C.8

Integrating GDE into teaching: theory and practice

GDEE | GLOBAL DIMENSION IN ENGINEERING EDUCATION

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EDITED BY
Global Dimension in Engineering Education

COORDINATED BY
Agustí Pérez-Foguet and **Enric Velo** *(Universitat Politècnica de Catalunya)*
Manuel Sierra *(Universidad Politécnica de Madrid)*
Alejandra Boni and **Jordi Peris** *(Universitat Politècnica de València)*
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CHAPTER 1

Key learning theories in GDEE

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EDITED BY
Global Dimension in Engineering Education

COORDINATED BY
Agustí Pérez-Foguet and **Enric Velo** *(Universitat Politècnica de Catalunya)*
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1 KEY LEARNING THEORIES AND THEIR RELATIONSHIP WITH GDEE

Jordi Segalàs, University Research Institute for Sustainability Science and Technology, Universitat Politècnica de Catalunya – Barcelona Tech

EXECUTIVE SUMMARY

This chapter will introduce key learning theories associated with Sustainable Development, and by corollary with the Global Dimension in Engineering Education.

It discusses the suitability of the key learning theories for improving sustainability teaching and learning processes in engineering education.

By learning from the experience of Engineering for Sustainable Development (ESD) teaching, this chapter will provide inspiration, examples and evidence for applying the learning theories to introduce the Global Dimension into Engineering Education.

LEARNING OUTCOMES

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

- Understand key learning theories
- Describe how the relate to GDEE
- Design curriculum strategies for GDEE

KEY CONCEPTS

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

- The need for self-reflective learners in GDEE
- How learning theories relate to curriculum design

GUIDING QUESTIONS

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

- Which pedagogy is most appropriate for GDEE?
- What is the role of teachers in GDEE?
- What pedagogical shifts are needed for GDEE?

INTRODUCTION

Learning is a complex metacognitive process that can be defined as the result of the process of continuous interaction of an individual or a group with the physical and social environment. Learning is partly an individual and partly a group process. In learning, social interaction is important because an individual learns by comparing their own mental models to those of others; a multi-disciplinary learning environment therefore can be a richer learning environment. In context-embedded learning, interaction between different disciplines and individuals should get a more prominent place in the design of learning.

Education can be described as an institutionalised process aimed at realising defined learning objectives for defined target groups. The learning objectives comprise disciplinary, social, cultural, and economic items. The target groups can be divided according to age and the level of prior education or development. The educational system tries to provide contexts that support the learning of individuals.

In relation to Sustainable Development, so far, there is no direct relation between societies with high rates of 'educated' citizens and high sustainability. Quoting E.F. Schumacher:

> "*The volume of education… continues to increase, yet so do pollution, exhaustion of resources, and the dangers of ecological catastrophe. If still more education is to save us, it would have to be education of a different kind: an education that takes us into the depth of things.*" (Schumacher, 1973)

Sustainability demands a specific kind of learning. Some authors call for a deep change in society to achieve a more sustainable path.

> "*Sustainable Development is not just a matter of acquiring some extra knowledge. Attitude is also important. Moreover, it is often necessary to change social structures.*" (Mulder, 2006)

Learning for Sustainable Development could be described as learning to deal with dilemmas in a complex societal context in which ecological, economic and socio-cultural aspects are at stake. It means taking into account the interaction between different levels of scale from local (the scale of human daily life) to global (the scale of economy, climate systems and world ecosystems) (Van Dam-Mieras, 2005; 2006).

In the curriculum design aspect, Sterling points out that if engineers are to contribute truly to Sustainable Development, then sustainability must become part of their everyday thinking. This can only be achieved if Sustainable Development becomes an integral part of engineering education programmes, not a mere ‘add on’ to the ‘core’ parts of the curriculum (Sterling, 2004).

On the pedagogy side there are also some definitions to be considered: Education for sustainability, above all, means the creation of space for transformative social learning. Such space includes: space for alternative paths of development; space for new ways of thinking, valuing and doing; space for participation minimally distorted by power relations; space for pluralism, diversity and minority perspectives; space for deep consensus, but also for respectful disagreement and differences; space for autonomous and deviant thinking; space for self-determination, and; finally, space for contextual differences (Wals & Corcoran, 2005).

What is needed is an integrated approach to teaching Sustainable Development which should provide students with an understanding of all the issues involved as well as raise their awareness of how to work and act sustainably (Perdan et al., 2000). John Fien (2006), besides highlighting the importance of pedagogy (since issues of pedagogy are vital in reorienting education towards sustainability) also claims that the teacher’s role is as important as the pedagogy used; the teacher’s beliefs and attitudes – together with the teaching strategies chosen – will significantly affect the nature of students’ learning experiences and the objectives achieved. Such choices and attitudes determine whether or not curriculum plans reproduce the existing social and cultural mores, or contribute to empowering people for participation in civil society.

All definitions mainly ask for an education where there is space for critical thinking. Social and cultural complexity is at stake. Values and ethics are important and trans-disciplinary and trans-cultural approaches are inherent to the learning process.

But what is needed to achieve an effective Education for Sustainable Development (ESD) in higher education, and specifically in engineering education? What pedagogy is especially good for Sustainable Development?

PEDAGOGICAL SHIFT TO EDUCATION FOR SUSTAINABLE DEVELOPMENT

A reorientation on pedagogy and learning processes is essential to achieve effective Education for Sustainable Development. The Barcelona declaration (Barcelona declaration, 2004) states: "*teaching strategies in the classroom and teaching and learning techniques must be reviewed*". In that direction, experts have recently been suggesting different schemes and actions to facilitate and promote the required pedagogy transformation in higher education institutions and in engineering education specifically.

