engineering project are:

- Detailed and structured guidance for students and community partners.
- A structured learning agreement that must be completed by the students and their community partner at the start of the project.
- A self-assessment sheet and marking sheet for graders that is available to the students and is in line with the learning objectives of the project, so that it is clear to the students what is expected of them.

- Marks are returned to the students with feedback within 2 weeks of submission of the project and before the end of the semester.
- The reports are sent to the community partner and they are asked for feedback.

Race (2007) gives some good advice on designing student projects. One suggestion is to work out specific learning outcomes for the projects. Race (2007) suggests that "*these will be of an individual nature for each project, as well as including general ones relating to the course area in which the project is located*". Each year there are approximately 50 to 60 individual community-based engineering projects completed by second year civil students (with one or two academics facilitating this). Therefore, it would not be feasible to write learning outcomes of an individual nature for each and every project. Following Race's advice, general learning outcomes are set for all projects and students write 2-3 learning outcomes that are specific to their project. This gives the students' scope to adjust the learning outcomes to suit their desired learning – and increases their sense of ownership over their learning (which is in the ethos of the project). Sample projects from previous years are made available to students. Seeing the standard of completed projects encourages students to at least meet, if not surpass, this standard.

Having staged deadlines for the project is very useful, such as for agreement of the learning outcomes with the community partner (this is also good practice for their future careers).

The students present their mini-projects both orally and in a written technical report. As well as receiving feedback on their written report, they also receive strong feedback on oral presentation skills from an external consultant in public relations. A question-and-answer session at the end of the presentations is used as both an assessment and feedback tool on technical capability. Questions are used to further assess the students' depth of knowledge. Instant feedback is given to the students on misconceptions or gaps in the knowledge.

> "*The significant feedback of learning and the potential of formative assessment to enhance pedagogy (York 2003) provide a strong argument that all assessment activity in universities should aim to provide effective feedback for students. Indeed, feedback is arguably the most important aspect of the assessment process in raising achievement (Black and Williams 1998; Gibbs and Simpson 2004)…*" (Bloxham & Boyd, 2007, p103).

The students' self-assessment evaluation is not currently taken into account in the final marks. However, there are many advantages to using both self-assessment and peer-assessment, which include making students aware of the characteristics of 'good work', encouraging them to take responsibility for their own learning, and encouraging them to reflect on themselves as learners and so learn how to learn (Race, 2007).

1(c). Community-based projects: Electrical and Electronic Engineering

All third year students in the Electrical and Electronic Engineering discipline within the College of Engineering and Informatics undertake Service Learning group projects. These usually involve the development of technology prototypes for the clients of various community organisations (such as the National Council of the Blind, Deafhear, Enable Ireland and organisations active in supporting homeless people and victims of domestic abuse). The project takes 50 hours over six months and is credit-rated with 5 ECTS.

Extract from Table 1 *Summary of the community-based engineering project:*

Module	Programme	Year	Number of students each year	Number of community partners
EE325/EE326 Third Year Project Module	BEng in Electronic and Computing Engineering; BEng in Electrical and Electronic Engineering.	3rd	35	5

Technology prototypes are the main focus of these projects because of, quite simply, the nature of the technology. Example projects include: 'Rowmate', a smartphone app that allows visually-challenged individuals to utilise and interact with screen-based indoor rowing machines; a system to allow older people with memory problems to manage the process of taking daily medications, and; the development of a solution to allow children with little or no limb control to interact with video games.

The project raises awareness amongst the students of how their design work and decisions can have very positive impacts on the lives of some groups within society. It teaches them to consider the issue of inclusivity when making a design decision by putting themselves in the place of a wide range of different potential users. A public poster event highlighting the projects takes place every year.

Further details can be found in a peer-reviewed conference paper by Liam Kilmartin (Kilmartin, 2010).

2. Multi-disciplinary projects

Collaboration between colleagues in Civil Engineering, Geography and CKI led to the introduction of an interdisciplinary project in 2010 into a number of programmes in NUI Galway. This multi-disciplinary module, entitled ‘Managing Development’, links the MA in Environment, Society & Development (Geography) with the BEng degrees in in Civil and Environmental Engineering and the BSc in Project & Construction Management. It involved 19 students from the School of Geography and Archaeology and 150 students from the College of Engineering and Informatics. It is a 60-hour module for undergraduate engineers (200 hours for postgraduate Geographers) over one semester, and is credit-rated with 3 ECTS (undergraduates) and 10 ECTS (postgraduates).

Extract from Table 1 *Summary of Managing Development module:*

Module	Programme	Year	Number of students each year	Number of community partners
Managing Development	BEng Civil Engineering; BEng Environmental Engineering; BSc in Project and Construction Management; MA in Environmental, Society and Development (Geography).	3rd yr (undergrad Engineering); 1st yr (postgraduate Geography)	170	38

The idea for the module was initially developed because faculty were keen to introduce approaches to teaching that would engage students with communities in a practical and meaningful way. Engineering and Geography clearly presented a number of dimensions for successful collaboration. This module complements the engineering projects that the engineering students carry out with community partners in the second year of their programme. Third year civil engineering students are also given the opportunity to work in developing countries with NGOs as part of their professional experience programme (see ‘Professional engineering placement in developing countries’ example below).

The module involves mixed groups of Geography and Engineering students developing critiques of a selected range of NGOs. Their task is to produce a set of evaluation posters which assist these NGOs in identifying strengths and weaknesses, and thereby contributing towards the improvement of approaches used in particular activities. The format provided an active learning environment for students, enabling them to apply classroom-based learning to an actual organisation in order to: identify how or whether such concepts and approaches are being interpreted and applied in a real-life setting; comprehend the potential gap between theory and practice in a real-life situation, and; suggest whether and how examples of actual policy and practice might be redefined and improved. This project-based approach involves students adopting specific roles as part of a team, collaborating with one another to devise the project structure, set realistic goals and timelines and then deliver an end product.

Figure 1 *Students presenting their posters to community groups in an open forum during the 'Management Development' project*

As mentioned, the exercise is multidisciplinary in nature and involves students from two separate Colleges. It also involves collaboration with CKI to incorporate a strong community-relevant dimension to each project. A deeper understanding of the NGO sector enhances students' awareness that altruism and civic responsibility are to be valued and encouraged in both personal and professional spheres. From the NGOs' perspective, the students' evaluations of their organisations often reveals the potential for continued collaboration into the future: "*What the students have revealed is that their particular perspectives, drawn from both geography and engineering, can provide very rich and critical insights that enhance understanding of a wide spectrum of development issues, and which in turn can help NGOs to better project the invaluable work they already do*".

Dr. Brenda Gallagher from NUI Galway's School of Geography and Archaeology has professional experience of development work in Malawi, and remarked that the project has helped the students develop a broader perspective on global development within national and international communities: "*There are many fixed ideas about the nature of NGO activities and often little awareness about the difficult practical and ideological environments which they must navigate. This project has helped to bring the students closer to an understanding of these issues, and to identifying ways they can constructively assist NGOs in their activities*".

3. Professional engineering placements in developing countries

Many engineering courses require students to gain professional work experience through placements with engineering organisations. In April 2009, the College of Engineering and Informatics at NUI Galway initiated a pilot programme with a partner called Alan Kerins Projects to give undergraduate students the opportunity to work in Zambia as part of their academic course. This was expanded in 2011, where another partnership was established with Foundation Nepal allowing students to complete their work placement in a remote region of Nepal. These last for around 16 weeks (8 weeks training and 8 weeks in the field) and the whole process takes a minimum of six months. They are credit-rated with 2 ECTS.

Extract from Table 1 *Summary of 'Engineering for Humanity' professional field placements:*

Module	Programme	Year	Number of students each year	Number of community partners
Engineering for Humanity – professional field placements	BEng Civil Engineering; BEng Environmental Engineering; BSc in Project and Construction Management.	3rd yr	8	2

The project is divided into three phases: completing initial training at university; on placement in Zambia or Nepal, and; completing the final year project on a related topic. Furthermore, several projects have led to a number of postgraduate research projects. Figure 2 shows the model of how these placements relate to different levels of education.

Figure 2 *Model for the 'Engineering for Humanity' projects*.

Students are chosen for this programme based on a competitive interview process. Students receive a conditional offer for a position on a project, provided that they fulfil all the requirements set out. They must complete pre-departure training and preparation and submit a signed pre-departure form (containing information such as contact details, travel itinerary, health insurance, medical examination, immunisations received, pre-departure training, etc). The form was adapted from that used by the School of Nursing & Midwifery at NUI Galway. There are a number of undergraduate degree programmes in NUI Galway where students work overseas and obtain credits towards their degree. Pre-departure training was developed in collaboration with other university departments. Specific technical training is also given to the selected students. Overall, the pre-departure training sees the students undertake laboratory-based work and research projects, as well as receiving courses on cultural awareness, security, child protection and issues in global development.

Examples of tangible outputs from the projects were:

- Detail design of a water system upgrade for an orphanage.
- Research into the agriculture and industry around in western Zambia, with specific attention to waste products that could be used in stabilised soil blocks.
- Engineering and science workshops.
- Digital survey of land and buildings.

Figure 3 *Repairing a borehole at Kaoma orphanage in Zambia (left) and a 3D model of planned project for the orphanage (right).*

This programme clearly indicates potential areas where ethical, globally aware, civically engaged and socially responsible engineering education can flourish. Benefits of the pilot programme have been highlighted by the author in academic publications (see, for example, Goggins, 2010).

4. Postgraduate module supporting community-engaged research

NUI Galway is the first university in Ireland to offer postgraduate students the opportunity to apply their discipline-specific knowledge and skills to the design, conduct and reporting of a community-engaged research project. Since September 2011, PhD students have the option of working in small teams to address the research needs of voluntary or community organisations as a credit-bearing module in a postgraduate research programme. The module is called 'Engaging with the Community: Research Practice and Reflection' and takes about 200 hours over one year. It is credit-rated with 10 ECTS.

Extract from Table 1 *Summary of 'Engaging with the Community' postgraduate module:*

Module	Programme	Year	Number of students each year	Number of community partners
Engaging with the community: research practice and reflection	Structured PhD in College of Arts, Social Sciences and Celtic Studies; Structured PhD in College of Engineering & Informatics.	MA / MEngSc / MSc / PhD	10	2

This module is one of the outcomes of the 'Community-Engaged Research in Action' (CORA) project, which is a partnership between NUI Galway and COPE (a local community organisation whose work includes supporting homeless people and victims of domestic violence). CORA aims to further enhance sustainable and collaborative research partnerships between the university and community. This module was developed by CORA together with the College of Medicine and Health Sciences, the Centre for Participatory Studies, CKI and the author (on behalf of the College of Engineering and Informatics).

This research initiative builds further on the international reputation NUI Galway enjoys for supporting civic engagement. With the implementation of this module, the university aims to develop PhD students' research skills in an applied, real-world setting to meet community needs. The module aims to give students the opportunity to:

- Enhance their personal effectiveness, capacity for innovation and professional competence thus increasing their employability
- Develop research skills in an applied, real-world setting, in response to an identified research need
- Apply discipline-specific knowledge and skills to a research project
- Work collaboratively with a community partner and/or as part of a research team
- Work with people from other disciplines in solving research problems

- Develop a deeper insight into the impact of socio-economic conditions and public policy on real world issues
- Scrutinise and reflect on social norms and their own role as agents of change.

MEETING HIGHER EDUCATION KEY SUCCESS FACTORS

- **Investment in resources**

  As has been discussed, the university itself has been extremely supportive of Service Learning modules and other community engagement activities. NUI Galway and its leaders place great importance on civic engagement and Service Learning is referenced as a key pillar in the past and current Academic and Strategic Plans. The CKI continue to provide support in maintaining Service Learning programmes including training for staff in best practice and the ongoing needs assessments for new community partners.

  Community engagement experiences have been expanded and embedded across the Civil, Electronic, Mechanical and Biomedical Engineering curricula. Furthermore, a cross-university approach to engage multiple departments has been developed. All students undertaking engineering undergraduate degree programmes in NUI Galway take a Service Learning component during their studies. This greatly supports the integration of the Global Dimension. Around 12 academic staff and a number of support staff are involved in Service Learning modules in the College of Engineering & Informatics. The college continues to allocate the necessary funds to support service learning modules. This includes basic costs related to managing the projects, as well as costs connected with their associated activities.

- **Innovation in education**

  Each Service Learning module is unique and has been designed to embed within the existing curriculum to improve students' learning. Using a model of experiential learning, the purpose behind the programmes is to encourage students towards community engagement by challenging them to develop a self-directed project that applies skills gained so far in their academic preparation.

  The projects offer students a unique learning experience, where creativity, teamwork, communication and real-world problem-solving abilities are recognised and rewarded. In the feedback studies and focus groups, students clearly stated that the real-world output was a motivator to stretch their abilities and to put the fundamental material learned into use. The learning is student-centred, with students taking responsibility of their projects and workload. Both student and community partner feedback highlighted the importance of the student-led approach, with staff and postgraduate students in the university acting in a facilitating role. The findings from these studies can be found in peer-reviewed international publications NUI Galway academic staff (Wallen & Pandit, 2009; Kilmartin, 2010; Byrne & McIlrath, 2011; Goggins, 2012).

- **Commercial potential of research**

  The Service Learning modules give students an opportunity to work on projects in a real-world context with a client, constraints and a real need. Students usually become acutely aware of the budget constraints of their community partner and the impact that will have on their engineering solutions. Further, the projects give students opportunities to experience a more ethical approach to engineering. Service Learning has its roots in social entrepreneurship, and in most disciplines the project groups are encouraged to remain aware of the commercial potential of the solutions they develop – and in particular the impact that the cost of their solution would have on its ‘market potential’, particularly in a market which is typically very cost sensitive.

Prototype products developed by students in Mechanical, Biomedical and Electronic Engineering degree programmes receive recognition for their potential impact through national awards and press coverage. Many recommendations from civil engineering projects have been implemented by community partners.

During the ‘Engineering for Humanity’ programme, some research projects have led to upskilling of the local workforce and increased employment by, for example, setting up a micro-enterprise facility for making stabilised soil blocks in western Zambia (where profits from the enterprise go towards running costs of the local orphanage).

- **Actual or potential contribution to the economy**

  Each year, the 200 engineering students who participate in Service Learning programmes complete well over 10,000 hours of service to the community. The students have established positive links between the university and many community partners. A wide variety of projects have been completed, with most producing a tangible tool or a service that had a significant impact on the quality of life of others in the community – and/or proposed multiple cost saving measures for their community partners. This constitutes a real economic benefit that complements the social contributions.

  Social connections amongst students and community partners inevitably strengthened, which allows for further relationships such as postgraduate research.

- **Differentiation**

  There are a number of factors that place NUI Galway’s initiative in engineering education through Service Learning as being unique and valuable. These include:

  - Recognition as ‘best practice’ internationally (for example through international awards or involvement in projects to embed the model in other countries).
  - Civic engagement and partnership.
  - Engaging new stakeholders in university education.
  - Problem-based learning, but fulfilling real needs.
  - Local, national and international projects (giving students global skills).
  - Academic staff buy-in in terms of time and vision.
  - Academic credit is given to the Service Learning projects.
  - Mandatory requirement of the curriculum for all engineering disciplines.
  - Broad and deep embedding of the Global Dimension across all levels.

CONCLUSION

This chapter provided examples from NUI Galway of how Service Learning can be used to integrate the Global Dimension into academia, from undergraduate programme modules to post-graduate research. The examples have demonstrated both very broad projects (such as the multi-disciplinary projects) and very deep projects (such as the field placements).

These are examples of the use of teaching and learning methods that encourage students to become independent, critical thinkers who are fully engaged with the subject matter. The curricular ‘domains’ of knowing, acting, and being (Barnett & Coate, 2005) relate to the content, skills acquired by the student, and human development, respectively. Introducing community-based projects improved the curriculum with respect to each of these domains. Firstly, the projects permit the students to obtain a deeper understanding of some aspect of the course. Secondly, students have the opportunity to develop their skills in areas such as research, teamwork and communication. Thirdly, working on community-based real projects can help students to develop through civic engagement, which may also improve their employability and mastery of a discipline.

Community-based projects help to link the information taught in lectures to what is needed in the commercial environment and in local communities. It is heartening to note that the benefits of the project were independently identified by the participating students. Furthermore, knowledge transfer takes place between the academic, students and local community. One of the advantages of this, noted by Trowler and Wareham (2008), is “*claims about a teaching/research nexus having instrumental value in terms of marketing of programmes and courses and institutional reputations*”. Using approaches like Service Learning to embed the Global Dimension, therefore, brings immediate benefits for students, academics, local communities, widening participation in engineering, attracting more young people into engineering and for the success of universities themselves. In the longer-term, civic-minded global engineers will be better able to respond to the challenges they will face in their own communities, and in the world at large.

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PHOTO: Practical Action

CHAPTER 4

"Nuts and Bolts": regulatory frameworks and barriers to inclusion

4

CHAPTER 4. "Nuts and Bolts": regulatory frameworks and barriers to inclusion

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4 ‘NUTS AND BOLTS’: REGULATORY FRAMEWORKS AND BARRIERS TO INCLUSION

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EXECUTIVE SUMMARY

National regulatory frameworks governing the activities of engineers vary around the world. They influence educational course design and the assessment of professional competence in such a way that mutual recognition of educational qualifications and registration systems between one country and another is complex (and very frustrating to those impacted by it).

This chapter looks at the purpose, rationale and the approach to registration and mobility through recognition of educational attainment and professional competence. It examines the principles and basis for the attributes and the differentiation between various categories of engineer. The chapter also reflects on the experience to date and possible future developments.

The chapter does this by examining systems which have been developed and tested over 25 years by the International Engineering Alliance.

LEARNING OUTCOMES

After you actively engage in the learning experiences in this module, you should be able to:

- Identify key learning outcomes of engineering education at various levels.
- Identify the key aspects of professional competence.
- Understand the indicators of attainment.
- Understand the common ethical considerations governing engineering activity worldwide.
- Understand why global consciousness and mobility of engineers is important.
- Understand the global responsibilities of engineers.
- Identify the regulatory constraints and barriers to the global dimension of education and training.

KEY CONCEPTS

These concepts will help you better understand the content in this session:

- Universal engineering education learning outcomes
- Definition of minimum levels of competence (independent of regulatory frameworks)
- Common ethical framework

GUIDING QUESTIONS

Develop your answers to the following guiding questions while completing the readings and working through the session:

- What are the graduate outcomes of a good engineering education programme?
- What are the characteristics of a competent engineer?
- What impedes the professional mobility of engineers?
- To what extent should engineers be self-regulated and why?

INTRODUCTION

With the continued increase of world trade in the 21st Century, engineering resources must become increasingly mobile to continue to provide for basic needs and support the emergence of new technologies all around the world. This fact underscores the importance of the Global Dimension in education and of improving the ability of engineers to be able to live and work in multiple countries (Bourn, 2008).

There are, however, numerous barriers to this professional mobility including language, culture, regulations and the cross-recognition of qualifications and competence. For example, countries with areas of engineering knowledge or capacity that require development may, at the same time, need to relocate their own engineers internationally in order for them to gain experience and competence in particular fields. Or, a country may have a requirement to integrate engineers from other countries into its own workforce (or within the workforce of international firms working there).

To deal with these issues individual by individual is both energy intensive and time consuming, and likely to lead to very slow progress in promoting international mobility (and widespread frustration). The problem is exacerbated where there is little understanding of the nature of engineering education and professional competence by either the importing or exporting jurisdictions (countries), which can sometimes lead to an overly bureaucratic and rigid regulatory system.

Hence the development of a common understanding of the content and standards of engineering education and competence – leading to cross recognition between jurisdictions is imperative. Historically this has been dealt with by bilateral agreements, but where engineering is regulated at state (sub-national) level rather than at national (federal) level – as is the case in the United States – the effort required to achieve broad mutual recognition is simply too great for most countries.

The problem is therefore not just regional but global. There have been various regional attempts to define and assess outcomes of engineering education including by: the European Federation of National Engineering Associations (FEANI); the European Network for Accreditation of Engineering Education (ENAEE); the Federation of Engineering Institutions of Asia and Pacific (FEIAP); and on a global scale by the OECD Assessment of Higher Education Learning Outcomes (AHELO) project, among others.

In the matter of defining both globally-relevant educational outcomes and professional competence standards and then attempting to obtain mutual recognition of these, the International Engineering Alliance (IEA) and its component educational accords and competence agreements (see Figure 1) have made considerable advances over the 25 years since they were first developed. The IEA has developed exemplar graduate attributes as a foundation for educational course design, accreditation and international benchmarking as well as developing competencies for professional engineers, engineering technologists and engineering technicians.

Table 1 *The component educational accords and competence agreements of the IEA:*

International Engineering Alliance						
Educational Accords			**Competence Recognition/Mobility Agreements**			
Washington Accord	Sydney Accord	Dublin Accord	International Professional Engineers Agreement	APEC Engineers Agreement	International Engineering Technologists Agreement	Technicians
Professional Engineers	*Engineering Technologists*	*Engineering Technicians*	*Professional Engineers*	*Professional Engineers (regional agreement)*	*Engineering Technologists*	*Future possibility*

This chapter looks at the purpose, rationale and the approach to registration and mobility through recognition of educational attainment and professional competence. It examines the principles and basis for the attributes and the differentiation between various categories of engineer, and reflects on experience to date and possible future developments.

THE REGULATORY FRAMEWORKS

Engineering around the world and at all levels is subject to a variety of regulation ranging from the completely open to the highly regulated or restricted. In some jurisdictions, the title ‘engineer’ is protected by law but in others it has no such restrictions. In some jurisdictions the engineering work in certain specialised areas is restricted to those licensed to undertake it, while in others the same fields are open.

In many countries there are also parallel professional accreditation and competence assessment systems which are used to evaluate education programmes and professional competence for membership of professional institutions. These are often benchmarked either against international norms, as is the case with the International Engineering Alliance, or regional norms as in the case of ENAEE/EURACE and FEANI.

However there are certain characteristics common to most licensing or professional competence evaluation regimes (whether in engineering or indeed other professions). These may include:

- A minimum standard of engineering education which may include particular subjects and specified educational qualifications or their equivalent,
- A minimum length of experience possibly of specified types,
- The meeting of certain ethical and personal criteria,
- An assessment and/or examination regime to confirm the standards are met,
- A requirement for continuing professional development to maintain licensure.

A typical model of professional development is shown in Figure 2 (Hanrahan, 2014).

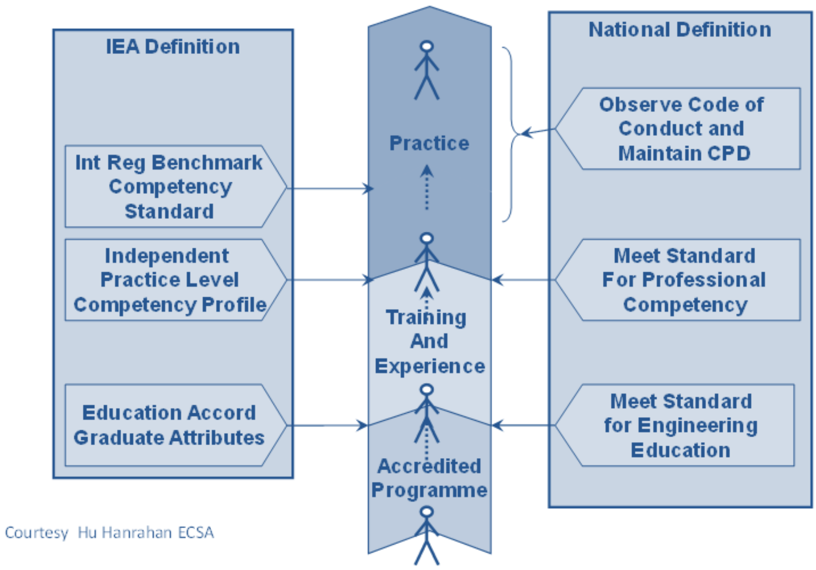

Figure 1 *Models for professional development*

Until about the end of 20th Century, most measures were largely based on input criteria e.g. years of study of particular subjects or years of particular experience etc. There are several problems with this sort of measurement. For example: the difficulty in determining the content of the courses, or; the difficulty in determining whether the knowledge and experience has transferred into practice by the engineer (particularly where the knowledge and experience has been gained in a foreign country, let alone in a foreign language with which the regulatory agency is unlikely to be familiar).

The determination of whether alternative education pathways were equivalent was also difficult. These factors obviously made the transfer from country to country of all professionals rather difficult – and certainly time consuming as well as consequently expensive. They were also perceived as restrictive by those doing the transfer. The problem is complicated by the wide range of engineering skills required in the modern world.