Wals and Corcoran (2005) propose eight principles that can serve as anchor processes to integrate sustainability in higher education, as shown in Table 1:

Table 1 *Principles to integrate sustainability in higher education* (Wals & Corcoran, 2005)

Principle	Description	Examples
1. Total immersion	• Fostering a direct experience with a real-world phenomenon	• Observing and monitoring sustainability impacts • Managing a specific site
2. Diversity in learning styles	• Being sensitive to the variety of learning styles and preferences that can be found in a single group	• Offering a variety of didactic approaches • Reflecting on the learning process with the learner
3. Active participation	• Developing discourse and ownership by utilising the learners' knowledge and ideas	• Soliciting the learners' own ideas, conceptions and feelings • Consulting learners on the content of the learning process
4. The value of valuing	• Exposing the learner to alternative ways of knowing and valuing through self-confrontation	• Giving learners opportunities to express their own values • Creating a safe and open learning environment
5. Balancing the far and near	• Developing empowerment by showing that remote issues have local expressions which one can influence	• Relating issues of biodiversity or sustainability to last night's dinner • Showing examples of groups of people successfully impacting the local and global environment
6. A case-study approach	• Digging for meaning by studying an issue in-depth and looking for transferability to other areas	• Assigning different people to explore different angles of a particular theme and bringing these together
7. Social dimensions of learning	• Mirroring the learners' ideas, experiences and feelings with those of others through social interaction	• Take time for discussion and exchange • Addressing controversy • Stimulating flexibility and open-mindedness
8. Learning for action	• Making the development of action and action competence an integral part of the learning process	• Allowing learners to develop their own course of actions and to follow through • Studying examples of action-taking elsewhere.

When referring to learning and pedagogy Sterling (2004) highlights the need to shift from mechanistic to ecological thinking, and proposes the change needed in learning and pedagogy in four areas (see Table 2):

Table 2 *Shift needed in ESD: from mechanistic to ecologic view* (Sterling, 2004)

	Mechanistic / traditional view of education	Ecological / alternative view of education
Teaching and Learning	Transmission	Transformation
	Product oriented	Process, development and action oriented
	Emphasis on teaching	Integrative view: teachers also learners, learners also teachers
	Functional competence	Functional, critical and creative competencies valued
View of Learner	As a cognitive being	As a whole person with full range of needs and capacities
	Deficiency model	Existing knowledge, beliefs and feelings valued
	Learners largely undifferentiated	Differentiated needs recognised
	Valuing intellect	Intellect, intuition and capability valued
	Logical and linguistic intelligence	Multiple intelligences
	Teachers as technicians	Teachers as reflective practitioners and change agents
	Learners as individuals	Groups, organisations and communities also learn
Teaching and Learning Styles	Cognitive experience	Also affective, spiritual, manual and physical experience
	Passive instruction	Active learning styles
	Non-critical inquiry	Critical and creative inquiry
	Analytical and individual inquiry	Appreciative and co-operative inquiry
	Restricted range of methods	Wide range of methods and tools
View of Learning	Simple learning (first order)	Also critical and epistemic (second/third order)
	Non-reflexive, causal	Reflective, iterative
	Meaning is given	Meaning is constructed and negotiated
	Needs to be effective	Needs to be meaningful first
	No sense of emergence in the learning environment / system	Strong sense of emergence in the learning environment / system

LEARNING AND TEACHING METHODS

Didactic strategy can be described as the set of procedures – supported by educational techniques – that have the goal to carry the didactic action to a good end; that is, to attain the goals of the learning (DIDE, 2004).

Likewise, a didactic technique is a procedure that helps to carry out a part of the learning of the strategy. It is also a logical procedure with psychological foundations, with the purpose of orienting the student learning. The technique arises in a specific sector or phase of the course (such as the presentation at the beginning of the course), the analysis of contents and the synthesis or the criticism of itself. The didactic technique is the particular resource that the teacher uses for attaining the purpose brought up from the didactic strategy.

Students learn in many ways: by seeing and hearing; reflecting and acting; reasoning logically and intuitively; memorising and visualising; drawing analogies and building mathematical models; steadily, and in bursts. Teaching methods also vary. Some instructors lecture, others demonstrate or discuss; some focus on principles and others on applications; some emphasise memory and others understanding. How much a student learns in a class is governed in part by that student's native ability and prior preparation, but also by the compatibility of their learning style and the instructor's teaching style. Richard M. Felder (Felder et al., 1988; 2000) defined four dimensions of learning styles and the teaching styles that adapt to them (see Table 3):

Table 3 *Dimensions of learning and teaching styles*

Learning		Teaching	
Sensory / Intuitive	Perception	Concrete / Abstract	Content
Visual / Verbal	Input	Visual / Verbal	Presentation
Active / Reflective	Processing	Active / Passive	Student participation
Sequential / Global	Understanding	Sequential / Global	Perspective

To increase students' success in engineering education, one must understand students' individual learning style and provide pedagogical methods and environments accordingly (Carver et al., 1999). Nevertheless, the conventional teaching approach used in engineering education: emphasises lectures over active engagement (favouring reflective and verbal learners over active and visual learners); focuses more on theoretical abstractions and mathematical models than on experimentation and engineering practice (favouring intuitive learners over sensing learners), and; presents courses in a relatively self-contained manner without stressing connections to material from other courses or to the students' personal experience (favouring sequential learners over global learners) (Felder et al., 1988, 1996).

Table 3 shows that there are 16 learning styles. Most instructors would be intimidated by the prospect of trying to accommodate 16 diverse styles in a given course. As mentioned before, the traditional methods of engineering education adequately address four categories (intuitive / verbal / reflective / sequential) and effective teaching techniques substantially overlap the remaining categories. The addition of a relatively small number of teaching techniques to an instructor's repertoire should therefore suffice to accommodate the learning styles of every student in the course.