The logical answer was to develop measures of learning outcomes against some universal standardised criteria which could be more easily recognised internationally. As these output measures assessed the outcomes of an educational programme or the competencies of the individual they could then be both less dependent on input criteria and more flexible with respect to alternative educational and development pathways.

A direct corollary is that the processes and systems for assessing the outcomes of educational programmes (graduate attributes) or the candidate’s competency in practice must also be assessed – for producing equivalent outcomes in terms of standards and robustness. This means that these assessment systems and processes (which cover programme accreditation in the case of education and registration assessments with respect to professional competence) must themselves be assessed against an international benchmark. Many jurisdictions have developed accreditation systems and competence assessment systems but benchmarking these against agreed international exemplar standards, and getting this accepted by others who have achieved the standards, has been challenging – particularly for the many developing countries.

PRINCIPLES UNDERLYING REGISTRATION SYSTEMS, EDUCATIONAL ACCORDS AND COMPETENCE AGREEMENTS

The aim of a registration system is generally to ensure a minimum level of competence either generally or for a particular class of work. The primary aim of the IEA accords and agreements is to improve the global quality, productivity and mobility of engineers by being an accepted independent authority on best practice in standards, assessment and monitoring of engineering education and professional competence. Mobility and a common universal competence are facilitated by mutual recognition that the standards of educational qualifications and competence are equivalent and of high quality, and that the processes for assessment of these are agreed to be robust, repeatable and substantially equivalent.

One may well ask why any country should be concerned with mobility issues when an obvious consequence of increasing international mobility could be greater numbers of engineers leaving the country, just when needed for its own national development. This is a somewhat short-sighted view. Taking the example of New Zealand, 75% of people own a passport and many engineers go abroad to work, but nearly all of them return with greater skills, new ideas and the breadth of vision which every country needs to grow. Nations cannot develop if the flow of people and ideas is restricted (as the collapse of the former communist states of Europe demonstrated, that approach is ultimately self-defeating).

The first principle is that mobility is or should desirably be primarily a consequence of mutual recognition and trust in the quality of standards and processes rather than specific mobility agreements between countries. Negotiation of specific agreements such as bilateral agreements is too expensive and cumbersome for many to achieve true internationalism, particularly for small or developing countries.

The second principle is that of competence. Professional competence comprises:

- An agreed educational base (in the IEA this is an Accord recognised degree, or equivalent), combined with…
- Experience after graduation to develop both professional and personal maturity (for the IEA, this requires a minimum of seven years including two years responsible experience and ongoing continuing professional development. In some jurisdictions which use outcome-based assessment against criteria, the minimum time is not specified – whereas others define the minimum period and type of work required – but, in general, most systems will require about four years’ experience to meet the registration criteria), and…
- Meeting an agreed competence typically measured by evaluation against defined characteristics (there are 13 elements considered by the IEA to define competence in the ‘art of doing engineering’. Similar elements may be found in

many registration systems. Common critical elements among all registration and competence assessment systems are ethical and societal obligations in addition to technical requirements).

Therefore let us examine the nature of the exemplar standards for engineering education and competence and why the particular elements defining engineers have been chosen.

THE NATURE OF ENGINEERING

Firstly what is the nature of engineering? Engineering is a creative art supported by science and mathematics, with the creative process usually preceding the confirmation of practicality and limitations by physical and mathematical laws. Thus competence is not determined solely by education about facts and science but requires a period of (usually post-graduate) experiential learning to develop competence and, in particular, judgment to a professional standard through a process of mentoring. Indeed one of the criteria common to most registration systems is that the level of competence which must be demonstrated is that required for independent practice. Therefore the fundamental principle is that competence is understood to comprise knowledge plus experience plus mature personal qualities which it is necessary to define.

But engineering is complicated because – unlike some professions where work has traditionally been divided into separate and distinct roles and categories (for example medicine where doctors and nurses have distinctly different roles) – engineering work is an activity generally undertaken by a team in which the roles and qualifications more or less comprise a continuum, with sometimes blurred boundaries. The continuum includes labourers, tradesmen, technicians, technologists, professional engineers, researchers and a host of other roles. It has been commonly observed that where there are insufficient numbers in one category of engineer, those in the next highest category end up working in the lower roles or sometimes the less educated fill the positions with a much increased risk of failure. In some countries, there exists a perceived hierarchy of education that can result in too many being educated in some categories while there are too few in others (so that there are inadequate skill levels or numbers of people in trades or technical support roles). Engineering is a team activity and any weakness in the team will reflect on the success of the engineering outcomes.

Engineering is a profession in which often only inadequate or approximate information is available, risks abound and the potential impacts on societal safety can be large. Hence it is necessary to develop sound judgment at all levels. The required skills range from practical manufacturing or fabrication skills to the need for deep theoretical understanding of the fundamental physical and mathematical laws on which designs may be based. In general not all these attributes are present within any one individual, and it necessary to distinguish between the competencies required for each type of engineer.

Therefore we must define the various levels of engineering.

THE RESPONSIBILITIES OF ENGINEERS

Let us look at the responsibilities of engineers. Unless these are understood, any regulatory framework is likely to be deficient.

As engineering increases in complexity it is less well understood by those who are not engineers. This places a greater responsibility on engineers to investigate, understand and manage the consequences of their engineering. This requires careful consideration of the short and long term consequences of engineering decisions and a proper balancing of societal, economic, environmental and resource considerations: that is to say knowledge of matters that may be outside the bounds of ‘normal’ technical engineering.

While engineering is extremely powerful in transforming society it often uses non-renewable resources or technologies. This places an onus on engineers to balance the use of these resources with the future needs of our planet. We have the technology to do many things but the downsides of engineering can have planet-threatening consequences. For example, nuclear engineering can provide us with clean electricity, but can also be used for weapons such as the atomic bomb. Another important issue for many communities around the world is the use of water for irrigation which, when used to excess, can cause land salination and river or aquifer depletion. When we fly at 10,000 metres about three quarters of the earth’s atmosphere is below us, so the earth is covered with a very thin skin of vital gases which we must manage carefully and on which engineers may well have the greatest influence. For engineers there is therefore a duty of care far beyond that which may be imposed by national regulations, which tend to be reactionary, often created after engineering disasters and often not sufficient of themselves to ensure appropriate future-driven activities. There is nowhere engineering does not have an influence and it is thus extremely powerful. Every engineer at every level must care.

While the volume of knowledge available to engineers is increasing exponentially, the philosophical and sociological development needed to properly use and control advancements derived from that knowledge is much more linear. The introduction of proper limits and controls on new technologies lags behind their development. Technology may temporarily or, in the worst case, irretrievably outstrip our ability to adequately control the outcomes.

Thus technical knowledge is only part of engineering. It is critical that the education and training of engineers allows them to develop philosophical maturity in such areas as sustainability, societal aspects, risk management, ethics and the exercise of judgment, not only to increase the standard of engineering but also for the sustainability of our life on earth. These so-called ‘soft skills’ are at least as important as technical knowledge. The generation of these must be commenced in the fundamental education of engineers and should be universal.

There is nowhere engineering does not have an influence and it is thus extremely powerful. Every engineer at every level must care. With great power comes great responsibility and engineers must learn to use their capability wisely.

THE REQUIREMENTS OF A PROFESSION

It is also helpful to look at the requirements of a profession. If the highest level of engineer is the professional engineer, what is a profession and what are the elements that define it? In deciding the requirements of a profession, the following definition has been helpful:

> “*A profession is an occupational group which specialises in the performance of such highly developed skills for the meeting of complex human needs that the right use of them is achieved only under the discipline of an ethic developed and enforced by peers and by mastery of a broader contextual knowledge of the human being, society, the natural world, and historical trends*" (Reeck, 1982)

This definition has as key elements: knowledge, skills, contextual knowledge, peer discipline, and ethics plus a knowledge of the effects on humanity and the world and implies that complexity and judgment are essential components. Thus a broad education is essential for success.

The fundamental knowledge component and some skills are initially acquired by education, but must be further developed by supervised practice to the level of professional competence for independent practice. In this integration of education with the longer term development of professional competence it is important that the essential features of the education and subsequent development, as well as any registration system, are built upon a common, mutually understood base.

This base is provided by the elements defining the graduate attributes for professional engineers, engineering technologists and technicians.

THE ELEMENTS DEFINING GRADUATE ATTRIBUTES

From consideration of the nature of engineering, the responsibilities of engineers and those of a profession it is possible to determine the key elements to define the engineer. The 12 elements used by the IEA to describe the educational outcome (graduate) attributes for the Accords are identical for each category of engineering (see Appendix A)[1]:

- Engineering knowledge
- Problem analysis
- Design and development of solutions
- Investigation
- Modern tool usage
- The engineer and society
- Environment and sustainability
- Ethics
- Individual and team work
- Communication
- Project management and finance
- Lifelong learning

Note that seven of the twelve elements are substantially independent of any technical engineering. This emphasises the importance being placed on the development of so called ‘soft’ knowledge and skills which are essential to manage and control engineering. The IEA has heard a lot from industry around the world of the importance of those.

The elements are differentiated between the engineer categories by the complexity of problem solving and engineering activities in terms of a range of attributes (these are detailed in Appendix B).

Some jurisdictions have added indicators of attainment for each element to further assist the evaluation (e.g. New Zealand[2]).

In addition it is necessary to define the levels of complexity in problem solving and engineering activities as well as the knowledge profile required for each type of engineer (see Appendix C).

Examination of these elements above and the range statements and knowledge profiles shows several features:

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[1] These are shown in detail on the IEA website www.ieagreements.com/GradProfiles.cfm
[2] See www.ipenz.org.nz/ipenz/forms/pdfs/ACC%2002%20(Final%20format)%20Feb%202014.pdf

- The elements are outcome-focussed rather than input or content-focussed. Thus for any particular programme there is a requirement to map the outcomes against the outputs sought by course assessments. For the registration or competence test there must be a must be an assessment against each element.
- Not all elements are of equal importance or weighting. For example, fundamental technical knowledge is of paramount importance (Element 1) as it underpins other elements, so a further knowledge profile has been developed for each of the Accord programmes. Hence it is not simply an arithmetical exercise to determine whether a programme meets the criteria. Holistic professional judgment is required not only in the accreditation of individual programmes but also in quality assurance and mutual recognition of accreditation systems and competence assessment processes.
- It is clear that much of engineering work can and should be done by engineering technologists and technicians particularly in well-established industries, with perhaps relatively fewer graduates in the professional engineering category operating at the complex forefront of the profession.

A sound educational programme must also demonstrate that it is robust and secure with respect to delivery of the learning outcomes. This includes evaluation of such input aspects as staffing, facilities, finance, connection with industry and freedom from corruption. These must be evaluated during the accreditation process. For example one critical aspect is that of adequate funding of education and it is clear that there are challenges in that regard for engineering education in many countries.

ENGINEERING EDUCATION PROGRAMME ACCREDITATION

The Washington, Sydney and Dublin Accords are the constituent educational agreements within the International Engineering Alliance. Participants in these agreements, termed signatories, are committed to benchmarking of engineering education standards for engineers, engineering technologists and engineering technicians respectively and to mutual recognition of the graduates of accredited educational programmes within each role. The Accords are concerned with the education process as part of the formation of independent engineering practitioners for the following roles:

- Washington Accord: engineering at the professional level;
- Sydney Accord: engineering technology practice within the engineering team;
- Dublin Accord: engineering technician practice within the engineering team;

Mutual recognition of programmes accredited by one signatory by other signatories is based on the verified comparability of accreditation criteria, including the outcome standards, policies and procedures. Such verification takes place when an agency applies to become a signatory and in periodic monitoring of existing signatory bodies. Two points of reference are used when an Accord reviews an accrediting agency. First, the standards applied by the agency under review are expected to be substantially equivalent to the Accord’s Graduate Attribute exemplars (IEA 2013) for each Accord. Second, the agency is expected to operate an accreditation process characterised by quality indicators specified in the Accords Rules and Procedures1 (IEA 2012), applicable under all Accords.

Signatories agree to grant (or recommend to the relevant national registration body, if different) graduates of each other’s accredited programmes the same recognition, rights and privileges as they grant to graduates of their own accredited programmes. By these provisions, the Accords facilitate mobility of graduates between signatory jurisdictions and deeper understanding and recognition of their engineering education and accreditation systems. Amongst the signatories’ educational providers, adherence to local accreditation requirements that are consistent with the professional engineer graduate attribute exemplars contributes to international benchmarking of programme outcomes.

PROFESSIONAL COMPETENCY

The IEA competency agreements are multi-national agreements between engineering organisations in the member jurisdictions. The agreements create the frameworks for the establishment of international standards of competence for professional engineering and engineering technology. They then empower each member organisation to establish a section of the International Professional Engineers (IntPE) and International Engineering Technologists (IntET) registers.

The matrix of elements to be considered in designing criteria to assess competence is multidimensional and must allow for variation in the importance of the various elements to describe the different types of engineer. Any system of elemental description of attributes of competence must also be able to describe the full range of engineering required.

The 13 elements describing professional competency of the mature engineering practitioner are not exactly the same as the graduate attribute elements but are built upon them and similarly differentiated between professional engineer, engineering technologist and technician on the basis of the range statements and knowledge profiles (those for professional engineers are summarised in Appendix D).

EVALUATION IN PRACTICE

Accreditation of Education Programmes

If we look at evaluation in practice, the IEA graduate attributes exemplars are intended to be of assistance in the design of both particular courses and national accreditation systems and, of course, evaluation of national systems by each of the accords. Among the IEA Accord members, the complete evaluation of national accreditation systems is initially done for any jurisdiction by a multinational three-person panel on initial application for signatory status and is revaluated every six years.

The internally similar and consistent design of the elemental criteria can allow concurrent evaluation of adjacent accord programmes in a single institution depending on individual institutional arrangements e.g. concurrent evaluation of Washington Accord (professional engineering) and Sydney Accord (engineering technologist) programmes or Sydney Accord and Dublin Accord (technician) programmes within a single institution.

The extent to which national systems have adopted outcome-based accreditation varies around the world but the nature of the elemental criteria does allow evaluation of the outcomes. There is some evidence that the adoption of outcomes-based accreditation systems has been a strong driver of educational improvement (King, 2012).

A comparison of the IEA Graduate Attributes with the EUR-ACE Framework Standards for the Accreditation of Engineering Programmes[3] shows that although both the IEA and the EUR-ACE criteria were designed to meet employment needs, the language used in the two sets of outcomes descriptors and the approach are different and in some cases less closely defined in the EUR-ACE document. Four signatories of the Washington Accord are also ENAEE members authorised to award the EUR-ACE label to accredited programmes.

Competence Assessment

The logical extension of the evaluation of academic programmes and national accreditation systems is the evaluation of professional competence in the various categories of engineer. It is clear that around the world the concept of professional competence varies in the extent to which it is developed and/or the formal expression of it. Indeed some countries have not yet developed the understanding of professionalism or the framework for assessing this which has led in some cases to significant disadvantages in attempting to up-skill the local engineering workforce through international construction contracts. Many examples exist of construction contracts awarded to international companies or through aid projects where the

[3] See www.enaee.eu/publications/european-framework-standards

offshore contractor brings all labour and there is little transfer of skills to the host country’s workforce, partly at least because of a lack of understanding of the local qualifications[4].
There is also the concurrent change in assessment methods from historical input measures i.e. years or hours of mathematics, science, experience etc., to the greater emphasis on assessment of outcomes and professional and personal attributes. The definition of a profession quoted earlier implies that it must be subject to self-discipline and self-regulation by peers and not only by the government.

Consideration of the FEANI requirements for EUR ING shows that FEANI allows for membership to be achieved from a variety of engineering education starting points but essentially requires three years of approved university engineering education or its equivalent. The International Professional Engineers Agreement in the IEA defines the required competencies of a professional engineer whereas FEANI does not explicitly do this. Thus the standards required for internationally recognised professional membership differs somewhat between the IEA and FEANI.

Experience to Date

The experience to date of both individual countries and within the Accords and Competence Agreements has demonstrated the validity of the approach. This has resulted in increasing interest and uptake from a wide range of countries who perceive both internal and mobility benefits (e.g. India has become a signatory to the Washington Accord and China has recently joined as a Provisional Member of the same Accord). The use of the range statements and concepts of variable complexity have enhanced the ability to distinguish between different classes of engineer and the educational programmes that underpin them.

One significant advantage of the Accords is that they evaluate national systems rather than individuals and thus achieve considerable benefit to individuals. There is however a somewhat uneven understanding of the differences between the various categories of engineer particularly between professional engineer and engineering technologist and their associated accords. The name ‘engineering technologist’ may be an unattractive title to those who think of themselves primarily as engineers.

The related competency agreements are based on exemplar competency standards in a manner similar to the accords for education. This system has improved mobility but the benefits vary from country to country. While at the moment the agreements describe standards of competence for individuals, in due course national systems may be declared to meet the required standards. This has the significant advantage of greater coverage for those jurisdictions while at the same time also covering individuals who meet the

[4] Personal discussions in Russia and Sri Lanka.

international benchmarks but who belong to jurisdictions whose national standards do not meet the required exemplars.

ISSUES

There are, of course, a significant number of issues and refinements needed, including:

- **Inconsistency in the methods of assessment of competence**
  Jurisdictions assess competence for institutional membership or registration by a variety of methods. Some have no further assessment after graduation with an approved qualification. Some require sitting examinations followed by interview. Some require submission of a portfolio of evidence of experience against criteria followed by essay and/or interview. Some have minimum experience requirements, some have none. Some are a combination of all of these. Reconciliation of these methods is an ongoing issue but the foundation on which they are all built is the basic engineering education.
- **Recognition of prior experience and credit for prior learning**
  One could reasonably expect that a recognised and accepted qualification gained by any route would be acceptable to registration authorities or professional bodies. However some bodies have some difficulty doing this because of the variety of entry routes and variable recognition of prior learning. Some specify minimum periods of study for the qualification which mitigates against recognition of prior learning. This can be a particular issue where qualifications are gained outside national boundaries.
- **Provincial/state versus national control of registration**
  In some jurisdictions where engineering is regulated at provincial or state level there is difficulty in negotiating international agreements because there may or may not be a national representative body authorised to negotiate on behalf of the individual provinces or states.
- **Registration versus membership of professional institutions**
  Professional membership of institutions may or may not require proof of competence other than graduation with an approved qualification but registration generally does. Many jurisdictions give institutional membership for life whereas most registration authorities require at least evidence of continuing professional development and some, such as New Zealand, require formal reassessment every few years based on a portfolio of evidence.

CONCLUSIONS

The experience of the International Engineering Alliance is that the international educational accords based on exemplar elemental graduate attributes have contributed to a wider understanding of the required outcomes of an engineering education and to the development of engineering education in a number of countries while not constraining educational individuality.

The further development of professional competencies for registration typically defined on an elemental basis has allowed a more robust assessment of individuals and national standards of engineering competence. However while engineering is governed by universal physical laws it is subject to local requirements and affected by cultural, social, environmental and risk considerations. Thus there is still further development work required by regional and global accreditation and competence assessment bodies to obtain a more universal understanding and definition of the various categories of engineer and the extent to which these should be benchmarked against common standards.

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IPENZ, Chartered Professional Engineer of New Zealand Rules www.ipenz.org.nz/IPENZ/Forms/pdfs/CPEngRules.pdf

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FURTHER/SUGGESTED MATERIAL

- International Engineering Alliance www.ieagreements.org
- Engineering Council UK www.engc.org.uk
- ENAEE Accreditation guidelines www.enaee.eu/publications/standardsguidelines-for-accreditation-agencies
- ENAEE Education standards www.enaee.eu/publications/european-framework-standards
- FEANI and EUR ING www.feani.org/site/index.php?id=111
- IPENZ Accreditation Requirements www.ipenz.org.nz/ipenz/forms/pdfs/ACC%2002%20(Final%20format)%20Feb%202014.pdf

APPENDIX A: Extracts from the IEA Graduate Attributes

Differentiating Characteristic	… for Washington Accord Graduate	… for Sydney Accord Graduate	… for Dublin Accord Graduate
Engineering Knowledge	**WA1:** Apply knowledge of mathematics, natural science, engineering fundamentals and an engineering specialization as specified in WK1 to WK4 respectively to the solution of complex engineering problems.	**SA1:** Apply knowledge of mathematics, natural science, engineering fundamentals and an engineering specialization as specified in SK1 to SK4 respectively to defined and applied engineering procedures, processes, systems or methodologies.	**DA1:** Apply knowledge of mathematics, natural science, engineering fundamentals and an engineering specialization as specified in DK1 to DK4 respectively to wide practical procedures and practices.
Problem Analysis: Complexity of analysis	**WA2:** Identify, formulate, research literature and analyse *complex* engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences. (WK1 to WK4)	**SA2:** Identify, formulate, research literature and analyse *broadly-defined* engineering problems reaching substantiated conclusions using analytical tools appropriate to the discipline or area of specialisation. (SK1 to SK4)	**DA2:** Identify and analyse *well-defined* engineering problems reaching substantiated conclusions using codified methods of analysis specific to their field of activity. (DK1 to DK4)
Design/ development of solutions: Breadth and uniqueness of engineering problems i.e. the extent to which problems are original and to which solutions have previously been identified or codified	**WA3:** Design solutions for *complex* engineering problems and design systems, components or processes that meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations. (WK5)	**SA3:** Design solutions for *broadly- defined* engineering technology problems and *contribute to* the design of systems, components or processes to meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations. (SK5)	**DA3:** Design solutions for *well-defined* technical problems and *assist with* the design of systems, components or processes to meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations. (DK5)
Investigation: Breadth and depth of investigation and experimentation	**WA4:** Conduct investigations of *complex* problems using research-based knowledge (WK8) and research methods including design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions.	**SA4:** Conduct investigations of *broadly-defined* problems; locate, search and select relevant data from codes, data bases and literature (SK8), design and conduct experiments to provide valid conclusions.	**DA4:** Conduct investigations of *well-defined* problems; locate and search relevant codes and catalogues, conduct standard tests and measurements.
Modern Tool Usage: Level of understanding of the appropriateness of the tool	**WA5:** Create, select and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modelling, to *complex* engineering problems, with an understanding of the limitations. (WK6)	**SA5:** Select and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modelling, to *broadly-defined* engineering problems, with an understanding of the limitations. (SK6)	**DA5:** Apply appropriate techniques, resources, and modern engineering and IT tools to *well- defined* engineering problems, with an awareness of the limitations. (DK6)

The Engineer and Society: Level of knowledge and responsibility	**WA6:** Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice and solutions to complex engineering problems. (WK7)	**SA6:** Demonstrate understanding of the societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to engineering technology practice and solutions to broadly defined engineering problems. (SK7)	**DA6:** Demonstrate knowledge of the societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to engineering technician practice and solutions to well defined engineering problems. (DK7)
Environment and Sustainability: Type of solutions.	**WA7:** Understand and evaluate the sustainability and impact of professional engineering work in the solution of complex engineering problems in societal and environmental contexts. (WK7)	**SA7:** Understand and evaluate the sustainability and impact of engineering technology work in the solution of broadly defined engineering problems in societal and environmental contexts. (SK7)	**DA7:** Understand and evaluate the sustainability and impact of engineering technician work in the solution of well-defined engineering problems in societal and environmental contexts. (DK7)
Ethics: Understanding and level of practice	**WA8:** Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice. (WK7)	**SA8:** Understand and commit to professional ethics and responsibilities and norms of engineering technology practice. (SK7)	**DA8:** Understand and commit to professional ethics and responsibilities and norms of technician practice. (DK7)
Individual and Team work: Role in and diversity of team	**WA9:** Function effectively as an individual, and as a member or leader in diverse teams and in multi-disciplinary settings.	**SA9:** Function effectively as an individual, and as a member or leader in diverse teams.	**DA9:** Function effectively as an individual, and as a member in diverse technical teams.
Communication: Level of communication according to type of activities performed	**WA10:** Communicate effectively on *complex* engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.	**SA10:** Communicate effectively on *broadly- defined* engineering activities with the engineering community and with society at large, by being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions	**DA10:** Communicate effectively on *well-defined* engineering activities with the engineering community and with society at large, by being able to comprehend the work of others, document their own work, and give and receive clear instructions
Project Management and Finance: Level of management required for differing types of activity	**WA11:** Demonstrate knowledge and understanding of engineering management principles and economic decision-making and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.	**SA11:** Demonstrate knowledge and understanding of engineering management principles and apply these to one's own work, as a member or leader in a team and to manage projects in multidisciplinary environments.	**DA11:** Demonstrate knowledge and understanding of engineering management principles and apply these to one's own work, as a member or leader in a technical team and to manage projects in multidisciplinary environments
Lifelong learning: Preparation for and depth of continuing learning.	**WA12:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.	**SA12:** Recognize the need for, and have the ability to engage in independent and life-long learning in specialist technologies.	**DA12:** Recognize the need for, and have the ability to engage in independent updating in the context of specialized technical knowledge.