It is also important to highlight that the average retention of learning varies between pedagogical methods, the most effective being the active methodologies (see Figure 1):

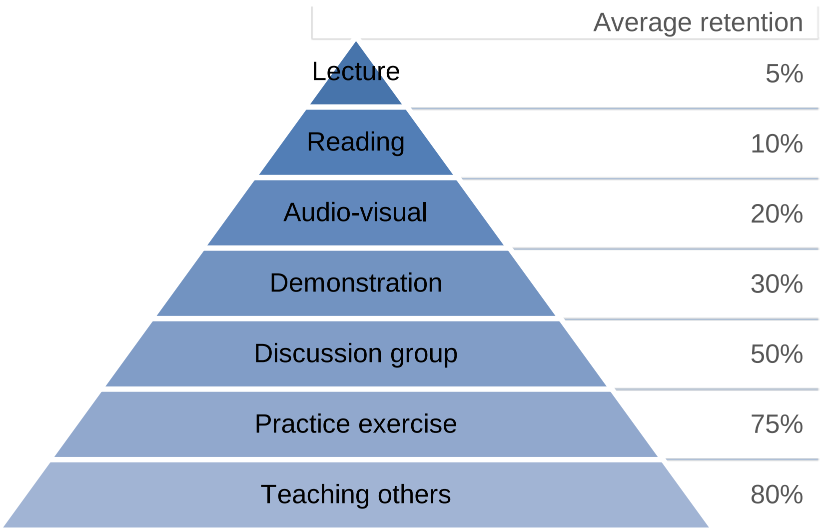

Figure 1 *Bales pyramid of learning average retention* (Bales, 1996)

The strategies and didactic techniques can be classified according to two different parameters:

- According to the degree of participation: the number of people involved in the process of learning, which can range from self-instruction to co-operative learning (see Table 4)
- According to their reach: the time involved in the didactic process is estimated, which can range from a single course to a whole curriculum (see Table 5).

Table 4 *Classification of didactic strategies and techniques according to participation*

Participation	Examples of strategies and techniques
Self-directed learning 	• Individual study • Search and analysis of information • Elaboration of reports • Individual tasks • Projects • Research • Etc.
Inter-active learning 	• Lecture exposition from the teacher • Speech of an expert • Interviews • Visits • Panels • Debates • Seminars • Etc.
Co-operative learning 	• Case study • Project-based learning • Problem-based learning • Service learning • Analysis and discussion in groups • Discussions and debates • Etc.

Table 5 *Classification of didactic strategies and techniques according to reach*

Reach	Examples of strategies and techniques
Techniques (Short periods and specific issues) 	• Method of consensus • Role plays • Debates • Seminars • Symposiums • Simulations
Strategies (Long periods: a semester or a degree) 	• Case studies • Project-based learning • Problem-based learning • Service learning • Personalised learning system

To briefly outline the three classifications of participation:

- **Self-directed learning:**
  In its broadest meaning, self-directed learning describes a process in which individuals take the initiative – with or without the help of others – in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies and evaluating learning outcomes (Straka, 1997).

- **Inter-active learning:**
  Defined as opportunities for students to make sense of the subject matter for themselves, and often contrasted with 'passive learning' that characterises the conventional student experience of lectures (Macmillan & Mclean, 2005). These concepts are derived from constructivist views of learning which emphasise that knowledge is actively constructed by the learner (not passively received from the environment) and that gaining knowledge is a process of adaptation based on, and constantly modified by, a learner's experience of the world.

- **Co-operative learning:**
  In higher education, this is instruction that involves students working in teams to accomplish a common goal, under conditions that include the following elements: positive interdependence, individual accountability, face-to-face promotive interaction, appropriate use of collaborative skills and group processing (Felder & Brend, 2007). Research studies on team-based learning in higher education show that both individual and group performance is superior when co-operative methods are used, compared with competitive or individualistic methods (Johnson et al., 2000). It has positive effects on a range of cognitive and affective outcomes (Terenzini et al., 2001; Springer et al., 1997).

Table 6 describes the general characteristics of pedagogical strategies and techniques and how they can contribute to ESD.

In relation to ESD most authors do not opt for one specific learning technique, but for using a wide range of pedagogical tools and strategies. Important aspects of pedagogy in ESD include encouraging students to explore questions, issues and problems of sustainability, especially in contexts relevant to them and their communities; this involves student-centred and interactive enquiry-based approaches to teaching and learning. Such approaches do not preclude the use of more teacher-centred methods such as explanation, narration and demonstration where appropriate. However, they do emphasise using the environment and community as a resource for learning and student-centred activities such as debating controversial issues, role play, simulation games, values clarification and analysis, as well as a range of creative and experiential activities.

Table 6 *Contribution to ESD from different pedagogical strategies* (Segalàs; 2009)

Strategy	Description	Contribution to ESD
Lecturing	Lecturing consists of the presentation of a subject in a structured way, where the main resource is the oral language, even though it can also be a written text.	Lecturing is a good method to introduce students to sustainability concepts (Azapagic et al., 2005).
Project-based learning	A set of experiences of learning that involve students in complex projects and of the real world through which they develop and apply skills and knowledge [10].	Project-based Learning, especially if it is organised as inter-disciplinary projects, could contribute to adapt engineering curricula to enhance mutual understanding of science and technology with social sciences (Mulder, 2006).
Case study	Case study learning consists in providing a series of cases that represent diverse problematic situations of the real life so that they can be studied and analysed.	Case studies are usually of a qualitative and descriptive nature and can be used to explore specific issues such as different stakeholder perspectives, examples of actual practice, and demonstrations of where progress towards sustainability is, and can, be made in the real world (Fenner et al., 2004).
Problem-based learning	In the Problem-based learning a small group of students meets, with the support of a tutor, to analyse and to solve a problem designed to attain certain goals of learning.	Problem solving prepares students to be 'persons'. The characteristics of Problem-based learning provide a unique opportunity for students to learn about themselves. As a part of the problem-solving process students must consider their own educational goal, which is likely to require introspection about students' values, ethics and beliefs (Huntzinger et al., 2007; McKay and Raffo, 2007).
Back-casting	Back-casting is the creation of a future vision, bearing in mind what is necessary to achieve in the future and then working towards that goal from this day forward.	Due to its normative and problem-solving character, back-casting approaches are much better suited (in reference to forecasting) to address long-term problems and sustainability solutions (Quist, 2007).
Role play	Role play can be defined as a learning process in which participants act the roles of other individuals in order to develop particular skills and to meet particular learning objectives.	The role play is an approach which combines at the same time complexity, the setting in situation, work in group, autonomy and action of the student is particularly relevant for ESD (McLaughlan, 2007; Maier et al., 2007).