APPENDIX B: IEA Complexity Definitions

Range of Problem Solving:

Attribute	Complex Engineering Problems have characteristic WP1 and some or all of WP2 to WP7:	Broadly-defined Engineering Problems have characteristic SP1 and some or all of SP2 to SP7:	Well-defined Engineering Problems have characteristic DP1 and some or all of DP2 to DP7:
In the context of both Graduate Attributes and Professional Competencies			
Depth of Knowledge Required	**WP1:** Cannot be resolved without in-depth engineering knowledge at the level of one or more of WK3, WK4, WK5, WK6 or WK8 which allows a fundamentals-based, first principles analytical approach	**SP1:** Cannot be resolved without engineering knowledge at the level of one or more of SK 4, SK5, and SK6 supported by SK3 with a strong emphasis on the application of developed technology	**DP1:** Cannot be resolved without extensive practical knowledge as reflected in DK5 and DK6 supported by theoretical knowledge defined in DK3 and DK4
Range of conflicting requirements	**WP2:** Involve wide-ranging or conflicting technical, engineering and other issues	**SP2:** Involve a variety of factors which may impose conflicting constraints	**DP2:** Involve several issues, but with few of these exerting conflicting constraints
Depth of analysis required	**WP3:** Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models	**SP3:** Can be solved by application of well-proven analysis techniques	**DP3:** Can be solved in standardised ways
Familiarity of issues	**WP4:** Involve infrequently encountered issues	**SP4:** Belong to families of familiar problems which are solved in well-accepted ways	**DP4:** Are frequently encountered and thus familiar to most practitioners in the practice area
Extent of applicable codes	**WP5:** Are outside problems encompassed by standards and codes of practice for professional engineering	**SP5:** May be partially outside those encompassed by standards or codes of practice	**DP5:** Are encompassed by standards and/or documented codes of practice
Extent of stakeholder involvement and conflicting requirements	**WP6:** Involve diverse groups of stakeholders with widely varying needs	**SP6:** Involve several groups of stakeholders with differing and occasionally conflicting needs	**DP6:** Involve a limited range of stakeholders with differing needs
Interdependence	**WP 7:** Are high level problems including many component parts or sub-problems	**SP7:** Are parts of, or systems within complex engineering problems	**DP7:** Are discrete components of engineering systems
In addition, in the context of the Professional Competencies			
Consequences	**EP1:** Have significant consequences in a range of contexts	**TP1:**Have consequences which are important locally, but may extend more widely	**NP1:** Have consequences which are locally important and not far-reaching
Judgement	**EP2:** Require judgement in decision making	**TP2:** Require judgement in decision making	

Range of Engineering Activities:

Attribute	Complex Activities	Broadly-defined Activities	Well-defined Activities
Preamble	**Complex activities** means *(engineering)* activities or projects that have some or all of the following characteristics:	**Broadly defined activities** means *(engineering)* activities or projects that have some or all of the following characteristics:	**Well-defined activities** means *(engineering)* activities or projects that have some or all of the following characteristics:
Range of resources	**EA1:** Involve the use of diverse resources (and for this purpose resources includes people, money, equipment, materials, information and technologies)	**TA1:** Involve a variety of resources (and for this purposes resources includes people, money, equipment, materials, information and technologies)	**NA1:** Involve a limited range of resources (and for this purpose resources includes people, money, equipment, materials, information and technologies)
Level of interactions	**EA2:** Require resolution of significant problems arising from interactions between wide- ranging or conflicting technical, engineering or other issues,	**TA2:** Require resolution of occasional interactions between technical, engineering and other issues, of which few are conflicting	**NA2:** Require resolution of interactions between limited technical and engineering issues with little or no impact of wider issues
Innovation	**EA3:** Involve creative use of engineering principles and research-based knowledge in novel ways.	**TA3:** Involve the use of new materials, techniques or processes in non-standard ways	**NA3:** Involve the use of existing materials techniques, or processes in modified or new ways
Consequences to society and the environment	**EA4:** Have significant consequences in a range of contexts, characterized by difficulty of prediction and mitigation	**TA4:** Have reasonably predictable consequences that are most important locally, but may extend more widely	**NA4:** Have consequences that are locally important and not far-reaching
Familiarity	**EA5:** Can extend beyond previous experiences by applying principles-based approaches	**TA5:** Require a knowledge of normal operating procedures and processes	**NA5:** Require a knowledge of practical procedures and practices for widely-applied operations and processes

APPENDIX C: IEA Knowledge Profile

A Washington Accord programme provides:	A Sydney Accord programme provides:	A Dublin Accord programme provides:
WK1: A systematic, theory-based understanding of the **natural sciences** applicable to the discipline	**SK1:** A systematic, theory-based understanding of the **natural sciences** applicable to the sub-discipline	**DK1:** A descriptive, formula-based understanding of the **natural sciences** applicable in a sub-discipline
WK2: Conceptually-based **mathematics**, numerical analysis, statistics and formal aspects of computer and information science to support analysis and modelling applicable to the discipline	**SK2:** Conceptually-based **mathematics**, numerical analysis, statistics and aspects of computer and information science to support analysis and use of models applicable to the sub-discipline	**DK2:** Procedural **mathematics**, numerical analysis, statistics applicable in a sub-discipline
WK3: A systematic, theory-based formulation of **engineering fundamentals** required in the engineering discipline	**SK3:** A systematic , theory-based formulation of **engineering fundamentals** required in an accepted sub-discipline	**DK3:** A coherent procedural formulation of **engineering fundamentals** required in an accepted sub-discipline
WK4: Engineering **specialist knowledge** that provides theoretical frameworks and bodies of knowledge for the accepted practice areas in the engineering discipline; much is at the forefront of the discipline.	**SK4:** Engineering **specialist knowledge** that provides theoretical frameworks and bodies of knowledge for an accepted sub-discipline	**DK4:** Engineering **specialist knowledge** that provides the body of knowledge for an accepted sub-discipline
WK5: Knowledge that supports **engineering design** in a practice area	**SK5:** Knowledge that supports **engineering design** using the technologies of a practice area	**DK5:** Knowledge that supports **engineering design** based on the techniques and procedures of a practice area
WK6: Knowledge of **engineering practice** (technology) in the practice areas in the engineering discipline	**SK6:** Knowledge of **engineering technologies** applicable in the sub-discipline	**DK6:** Codified **practical engineering knowledge** in recognised practice area.
WK7: Comprehension of the role of engineering in society and identified issues in engineering practice in the discipline: ethics and the professional responsibility of an engineer to public safety; the impacts of engineering activity: economic, social, cultural, environmental and sustainability	**SK7: Comprehension of** the role of technology in society and identified issues in applying engineering technology: ethics and impacts: economic, social, environmental and sustainability	**DK7: Knowledge** of issues and approaches in engineering technician practice: ethics, financial, cultural, environmental and sustainability impacts
WK8: Engagement with selected knowledge in the **research literature** of the discipline	**SK8:** Engagement with the **technological literature** of the discipline	
A programme that builds this type of knowledge and develops the attributes listed below is typically achieved in 4 to 5 years of study, depending on the level of students at entry.	A programme that builds this type of knowledge and develops the attributes listed below is typically achieved in 3 to 4 years of study, depending on the level of students at entry.	A programme that builds this type of knowledge and develops the attributes listed below is typically achieved in 2 to 3 years of study, depending on the level of students at entry.

APPENDIX D: Professional Competency Profile

To meet the minimum standard of competence a person must demonstrate that he/she is able to practice competently in his/her practice area to the standard expected of a reasonable Professional Engineer/Engineering Technologist/Engineering Technician.

The extent to which the person is able to perform each of the following elements in his/her practice area must be taken into account in assessing whether or not he/she meets the overall standard.

Differentiating Characteristic	Professional Engineer	Engineering Technologist	Engineering Technician
Comprehend and apply universal knowledge: Breadth and depth of education and type of knowledge	**EC1:** Comprehend and apply advanced knowledge of the widely-applied principles underpinning good practice	**TC1:** Comprehend and apply the knowledge embodied in widely accepted and applied procedures, processes, systems or methodologies	**NC1:** Comprehend and apply knowledge embodied in standardised practices
Comprehend and apply local knowledge: Type of local knowledge	**EC2:** Comprehend and apply advanced knowledge of the widely-applied principles underpinning good practice specific to the jurisdiction in which he/she practices.	**TC2:** Comprehend and apply the knowledge embodied procedures, processes, systems or methodologies that is specific to the jurisdiction in which he/she practices.	**NC2:** Comprehend and apply knowledge embodied in standardised practices specific to the jurisdiction in which he/she practices.
Problem analysis: Complexity of analysis	**EC3:** Define, investigate and analyse complex problems	**TC3:** Identify, clarify, and analyse broadly-defined problems	**NC3:** Identify, state and analyse well-defined problems
Design and development of solutions: Nature of the problem and uniqueness of the solution	**EC4:** Design or develop solutions to complex problems	**TC4:** Design or develop solutions to broadly-defined problems	**NC4:** Design or develop solutions to well-defined problems
Evaluation: Type of activity	**EC5:** Evaluate the outcomes and impacts of complex activities	**TC5:** Evaluate the outcomes and impacts of broadly defined activities	**NC5:** Evaluate the outcomes and impacts of well-defined activities

Protection of society: Types of activity and responsibility to public	**EC6:** Recognise the reasonably foreseeable social, cultural and environmental effects of complex activities generally, and have regard to the need for sustainability; recognise that the protection of society is the highest priority	**TC6:** Recognise the reasonably foreseeable social, cultural and environmental effects of broadly-defined activities generally, and have regard to the need for sustainability; take responsibility in all these activities to avoid putting the public at risk.	**NC6:** Recognise the reasonably foreseeable social, cultural and environmental effects of well-defined activities generally, and have regard to the need for sustainability; use engineering technical expertise to prevent dangers to the public.
Legal and regulatory: No differentiation in this characteristic	**EC7:** Meet all legal and regulatory requirements and protect public health and safety in the course of his or her activities	**TC7:** Meet all legal and regulatory requirements and protect public health and safety in the course of his or her activities	**NC7:** Meet all legal and regulatory requirements and protect public health and safety in the course of his or her activities
Ethics: No differentiation in this characteristic	**EC8:** Conduct his or her activities ethically	**TC8:** Conduct his or her activities ethically	**NC8:** Conduct his or her activities ethically
Manage engineering activities: Types of activity	**EC9:** Manage part or all of one or more complex activities	**TC9:** Manage part or all of one or more broadly-defined activities	**NC9:** Manage part or all of one or more well-defined activities
Communication: No differentiation in this characteristic	**EC10:** Communicate clearly with others in the course of his or her activities	**TC10:** Communicate clearly with others in the course of his or her activities	**NC10:** Communicate clearly with others in the course of his or her activities
Lifelong learning: Preparation for and depth of continuing learning.	**EC11:** Undertake CPD activities sufficient to maintain and extend his or her competence	**TC11:** Undertake CPD activities sufficient to maintain and extend his or her competence	**NC11:** Undertake CPD activities sufficient to maintain and extend his or her competence
Judgement: Level of developed knowledge, and ability and judgement in relation to type of activity	**EC12:** Recognize complexity and assess alternatives in light of competing requirements and incomplete knowledge. Exercise sound judgement in the course of his or her complex activities	**TC12:** Choose appropriate technologies to deal with broadly defined problems. Exercise sound judgement in the course of his or her broadly-defined activities	**NC12:** Choose and apply appropriate technical expertise. Exercise sound judgement in the course of his or her well- defined activities
Responsibility for decisions: Type of activity for which responsibility is taken	**EC13:** Be responsible for making decisions on part or all of complex activities	**TC13:** Be responsible for making decisions on part or all of one or more broadly defined activities	**NC13:** Be responsible for making decisions on part or all of all of one or more well-defined activities