There are innovative approaches that promote dialogue and community, higher-order critical thinking and problem-solving. Some strategies to facilitate integrative teaching and learning are as follows:

- Team-teaching and team planning
- Collaborative learning and learning communities
- Clustered and linked courses
- Core seminars at introductory and capstone levels
- Theme or problem focus in courses
- Proactive attention to integration and synthesis
- Models of interdisciplinary and integrative process
- Theories and methods from interdisciplinary fields
- Projects and case studies
- Dyads, triads, and small groups for discussion
- Game and role playing
- Inquiry- and discovery-based learning
- Learning portfolios
- Experiential- and service-learning, internships, and fieldwork
- Residential living-learning experiences

In addition, respecting a variety of different approaches towards ESD may be the best way forward and may lead to emancipation for tutors, rather than inhibition under yet another – as it might be perceived – set of rules and regulations. Rather than be too formulaic or 'legislative' about approaches to be adopted, respecting often divergent (even 'imperfect' approaches) and exploring their apparent contradictions will encourage tutors to find their own space in which to express ESD. Indeed, this very diversity of approaches can be said to be at the philosophical heart of sustainability.

When referring to curriculum Azapagic (2005) proposes the three-tier approach to teaching sustainability, as illustrated in Figure 2. The three-tier approach comprises the following elements:

1. dedicated lectures and tutorials on Sustainable Development;
2. specific case studies;
3. integration of sustainability into the overall curriculum.

The first tier introduces students to sustainability concepts as one of the key learning areas through a series of lectures and tutorials. In the second tier, students are exposed to specific, practical case studies, to enable them to apply the sustainability concepts and identify sustainable solutions. Taking a life-cycle approach to address economic, environmental and social issues, a series of practical case studies have been developed from a range of industrial sectors including water, energy, waste, chemicals, glass and mining and minerals. The third and final tier is integration of sustainability thinking into the overall curriculum, from the fundamentals (e.g. thermodynamics) through quantitative methods and tools (e.g. mathematical modelling) to the design projects (e.g. processing plants, facilities and products). This is probably the most challenging task, which is best facilitated through further, more complex case studies and multidisciplinary design projects. Furthermore, students could learn how to integrate different sustainability criteria into the conventional design approaches by using, for example, life cycle thinking, industrial ecology approaches and appropriate ethical principles.

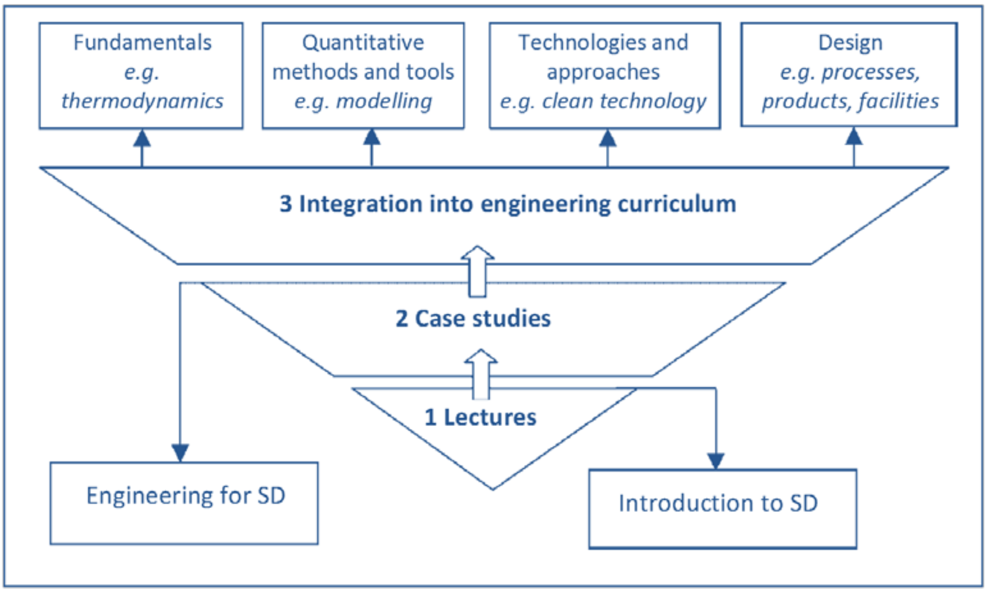

Figure 2 *The three-tier approach to teaching sustainability* (Azapagic et al., 2005).

Such an integrated approach enables a systematic introduction of sustainability criteria into the curriculum, starting with a lower level of complexity and progressing towards more complex considerations at the higher levels of study. It promotes learning outcomes that enable graduates to establish a clear connection between engineering and Sustainable Development and helps them in practising sustainable engineering (Azapagic et al., 2005).

CONCLUSIONS

This chapter showed the characteristics of some pedagogical strategies and their role in ESD, so that they inform strategies for GDEE.

The literature shows that learning is an important condition but not a guarantee for change. Learning about Sustainable Development does not guarantee realisation of actions and activities supporting changes necessary for sustainability. Sustainability learning for change needs a deep knowledge of the basics of sustainability, but furthermore it has to capacitate students with the appropriate competences in relation to their future profession. The same will be true for the Global Dimension.

Studies on learning reveal that students learn in different ways; therefore a multi-pedagogical active methodology approach is needed in order to reach all of them. The literature supporting the notion that active, student-centred learning is superior to passive, teacher-centred instruction is encyclopaedic.