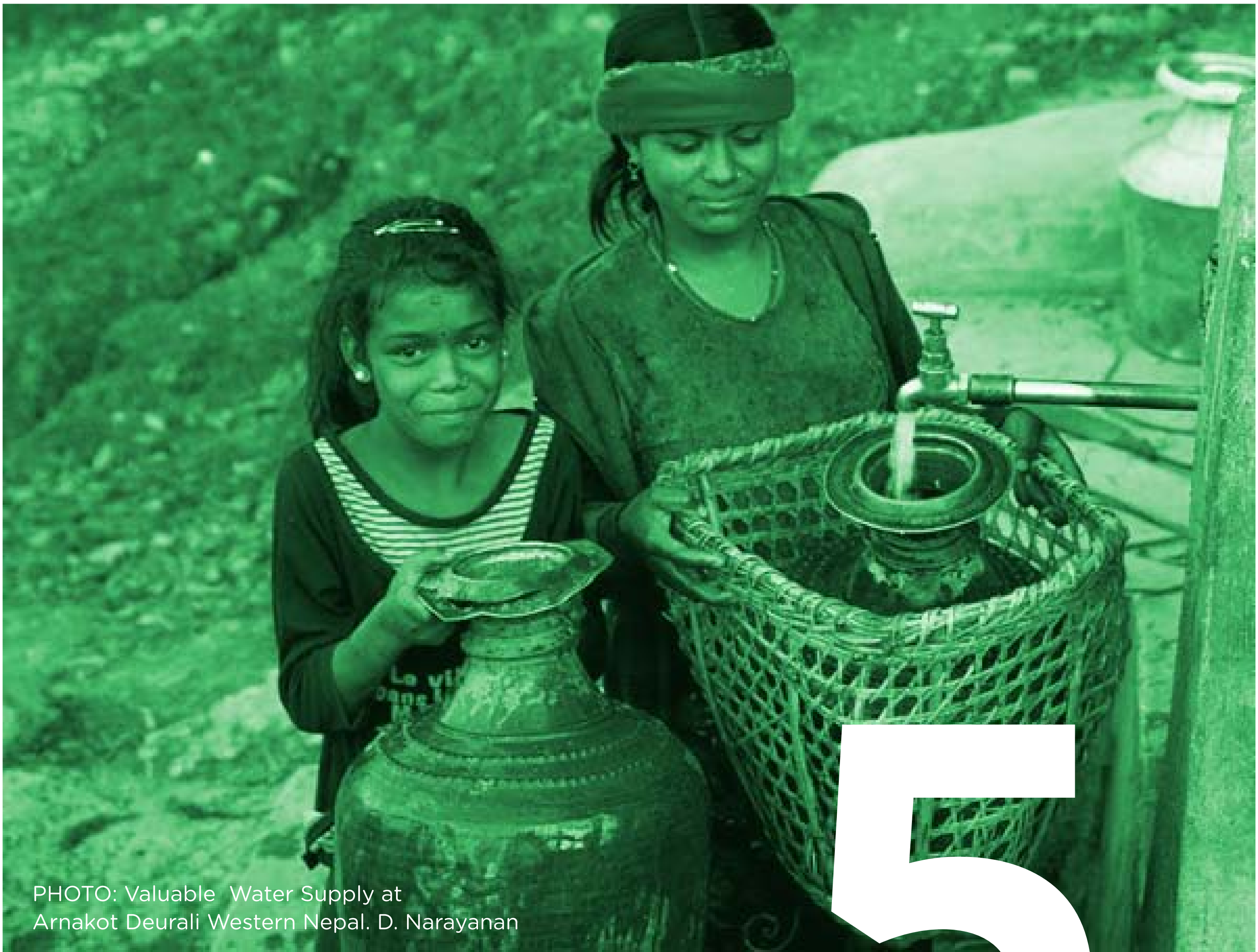

PHOTO: Valuable Water Supply at Arnakot Deurali Western Nepal. D. Narayanan

CHAPTER 5

Monitoring and evaluation

5

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5 MONITORING AND EVALUATION

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EXECUTIVE SUMMARY

It is important to monitor and evaluate the effectiveness of learning and teaching interventions to inform a process of improvement and development. When proposing a new curriculum development to deliver the Global Dimension, design of the evaluation scheme should form part of the initial planning.

This chapter will look at approaches to monitoring and evaluating the effectiveness of learning and teaching interventions, including different methods used to monitor and evaluate student learning and student engagement with the learning process. Examples of evaluation in the 'Global Engineering Challenge' project week at the University of Sheffield – where approximately 1,000 students participate in the Engineers Without Borders Challenge – are used to illustrate some evaluation methods and provide a review of what worked well and the difficulties encountered.

LEARNING OUTCOMES

After you actively engage in the learning experiences in this module, you should be able to:

- Understand the importance and relevance of monitoring and evaluation in the development of new courses.
- Understand the principles for conducting an evaluation.
- Design an outline monitoring and evaluation programme for a curriculum intervention.

KEY CONCEPTS

These concepts will help you better understand the content in this session:

- Aims of Evaluation
- Evaluation approaches and methods
- Survey Construction

GUIDING QUESTIONS

Develop your answers to the following guiding questions while completing the readings and working through the session:

- What is the purpose of your evaluation? – i.e. what aspects of the intervention are you trying collect information about?
- When are appropriate times to collect and interpret information during the learning process in order to take effective action to develop and improve the effect of the teaching?
- What evaluation techniques would be appropriate for your specific type of teaching intervention / learning environment?
- What technologies do you have for surveying your students (questionnaires, Virtual Learning Environment (VLE) such as Blackboard or Moodle, Google forms, electronic instant polling systems?) and how will these affect the response rate and types of response?
- How will you communicate with your students?
- How might you enhance the engagement of your students with an evaluation survey?
- What risks / problems do you need to be aware of?

INTRODUCTION

Evaluation is a means by which we gauge success and initiate improvements. It is important at all stages of learning and teaching, and should form part of the initial planning of a course rather than just the final activity to be considered and reviewed once the course is finished. By considering monitoring and evaluation at the outset, it can be planned effectively, designed to feed forward and to improve the course as it progresses, and implemented at relevant stages of the course.

Effective monitoring and evaluation of the Global Dimension in Engineering Education can also provide evidence for making a case for embedding it across the engineering curriculum, and for discussion in papers that contribute to the literature.

This chapter is illustrated with examples from the Global Engineering Challenge (GEC) project week at the University of Sheffield. Following a brief overview of the GEC project at Sheffield, discussion on evaluation starts with a review of why we should evaluate and definitions and aims of monitoring and evaluation, before progressing to look at approaches to evaluation and techniques that can be applied.

A brief overview of the Global Engineering Project Week at the University of Sheffield

The Global Engineering Challenge (GEC) Project Week at the University of Sheffield takes place over one week, and involves all 1,000 first year engineering and computer science students working in multi-disciplinary, international groups to tackle projects associated with the Engineers Without Borders Challenge (see www.ewb-uk.org/ewbchallenge). The project week is currently non-credit-bearing, but compulsory for progression. The overall aims of the project week are to promote awareness and understanding of the Global Dimension of engineering and to develop professional / employability skills, including experience of collaborating and working in diverse teams, project management and communication.

Each group comprises six students, and six groups are organised into a “hub” (i.e. 36 students in total). Each hub has a dedicated room for the week and also a dedicated Graduate Teaching Assistant (GTA) Facilitator. The week commences with an opening plenary involving invited and internal speakers, to motivate, inspire and convey the aims of the week. Thereafter students work with their groups in their hub rooms with group project working time interspersed with interactive, facilitated sessions (led by the GTAs) on global dimensions, communication, problem solving and project management.

Examples of evaluation undertaken in the GEC are used throughout the text to illustrate and provide ideas for what has gone well and pitfalls to avoid. A summary of the various assessment and evaluation opportunities is outlined below.

- **Learning outcomes & formative assessment:**
  The overt learning outcomes were conveyed to the students via assessment criteria around the Global Dimension. These were publicised by having an electronic copy hosted in the VLE course, by issuing paper copies to each group and also having posters displayed in each hub. However, to ensure a mid-week formative assessment stage, the groups were further asked to grade their progress against the assessment criteria and to create a poster reviewing their progress (achievements, what could have been done better, proposed changes and renewed objectives).

  A further set of learning outcomes, not conveyed to the students and part of the 'hidden curriculum' (Jackson, W., 1968) surround their ability to work successfully in diverse groups and develop professional skills. While there were daily group review exercises, the mid-week formative stage also asked the students to create a second poster, this time reviewing their group working (again achievements, what could have been done better, proposed changes and renewed objectives).

  Both posters were then presented to a 'hub board' comprising the GTA, a staff member and visiting alumni. The groups presented their posters and received feedback on both aspects of their working: their review of progress in achieving the assessment criteria and their review of their group working.

- **Summative assessment:**
  At the end of the week, groups submit a final report through the VLE and give a group presentation within the hub. In both cases, marking and feedback is given around the assessment criteria. The report is marked within the VLE by the GTAs. The group presentations are marked by all present in the hub – i.e. all students not presenting, the GTA and a staff member. Since everyone is treated equally, the bulk of the opinion comes from the peer-vote. This is done using clickers (or smart devices) to poll against the assessment criteria and sum the results. An in-house macro was designed to extend the functionality of the polling software in order to do this.

- **Transformative evaluation:**
  Have students transformed their behaviour as a result of engagement in the GEC? Students were asked to complete a pre and post GEC questionnaire in order to establish whether they perceived a change in their behaviours from engaging in the week. The questionnaire was created in the VLE using the Survey tool and comprised a set of Multiple Choice Questions (MCQs).

- **Process evaluation:** How can we improve the week for the future? As an innovative activity, we were keen to understand student what students thought of the week, what they thought had been valuable and to gain insight into things we could improve for the future. We did this by way of a Survey Monkey quiz which involved both MCQs and open text responses. Google forms would offer similar functionality.

Once we had processed this data, we followed up with a Focus Group which we conducted as a semi-structured interview. This enabled us to delve into more detail into the initial quantitative responses and gain greater insight into the "why" behind some of the responses.

Why Evaluate?

> "*Effective teaching refuses to take its effect on students for granted*" (Ramsden 2003 pp 98)

Teaching and learning are directly linked, but the strength of this link – i.e. the learning resulting from the teaching intervention – is not assured. Good teaching recognises this, and involves constantly trying to find out what the effects of the intervention are on learning, and then developing the intervention based on the feedback evidence. Thus a cycle of evaluation (collecting and interpreting feedback) and development is a fundamental part of the process of quality improvement.

Definition and Aims: What is evaluation?

Evaluation is:

> "*The systematic acquisition and assessment of information to provide useful feedback about some object*" (Trochim, 2006)

> "*the collection of, analysis and interpretation of information about any aspect of a programme of education or training as part of a recognised process of judging its effectiveness, its efficiency and any other outcomes it may have*" Mary Thorpe in "Handbook of Education Technology (Ellington et al., 1988)

From these definitions, it can be seen that evaluation is a systematic, planned process that aims to find out what works and what doesn't work – to provide useful feedback.

Feedback is only 'useful' if it is acted on – i.e. if it is used in decision-making – so evaluation of a course needs to be well planned and integrated into a review process that is used to inform further development of the learning and teaching content and methods (Parker, 2014). It is important that evaluation is not just downgraded to the action of collecting data, rather than collecting, interpreting and acting on it (Ramsden 2003).

The words ‘evaluation’ and ‘assessment’ are often used interchangeably, however the goals are different and refer to different levels and different audiences. The overall goal of evaluation is to provide useful feedback to the people delivering (planning, facilitating, lecturing, teaching etc) the course. Assessment refers to the measurement of student learning. Reflecting on student performance in assessment forms a valuable part of the evaluation process (feedback to the course deliverers), but as ‘assessment’ its main goal is feedback to the course participants on their performance.

Evaluation of the overall learning experience can be broken down into two linked elements:

- Effectiveness of the intervention on learning (i.e. whether the course has had the desired effect on the participants’ knowledge, understanding and skill level)
- Participant perceptions of the effectiveness / success of the process / delivery (i.e. the structure and teaching on the course and student engagement).