Several theories substantiate that sustainability and the Global Dimension need systemic thinking; a lot of pictures are still in a mechanistic mode, understanding which is divided into boxes, etc. To create a pedagogical approach that optimises the understanding of flows of relationships between concepts of all kind is needed. Sustainability and the Global Dimension are clear multi-disciplinary ‘potpourri’ (environmental, social, economic, values, future, culture, diversity, etc…) and thus, trans-disciplinary teaching and learning processes are necessary. Moreover, these must be active and co-operative learning processes under the constructivism paradigm – not forgetting that the process of teaching is as important as the content.

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PHOTO: Women involved in construction. A. Elias

CHAPTER 2

Skills and competencies for GDEE

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COORDINATED BY
Agustí Pérez-Foguet and **Enric Velo** *(Universitat Politècnica de Catalunya)*
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Emily Mattiussi, Sylvia Roberge and **Katie Cresswell-Maynard** *(Engineers Without Borders - UK)*

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2 SKILLS AND COMPETENCIES FOR THE GLOBAL DIMENSION IN ENGINEERING EDUCATION

Katie Cresswell-Maynard, Head of Learning, Research & Innovation, Engineers Without Borders UK
Alistair Cook, former Head of Learning, Engineers Without Borders UK

EXECUTIVE SUMMARY

This chapter will introduce the skills and competencies that are needed for the Global Dimension in engineering education programmes and will demonstrate how they can be related to an engineering discipline.

The chapter gives guidance around preparing programmes to address the development of certain skills in students and the evaluation of their impact.

It draws on work in the publication 'The Global Engineer: Incorporating global skills within UK higher education of engineers' (Bourne and Neal, 2008).

LEARNING OUTCOMES

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

- Define the skills that need to be developed in engineering students, through Global Dimension programmes.
- Define the competencies need to be developed in engineering students, through Global Dimension programmes.
- Recognise and explain the essential elements of these skills and competencies within the context of specific engineering disciplines.

KEY CONCEPTS

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

- An understanding of your discipline's required skills and competencies.
- An understanding of the links between the Global Dimension and these requirements.
- An understanding of how to implement student engagement and learning of the Global Dimension skills and competencies.
- Use of simple methods to evaluate the Global Dimension into a course and develop monitoring and evaluation of its impact.

GUIDING QUESTIONS

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

- Which Global Dimension skills and competencies are relevant to your discipline of engineering?
- How could the Global Dimension skills and competencies that are relevant be incorporated into teaching this discipline?
- How can the learning outcomes be built upon to increase the Global Dimension of the course?
- How can the impact be measured?

INTRODUCTION

The issues of climate change, sustainable development, globalisation and poverty reduction have led to much discussion on the changing understanding of engineering and on the changing role of the engineer in the 21st Century. One of the strongest themes coming out of this discussion is an increasing recognition of the need for comprehending the Global Dimension in engineering to address current and future economic, social and environmental challenges (both known and unknown). Engineering education – and its effectiveness in preparing engineers in the Global Dimension – is seen as a key area that is capable of helping humanity to respond to these global challenges.

Many universities are being introspective about the impact that their education is having on the engineers of tomorrow. Emerging research from these universities clearly demonstrates how vital the Global Dimension is to educating top-quality engineers.

This research is reflected by the demands of engineering industry. The Global Skills Gap report from 2011 undertook a survey of 500 Chief Executives and board-level directors of business from around the world. It gauged the extent to which business leaders see 'global thinking' as an important skill amongst employees and potential recruits to their companies:

> "*What global companies look for are people who can take a global perspective. Students are well placed to do this if they have taken opportunities to widen their cultural perspective. The people that succeed can work in multi-disciplinary, multi-cultural and multi-locational teams. If students have demonstrated that they can work with other cultures and teams, then that's a big plus since we need students to be intellectually curious and culturally agile if they are going to work in a global context.*"
> (Think Global & British Council, 2011)

The case for the 'Global Engineer' and, by extension, the inclusion of the Global Dimension in Engineering Education is outlined in more depth in the GDEE course '*Making the case for the critical global engineer*'. This chapter builds on that case towards outlining the skills and competencies associated with the Global Engineer. It is therefore supplementary to the practical means by which engineering curriculum can embrace its responsibility to educate engineers for today's and tomorrow's global challenges.

It is important that the formation of the Global Engineer and including the Global Dimension in Engineering Education is not just a simple 'add-on' to traditional engineering education:

> "*The concept of the Global Engineer as suggested is much more than bringing in elements of knowledge about global issues, it is also more than*

> *making reference to 'softer skills' such as teamwork or respect for other cultures... starting from real-world examples and looking beyond the solution to understand the problem, how it was formed and who needs to be involved in resolving it are all parts of being an effective Global Engineer.*" (Bourn, 2014)

There are bottom-up and top-down approaches that can be implemented in engineering education to bring about the curriculum change that enables the skills and competencies of the Global Dimension. As is often the case, the most effective solutions include elements of both but, to date, the majority of traction has been achieved from the bottom-up. This chapter refers to some illustrative examples.

Of equal importance is the recognition that the world around us is constantly changing in new and often uncertain ways. Perhaps ironically, this uncertainty is certain – and therefore is an inherent part of understanding the Global Dimension. Institutional measures must therefore be in place for curriculum to keep pace i.e.: the engineering curriculum must itself have the Global Dimension embedded in its continuous development and improvement. As a result, there is no real 'end-state' associated with achieving the Global Dimension in Engineering Education. In many cases we can make great leaps forwards today to bring existing curricula up-to-date and in-line with this philosophy, but measures must be adopted that support further (incremental or perhaps wholesale) change in the future.

THE SKILLS AND COMPETENCIES OF A GLOBAL ENGINEER

[Note: The UK engineering sector will be used as a reference due to the author's experience. Also, for the purposes of this chapter, the term 'Global Engineer' describes an engineer with the skills and competencies to comprehend and apply the Global Dimension in engineering.]