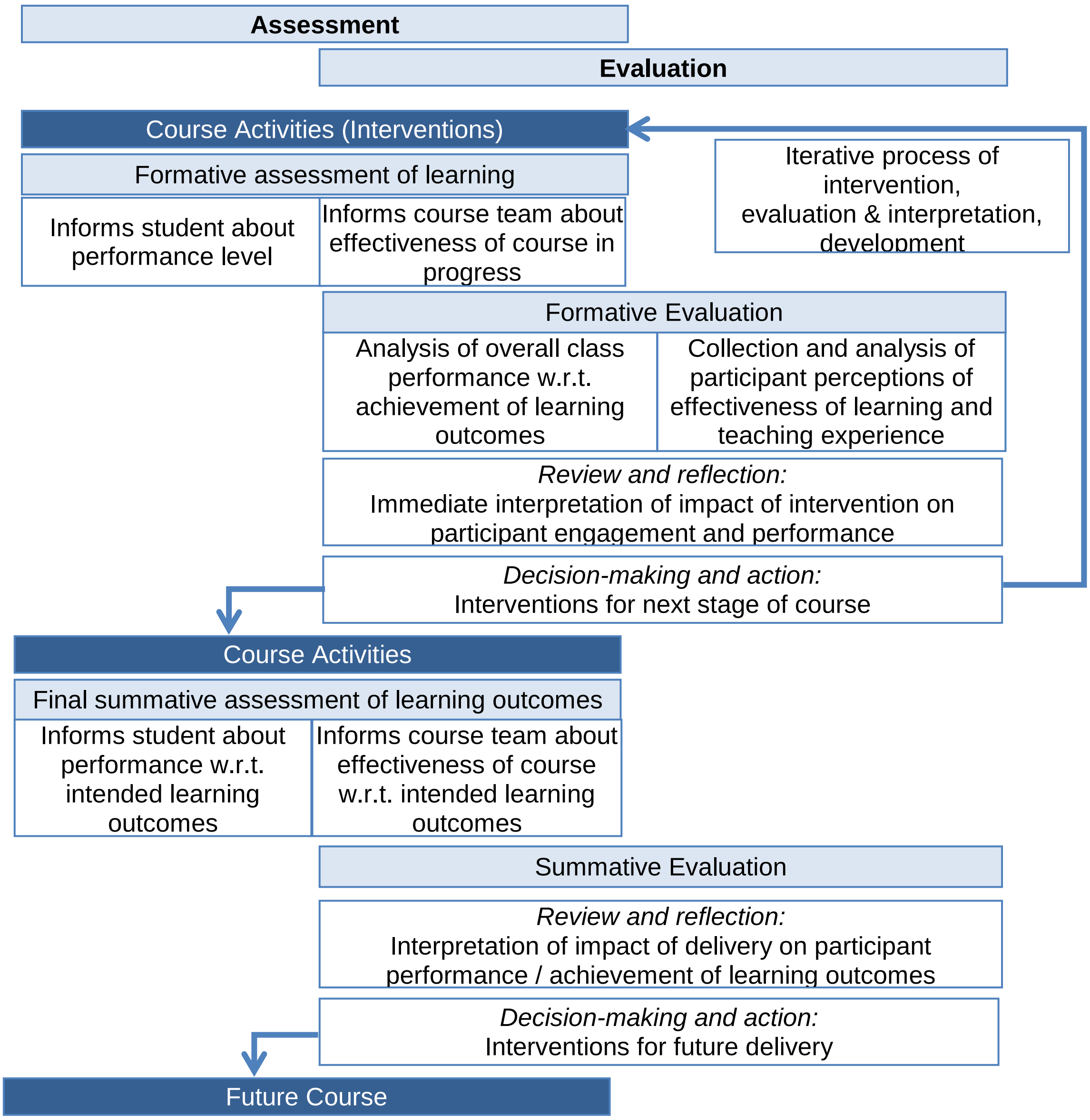

Figure 1 *Assessment and Evaluation within the Learning Process*

ASSESSMENT AND EVALUATION OF EFFECTIVENESS OF THE INTERVENTION ON ACHIEVEMENT OF LEARNING OUTCOMES

Achievement of the learning outcomes by the students is the most obvious indicator of success. However, for this to form part of an ongoing evaluation process, opportunities for formative and summative assessment (tests, informal quizzes, presentations, draft essays, show of hands etc) need to be built in to the learning process. In addition to providing opportunities for students to gain feedback on their progress (from teachers, peers or by self-reflection), these should allow course deliverers to observe and reflect on overall cohort achievement of / progress towards learning outcomes, and to identify common misconceptions or gaps in the knowledge and understanding. These observations can then form the basis for rapid intervention or adjustment to overcome any problems identified.

Learning involves a process of change – the learners should have developed new proficiencies, knowledge and understanding as a result of the teaching intervention. While assessment of the achievement of learning outcomes is a common element of academic courses, outcome evaluation – i.e. evaluation of transformative change achieved as a result of the intervention – is more difficult. This requires initial assessment of the learner's status prior to the learning event (possibly in the form of a pre-intervention test or quiz), and comparison with the final assessment (i.e. post intervention) of the learning outcomes.

Evaluation of the effectiveness of the Global Engineering Challenge on student development or learning and perception of the Global Dimension of Engineering

- **Pre-and post-intervention surveys:**
  The GEC project week is based on the EWB Challenge, and each year, EWB-UK conducts an online survey for participants both prior to and as a follow-up to the EWB Challenge. This survey aims to evaluate the success of the curriculum interventions across the UK in enhancing student understanding of the Global Dimension.

  In addition to the EWB-UK survey, the GEC project week involves a range of assessments and pre / post intervention surveys. We are aware that many students choose to study engineering due to its technical content, rather than the global engineering context, so we have tried to find out whether the project week would have any impact on their attitude to the importance of the non-technical elements of their courses. Therefore, in addition to the EWB-UK surveys, at the start of the week we surveyed students on their perceptions of the overarching aims of the week, which relate to developing a range of skills (communication, teamwork etc.) as well as awareness of the global, environmental or social dimension of engineering. A selection of questions is shown in Table 1. Questions with the darker shaded background are demographic questions that allow response data to be "sliced" for analysis of the perceptions of different types of students. This pre-GEC survey was followed up with similar questions after the end of the week, to gauge any change in student attitude.

Table 1 *Selection of questions from the pre-GEC survey on student perceptions of the importance of non-technical learning for student engineers.*

Question	Responses
Are you…	Male / Female
Where do you come from?	The UK / Other parts of Europe / International
Which department are you in?	ACSE / Aero / Bio / Chem / Civ / Com / EEE / Mat / Mech
Rate your ability to work with students from other parts of the world?	Excellent / Good / Average / Below Average / Poor
How important do you think it is for student engineers to learn about global issues?	Extremely / Very / Average / not Very / Not at all
How important do you think it is for student engineers to learn about social issues?	Extremely / Very / Average / not Very / Not at all
Rate your ability to communicate and promote your ideas to other people?	Excellent / Good / Average / Below Average / Poor

Questions about attitude rely on self-evaluation and perceptions of ability, assessed on a relative scale, with no specific benchmark, so it is difficult to identify transformation in attitude across the student cohort. However, this survey did reveal that 'home' students generally thought they were already good at teamwork and communication, while 'international' students thought that the project week had helped them improve their skills in in these areas. The survey also revealed that a few students found difficulty in working with international students, and there was more dissatisfaction amongst Computer Science students than other departments. The format of this survey did not provide any further detail as to what the problems were, so was followed up with a focus-group discussion later.

- **Assessment and evaluation of effectiveness of the intervention with respect to learning outcomes:**
  As the GEC only runs for one week, there are limited opportunities for formative assessment and evaluation. However, there are opportunities for gauging the level of understanding / progress throughout the week through: informal discussion (GTA facilitators and staff discuss progress with individual student groups throughout the week); the intermediate boardroom session – a formal poster presentation and question session for students to demonstrate their progress, with immediate verbal feedback, and; the final report submission and presentation session, assessed against the project learning outcomes, with same day written / immediate verbal feedback respectively.

Staff and GTAs involved in assessments and discussions with student groups gain an impression of the level of understanding and progression towards the learning outcomes, and are able to provide feedback directly to students. However, due to the size of the student cohort (>170 groups) and dispersed hub-format of the week, data on achievement of learning outcomes is not formally collated and reviewed.

EVALUATION OF THE LEARNING PROCESS / PARTICIPANT PERCEPTIONS OF THE CURRICULUM INTERVENTION: WHO, WHEN, WHAT AND HOW

If evaluation is to be useful, the evidence needs to be robust enough for decisions taken on the basis of the feedback to be effective and lead to improvement. Poor data may lead to ineffective action. This means it is important to achieve good involvement of the course participants in the evaluation, and to elicit meaningful feedback. In designing an evaluation, it is therefore necessary to consider:

- Who should be involved & their willingness to participate in the evaluation
- When: timing of evaluation
- What is being evaluated – what is useful feedback and question design to achieve useful feedback
- How: format and method of engaging students in the evaluation process to achieve representative participation at the level of depth required

Who should be involved and their willingness to participate

There are several valid sources of feedback on a teaching intervention. The most important, and most obvious is the students who are undertaking the learning and who therefore have direct experience of how well or badly the intervention is received. However, other participants may include the GTAs involved in delivery or demonstration, and colleagues either involved in delivery or asked to attend sessions as observers. Observation and reflection of one's own experience, and students' reaction to interventions can also provide powerful feedback.

"*Oh not another questionnaire!*". Students are asked to provide their views on a wide range of aspects of their course experience with a result that they are over-surveyed. This means that an email request can be seen as 'spam' and that responding to surveys is seen as boring and is not taken seriously. This is likely to result in feedback that is not worthy of more than a superficial review and cannot provide meaningful data analysis or the basis for subsequent action.

One of the common problems of evaluation surveys is that students do not see any action as a result of their feedback. This can contribute to students becoming cynical about the process and less inclined to participate. Many students are averse to completing surveys if they can see no personal benefits (Warnes and Warman 2008). These aspects mean it is important to consider the timing of the evaluation, and to identify how to close the feedback loop. Figure 2 shows processes in the feedback loop or satisfaction cycle (Harvey 2003).

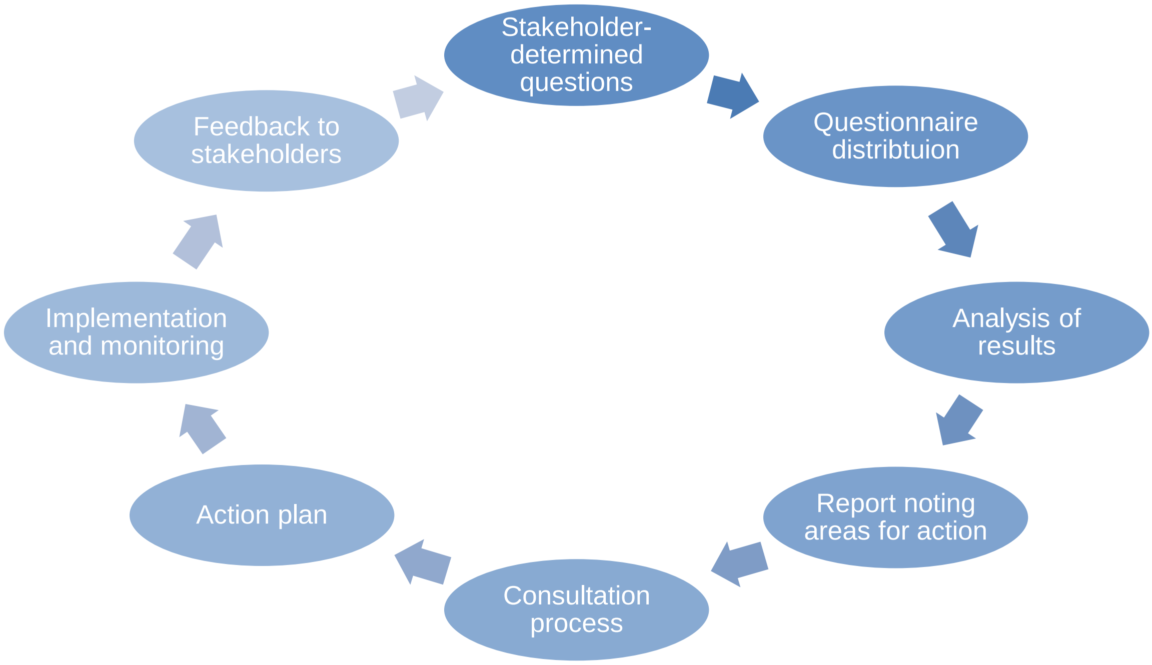

Figure 2 *Satisfaction cycle* (Harvey 2003)

Who is involved in evaluating GEC at University of Sheffield

A large number of people are involved in designing and delivering the GEC, so in addition to surveying students, we also collect feedback from a range of groups who help us recognise success, suggest improvements for subsequent years and provide research data for publications. These are: students, the GTAs (Graduate Teaching Assistants = PhD student facilitators), staff, alumni (who visit hubs during the week), the working party (who devised the original aims of the week and acted as consultants throughout the design process) and the organisers (who designed the taught content and project manage the week).