The specific skills and competencies required of a 'traditional engineer' differ from place to place and discipline to discipline. But in general terms, they will often be considered as those currently required by governing engineering institutions that hold professional engineers to account and have that common values around the responsibility of engineers.

The skills and competencies required of a 'Global Engineer', in a similar fashion to those of a traditional engineer, are not universal. However, again, there is a core concept that is broadly understood (and this is discussed throughout these GDEE courses). This core concept is based around a comprehensive comprehension of context and the ability to apply this comprehension into engineering:

> *"The framework of a Global Engineer suggests going beyond just seeking technical solutions to an understanding of the problems... to encourage a more critically reflective approach towards addressing problems that need to be tackled, understanding and valuing different perspectives and recognising that external factors, be they economic, political or cultural, do play a role in influencing the decisions we make [as engineers]."* (Bourn, 2014)

Equally, the skills and competencies of a Global Engineer should not be viewed as separate or distinct from those of a traditional engineer. The key aim of the Global Dimension in Engineering Education is for the Global Engineer skills and competencies to be recognised and treated as core to any engineer; a paradigm shift from all engineers being 'traditional engineers' to being 'Global Engineers'. As with any agenda of change, the starting point is often to identify distinctions that mark the difference between the status quo and what you are aiming for – and, over time, these distinctions should become less apparent because the 'traditional engineer' takes on the 'Global Engineer' concept as the new status quo.

So, what are those skills and competencies of the 'Global Engineer'? As our society, the environment and the role that engineering plays becomes ever more complex, integrated and interdependent, engineers will be required to have broader comprehensions (and therefore their education must adapt to this and requires an associated skill set to be identified). The Global Engineer report maps out what it defines as the key issues and skills for the Global Dimension in Engineering – this definition has been reproduced in Table 1.

Table 1 *Mapping key issues and skills that define the Global Dimension of engineering* (Bourn & Neal, 2008)

Social	Environmental

• Poverty reduction:
  • Enterprise solutions to poverty
  • Emerging business opportunities in developing countries
  • Challenges of working in developing countries
  • Working in fragile, conflict and crisis prone regions
  • Engaging marginalised and disadvantaged groups
• Engineering and humanitarian relief
• Stakeholder analysis and dialogue and public engagement
• International politics and political analysis
• Science and engineering in society and social impacts of engineering
	• Sustainable development
	• Climate change
	• Soil and water management
	• Flooding
	• Bio-diversity
	• Energy security and 'peak oil'
	• Barriers to sustainable development
	• Operation and maintenance
	• Recycling, waste management and resource optimisation

Professional and Management skills	**Business and Enterprise skills**
• Contextual analysis (STEEP: social, technical, economic, environment and political) • Needs assessment and feasibility studies • Design and project management skills • Systems thinking and systems engineering • Full life-cycle analysis • Communication skills • Team working skills • Critical thinking skills • Creativity and conception skills • Cultural sensitivity and adaptability	• Business ethics: governance, human rights, transparency, accountability and corruption • Corporate responsibility: social and environmental impacts of business, impacts and trends of globalisation, 'socially responsible investment', fair and ethical trade • Aligning shareholder and social value • Conflict sensitive business practice • Innovation and enterprise: emerging technologies and their application to global challenges • Emerging ethical issues arising from emerging technologies • Emerging markets in low-carbon economy and growth in developing country investment

The top row of this table shows issues associated with the Global Dimension of engineering. If the inclusion of the Global Dimension into engineering curriculum were solely about knowledge of Global Dimension issues, then teaching about this top row of items would be the focus of GDEE activity. However, as previously pointed out, the Global Dimension of Engineering goes beyond this. In the bottom row of the table, Bourn & Neal illustrate the skills that are needed to equip engineers with the capacity to comprehend the Global Dimension issues that are illustrated in the top row – and then to apply that comprehension effectively to engineering.

So what about competencies? In a working paper remarking on the international development sector, Professor Robert Chambers has described the competencies (or perhaps the mindsets) that have dominated development professionalism, thinking and practice as being of "*two paradigms: one, often dominant, associated with things; and one, often subordinate, associated with people*" (Chambers, 2010).

As is highlighted as a common thread in GDEE, engineering is undoubtedly associated with human development and it can therefore be justified that development mindsets are relevant to engineering mindsets (while obviously retaining the comprehension of engineering). The two paradigms of the 'traditional engineer' and the 'Global Engineer' are, as suggested, most easily understood by comparing distinctions between the two.

However, Chambers points out the limitations of this approach which can "*polarise, exaggerate differences and even caricature*" (Chambers, 2010) and often causes discourse to be dominated by over-simplification and the reductionist nature of characterisation (rather than progressing towards the intended aim of converging on a paradigm shift). With this in mind, Chamber is also a pragmatist and recognises the value of starting from understanding distinctions. He calls the two paradigms 'Neo-Newtonian Practice' and 'Adaptive Pluralism' are compares them by highlighting their distinct approaches to practice (which encompasses methods, processes, procedures, roles and behaviours). His comparison table is reproduced in Table 2 and are also represented in Figures 1 & 2 on the following pages.

In Table 2, Chambers' descriptors of the 'Neo-Newtonian Practice' can be interpreted as a way of expressing the traditional engineering mindset; and 'Adaptive Pluralism' can be interpreted as a way of expressing the mindset, and therefore competencies, that are additionally required of the 'Global Engineer' (as an extension of the skills set out in the bottom row of Table 1 from the Bourn & Neal description).

The skills described by Bourn & Neal are recognisable to a lesser or greater extent and many already exist in engineering curriculum. For example team skills, business skills, communication skills and innovation and enterprise are often highlighted to the young engineer as important and are supported through teaching. The broader list by Chambers is less well embraced, but the skills highlighted have strong and tangible resonances (and almost sound like module descriptions themselves).