When to evaluate

Timing of an evaluation is an important factor, particularly if the feedback loop is to be closed, and students are to gain personal benefit or see action as a result of their feedback.

Many course evaluation questionnaires are administered at the end of a programme or intervention, effectively providing a retrospective analysis of the intervention to assess how effective it has been. The feedback can offer explanations for how well the learning outcomes have been achieved and help to identify key aspects of the design and delivery of interventions that could be improved in future iterations of the course, but do not provide opportunity for immediate benefit to the students who have undertaken the learning.

Formative evaluation, undertaken during implementation of the teaching and learning process, can have greater immediacy and relevance for those responsible for the delivery as it can provide essential information and feedback to guide responsive action and developments.

When to evaluate - GEC at University of Sheffield

As the GEC only runs for one week on a dispersed format of approximately 30 hubs, there are very limited opportunities for formal formative evaluation of the delivery and adaptation of the teaching materials and format during the week. The main evaluation survey takes place after the end of the week, eliciting views to enable improvements for the following year.

Ongoing evaluation and adaptation is achieved, however, through daily debriefing / briefing sessions held with the GTA facilitators. The GTAs meet in a lecture theatre with the project organisers and discuss their hubs – what has gone well, what needs improving – swapping ideas and helping to solve each other's problems, as well as feeding back to the project organisers any common themes to be addressed. Some of this feedback leads to immediate adaptations, while others are noted for future iterations of the project.

What to evaluate: and how to elicit useful feedback?

For the evaluation to be effective, it is important that it is clear what feedback is sought on which aspects of the course. The questions posed in the evaluation will depend on the content and nature of the teaching intervention, but some of the typical areas of the learning process to investigate are:

- How clear do students find the aims of the intervention?
- Quality of teaching / learning methods and support
- Content (volume / level of difficulty / level of interest)
- Appropriateness of the assessment
- Quality and timeliness of the feedback

In addition to identifying which aspects to evaluate, consideration should be given to the depth and type of feedback sought. Questions usually elicit responses in one of two forms: closed questions that result in quantitative responses – i.e. data that can be analysed statistically, or open-ended questions that provide more qualitative detail. Open text questions are more difficult / time consuming to analyse, but can provide a much richer insight. A further consideration when developing an evaluation is the design of the questions in order to avoid influencing the responses, e.g. framing a question such that the responses are only positive.

How: evaluation techniques and technologies and their advantages & disadvantages

There are many techniques and instruments available to undertake evaluation, and the technique chosen will depend on the nature of the feedback sought, the learning environment, including the size and location of the student cohort, the need to keep the evaluation attractive to the participants such that sufficient numbers complete it and finally, the ability to process the data – i.e. the technology available. Some examples of evaluation techniques are as follows (pros and cons are summarised in Table 2):

- Questionnaires (paper-based, online, electronic instant polling, show of hands)
- Structured or semi-structured interviews (with individuals or groups)
- Informal chats

A questionnaire may be characterised as a survey that is undertaken individually. There are numerous technologies that allow the creation of questionnaires and also ready processing of the data, for example, the survey tools in VLEs such as Blackboard or Moodle, the online tool Survey Monkey or Google forms (part of the suite of Google Apps).

Paper-based questionnaires have the advantage of being immediate and class-room based, therefore eliciting high response rates. However, there are drawbacks associated with analysing responses from large numbers of students and potential positive bias (some people like to please, rather than show their real views, particularly when the course leader is in the same room). Optical Character Recognition (OCR) software could be used for processing paper-based responses. While processing the responses through an OCR reader is fast, it is still an additional job compared with the entirely electronic methods.

Electronic online questionnaires enable collection of large amounts of quantitative information such as from Multiple Choice Questions (MCQs) (tick box or ratings on a Likert scale). Such data can be very efficiently processed. Open text questions are often also possible in electronic questionnaires and while software does exist for identifying specific text or phrases, it is less commonly utilised. The main problem with online questionnaires is the low response rate due to the remote administration. Actions that may help improve response rates include ensuring the sender of the email is someone known to the students, clear indications of how their opinions will influence future decisions and enticements such as entry into prize draws. The latter is not entirely simple since the students would need to identify themselves for the draw, while having done the questionnaire anonymously.

There are numerous technologies that allow for the instant opinions of students to be recorded using dedicated physical devices (clickers) or the students' own smart devices (tablets/phones). These electronic instant polling systems permit rapid response to MCQs asked in lectures or classrooms. If students are using smart devices, then the polling can include more versatile question types, including those that require a text response. These systems offer the advantages of a high response rate, and rapid analysis, but need to be used with care to avoid 'clicker fatigue' resulting in superficial responses.

While MCQs and short answers can provide a good overview of the participants' perceptions of the learning process, it is often useful to ask follow-on questions to find the reasons for particular responses. In this case, a semi-structured interview may be appropriate. Such interviews can be done on a one-to-one or on a small group (one-to-several) basis but they require more time from the interviewees and more processing time from the surveyor.

Table 2 *Pros and cons of survey methods*

Method	Pros	Cons
Paper questionnaire	• Classroom-based so high engagement / response rate • Immediate • Opportunity for open text answers • Individual completion, so little potential for peer influence in the responses	• Inflexible • Lack of time to think • Potential positive bias • Time-consuming collation and analysis of responses
Online questionnaire	• Flexibility, • Opportunity for open-text responses • Automatic reminders • Individual completion, so little potential for peer influence in the responses • Easy administration and collection of large amounts of data, with ready statistical analysis including slicing by demographic responses	• Remote – lack of engagement leading to low response rate (consider incentives to encourage responses) • Potential negative bias – more likely to receive responses from those with something to complain about • If administered through a VLE, students may be suspicious of the anonymity of the survey, as they know other VLE activity is identifiable.
Electronic instant polling system	• Classroom-based so high engagement / response rate • Immediate • Maintains anonymity • Automatic aggregation of results and manipulation of data including slicing by demographic questions	• Inflexible • Lack of time to think • Potential positive bias • "Clicker fatigue" if too many questions • Potential lack of opportunity for long answers • Although completed individually, student responses may be affected by their peers (potentially worse in large lecture theatres due to remoteness of the lecturer)
Focus group / semi-structured interviews	• Good insight into student views –detailed discussion that can probe areas identified in questionnaire-type surveys	• How representative is the focus group? • Each interview / discussion can be different, even when following a semi-structured list, so comparison between groups can be difficult • Students may be reluctant to criticize when face-to-face with the course leaders • Time-consuming for the participant and the evaluator – consider an incentive like free lunch to generate participation. • Time consuming to transcribe and analyse

Informal chat	• Good insight into student views – more detailed discussion	• Not clear how representative the views are • May be reluctant to criticise when face-to-face • Unlikely to get a statistically significant sample • Difficult to record comments

PROBLEMS WITH EVALUATIONS AND FINAL ISSUES TO CONSIDER

One of the main problems with evaluation is achieving adequate participation to ensure a representative response. However, when designing a questionnaire or interview evaluation, there are various techniques and issues to consider to improve response rates, including:

- Limit the number and length of the questions on a questionnaire, particularly open-ended questions. Two simple open-ended questions that aim to achieve constructive criticism are "*what went well?*" and "*how could it be improved?*"
- Pilot the questionnaire with students, or get groups of students to design the questionnaire
- Offer incentives to encourage a response (e.g. entry into a prize draw), free lunch, but beware of affecting anonymity if this is through a survey.

As with all evaluation methods, interpretation of the results needs to be done with reflection and should consider the limitations of the process – e.g. whether elements of the evaluation process could have influenced the responses. For example, participant responses can be coloured by how people feel when they are completing their questionnaire, so if it is administered immediately after a difficult exam, the responses about the teaching delivery may be different from responses gathered before the exam.

The final issue to consider relates to use of the data gathered. In addition to undertaking evaluation to identify actions to improve future iterations, the results may also be used for other purposes such as to provide research data for publications. Note that in order to publish, the method for acquiring the data is subject to ethics approval.

- **GEC summative evaluation – techniques, technologies and actions taken**

  In addition to the questions shown in Table 1, after completion of the project week, a more in-depth online questionnaire was undertaken using the online tool, Survey Monkey. In addition to a number of MCQs, we also asked questions with free text responses to elicit student views on what could be improved. A selection of final evaluation questions is shown in Table 3; again demographic questions are indicated with a darker shaded background.

When the survey was administered via Survey Monkey, i.e. as an online evaluation, the response rate was poor. For the past two years, students have all been issued with a clicker, and have been able to respond to MCQs in lectures. The Faculty has since moved to purchasing licences such that the students are able to use their own devices to respond to the questions. This has also opened up the ability to ask more versatile, open-text-response-type questions. We have therefore experimented with undertaking the summative evaluation using the electronic instant polling system. This resulted in higher response rates, though some students forgot their smart device. We were, however concerned about 'clicker fatigue', surface responses and that although the questions were answered individually, student responses may have been affected by their peers, resulting in non-representative feedback.

Table 3 *Selection of questions from the post-GEC survey on student perceptions of the GEC*

Question	Responses
Are you…	Male / Female
Where do you come from?	The UK / Other parts of Europe / International
Which department are you in?	ACSE / Aero / Bio / Chem / Civ / Com / EEE / Mat / Mech
What motivated you in the week (you can choose more than 1)?	• Interested in the topic • Winning a Prize, being the best in the Hub • Opportunity to represent the Sheffield in the EWB Challenge • Helping the people who live in [EWB Challenge country name] • Becoming a better engineer • Becoming more employable • I wasn't motivated
Did your group use the project working time effectively?	• Our group was independently motivated and used time very effectively • Our team was reasonably independently motivated and used the time reasonably effectively • We needed the facilitators there in order to keep our team working • It was hard to keep the team working irrespective of whether the facilitators were there
What was the best thing about the week?	[Text response]
What could be done to improve it (that you haven't already suggested)?	[Text response]
Do you think the GEC has helped you develop skills for a future career as a Professional Engineer?	A lot / A little bit / Not at all

- **GEC Focus Groups**

Having processed results from our online surveys, we identified a need to gain greater insight into some of the responses, so followed up with focus groups on a semi-structured interview format. An example of some of the questions asked is shown in Table 4. Because of the time commitment it was difficult to get students engaged, so we offered a free lunch and this has proven successful.

Table 4 *A selection of follow-up questions used to gain greater insight into evaluation responses*

Survey Monkey results …	Discussion Question
On motivations… A higher proportion of UK males (followed by European males) are unmotivated by the GEC week.	Why? What would motivate them?
On session popularity… 'Final Presentations' was most popular for UK students but not for other groups. 'Team Building' was most popular for International students.	Why? Why?
On usefulness… A higher number of International students (than UK or European) with UK always lowest 'Found facilitated sessions useful'	Why?

- **GEC Evaluation interpretation and action to improve**

The results from this evaluation have been taken into consideration in developing subsequent iterations to the GEC delivery. Over the past couple of years, changes have been made to the timing, delivery, facilitated content, project selection and group participants. The iterative process of evaluation and development is still ongoing, and will continue when the project next runs.

CONCLUSIONS

Monitoring and evaluation schemes are important should be considered when planning a course so that they can be designed effectively to allow opportunity to develop and improve the course as it progresses. Both assessment of progress towards learning outcomes and evaluation of student engagement / perception of the learning experience can contribute to the ongoing monitoring and evaluation.

There are many techniques available for monitoring and evaluating, including various types of survey, interviews / focus groups as well as pre and post intervention tests and the course assessment itself. The techniques and technologies used and the aspects of the learning / process to be monitored and evaluated will depend on the nature of the teaching delivery (project / lecture), but whatever the evaluation, it is important that the feedback gained leads to action and development of the intervention, preferably on an on-going basis, but certainly for the next iteration.

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FURTHER/SUGGESTED MATERIAL

- Practical Evaluation for Educators: Finding What Works and What Doesn't. Corwin Press, Thousand Oaks. http://srmo.sagepub.com/view/practical-evaluation-for-educators/SAGE.xml
- Course Evaluation Methods: http://reviewing.co.uk/evaluation/methods1.htm
- Evaluation Cookbook. www.icbl.hw.ac.uk/ltdi/cookbook/contents.html
- Wikipedia Entry: Course Evaluation: http://en.wikipedia.org/wiki/Course_evaluation
- Example online evaluation questionnaire: Survey Template Library - Student Course Evaluation (Teacher Evaluation). www.questionpro.com/survey-templates/student-course-evaluation-teacher-evaluation/

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