When we look at Chambers' list for the Adaptive Pluralism characteristics, the sentiment feels much more radical (and perhaps less tangible) in comparison; it pushes the Global Dimension to explore the understanding of the mindsets – and therefore competencies – under discussion. As pointed out by Bourn & Neal and referred to earlier, it is not sufficient to include teaching of global issues to bring about the Global Dimension in engineering education. Equally, it is not sufficient to include teaching of the skills identified. To get to the heart of the Global Dimension in Engineering – and to develop Global Engineers who are ready to rise to global challenges – the focus must be on the competencies or mindsets that are needed to operate in the development space. Therefore we must understand these mindsets. The Adaptive Pluralism mindset seems fitting for the Global Engineer but, as Chambers himself implores, it is an area that demands continuous discussion and the reader is welcomed to enter the debate and offer their own interpretations (one is shared later).

	Neo-Newtonian Practice	Adaptive Pluralism
Ontological origins and assumptions	Things, the physical world Newtonian science Order Laws of nature Linearity	People, the social world Complexity science Edge of chaos Emergence Non-linearity
Pervasive concepts	Universality Uniformity Stability Equilibrium Controllability Predictability	Local specificity Diversity Dynamism Emergence Uncontrollability Unpredictability
Methods, procedure, processes	Standardise Sequential routines Fixed menu Manuals Best practices	Pluralist Iterative adaptation A la carte and combinations Repertoires Fitting practices
Embodying and expressing	Comprehensive rules to regulate Conventions, conformity	Parsimonious rules to enable Originality, inventiveness
Roles and behaviours	Supervising Auditing Controlling Conforming, complying	Facilitating Coaching Empowering Performing, improvising
Favoured and prevailing approaches and methods	Questionnaires Randomised Control Trials Logical frameworks	Participatory Methods Information Communication Technologies Participatory Review and Reflection Processes
Valuing and relying for quality	Conventional rigour – best practices: • Specialisation • Standardised regulation • Measurement • Precision • Statistical analysis	Complexity rigour – fitting practices: • Versatility • Adaptive pluralist • Eclecticism • Facilitation, alertness • Surprises • Relevance • Triangulation, successive approximation
Relationships	Vertical Hierarchical Impersonal Unidirectional	Lateral and 360 degree Democratic Personal Reciprocal
Goals, design and indicators	Planned, pre-set and fixed	Negotiated, evolving, emergent

Table 2 *Paradigmatic characteristics of Neo-Newtonian Practice and Adaptive Pluralism* (Chambers, 2010)

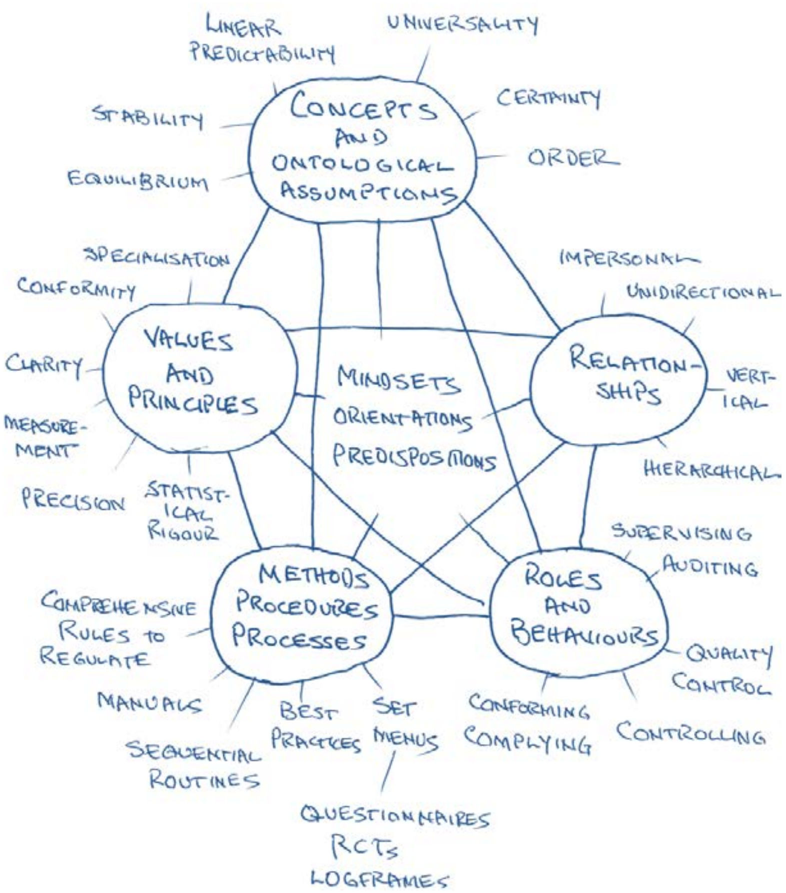

Figure 1 *Elements in a paradigm of Neo-Newtonian Practice* (Chambers, 2010)

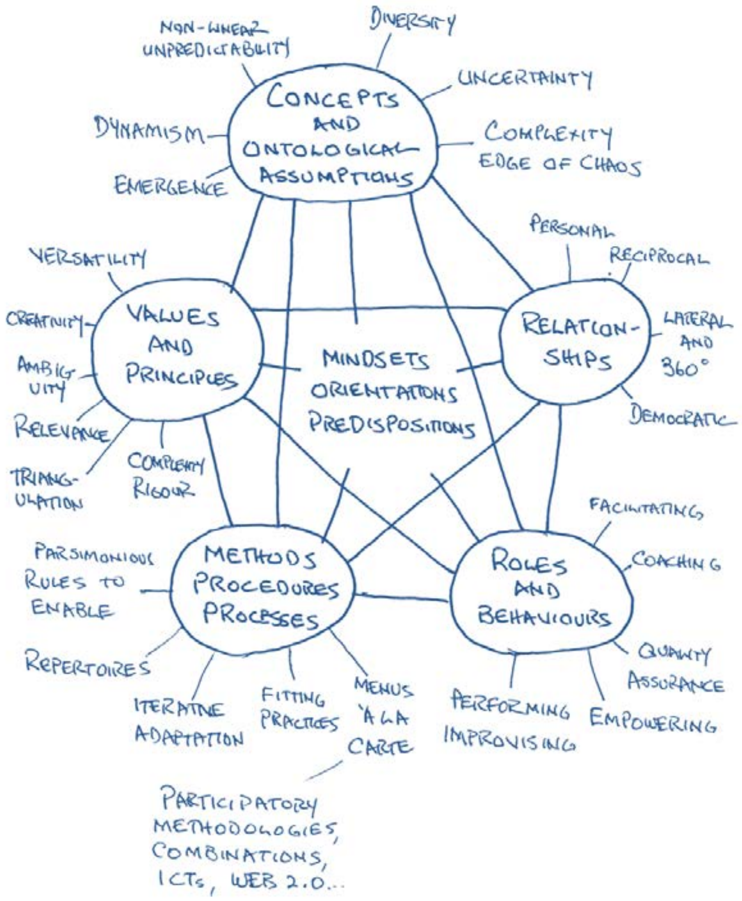

Figure 2 *Elements in a paradigm of Adaptive Pluralism* (Chambers, 2010)

At this point, it is also worth noting that Global Dimension skills and competencies may be seen by some to conflict with traditional views that engineering is necessarily reductionist (as opposed to holistic) and should be continue to be inclined towards an ever-more precise and defined understanding of the world around us. We see this often reflected in our educational structures with – for example – different departments for different disciplines that work separately from one another. The mindset for this more traditional view could be interpreted from Chambers' descriptors of 'Neo-Newtonian practice' and it cannot be dismissed or reduced – because it has been fundamental to human development since the Enlightenment, enabling the scientific revolution and the advancement of technology.

Exploring the view that the Global Dimension is in conflict with traditional approaches – in an open forum that is accepting of diverse opinions – is one of the first steps from which a 'change strategy' should develop. The debate may then move towards the question of, say, space in the curriculum or in the timetable to combine both the traditional and Global Dimension competencies together.

Throughout such debates, as has already been highlighted, it is important that the skills and competencies of a Global Engineer are not viewed as entirely separate or distinct from those of a traditional engineer. Whilst dwelling on the differences can help to articulate what is meant by the Global Dimension of Engineering, maintaining the differences cannot be the longer term intention (nor is it helpful in the change process to reach a new status quo). In short, it is imperative to recognise from the outset that a Global Engineer must still be an engineer – in order to meet the important traditional obligations of the professional engineer.

An example interpretation of the skills and competencies of the Global Engineer was the production of the diagram in Figure 3 taken from the Engineers Without Borders UK (EWB-UK) 2012-2017 organisational strategy. The figure visually demonstrates that at the heart of an individual 'Engineer Without Borders' (the organisation's interpretation of a Global Engineer) lies 'a great engineer'. It recognises that a Global Engineer is not a distraction from, nor in conflict with, what it means to be an engineer. Indeed, it is interpreted as an enhancement of what it means to be an engineer in acknowledgement of the changed and changing world. The descriptors of skills and competencies in the surrounding space was the result of consulting hundreds of engineers for their input on the concept of the 'Engineer Without Borders' and is now used as a guide for the learning journey of EWB-UK members.

To therefore provide a true discourse on the skills and competencies of a Global Engineer, reference and mapping to the skills and competencies of an engineer of any discipline is essential will now be introduced (this mapping and embedding of the Global Dimension in Engineering Education is also discussed in the following chapters of this course and in the GDEE course chapter entitled '*Mapping the Global Dimension in Teaching and Learning*').

Figure 3 *Descriptions of the skills and competencies of the 'Engineer Without Borders' – the interpretation of the Global Engineer concept by Engineers Without Borders UK – showing that a great engineer lies at the heart of the interpretation* (EWB-UK, 2012).

STAGES FOR EMBEDDING SKILLS AND COMPETENCIES FOR GDEE

To begin the process of embedding the skills and competencies needed for the Global Dimension in Engineering Education, a five stage process was first outlined by Bourn & Neal in their 'Global Engineer' report in 2008. In the GDEE course entitled '*Mapping the Global Dimension within Academia*', Byrne has summarised this process with a discourse more specifically tailored to academics and course leaders who wish to embed the Global Dimension into their programmes. Byrne's summary is reproduced in Table 3.

Table 3 *Five stage process to embed the skills and competencies for GDEE* (Byrne, 2014)

Stage 1	Develop 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 addressed 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.

This process focuses on demonstrating that the skills and competencies for the Global Dimension in Engineering can be linked to the existing skills and competencies identified by the governing engineering institutions for the development and accreditation of engineers. Again, it is very much in line with the idea that the Global Engineer is not a diversion from the idea of the traditional engineer and attempts to bring the traditional engineer up to date.

This process is therefore ideal for facilitating change because it references what is already known and accepted. As a result, the change appears incremental rather than radical. Radical change is very difficult to achieve and often needs extraordinary circumstances as well as buy-in from multiple stakeholders at all levels to be successful (it is also the most risky). It is therefore suggested that, when moving through the suggested process stages, particular importance is paid to Stage Five and the link back to Stage One so that a longer-term process of change is achieved that continuously adapts to the changing context of the world around us.

Stage One: Mapping

The initial stage of embedding the skills and competencies needed for the Global Dimension in engineering requires in-depth understanding to identify them. With the guiding concepts highlighted in this chapter, as well as throughout these GDEE Courses, this exercise is about exploring those concepts for yourself to be able to interpret the term ‘Global Engineer’ and the ‘Global Dimension in Engineering’ as seems fit for your institution, curriculum programme(s) and course(s). In particular, it is useful to highlight where these particular skills and competencies are being addressed already (one example of this is a search of course materials using Global Dimension keywords that was undertaken at the University of Brighton (Diakoumi, et al., 2012)). Note that this approach itself embeds the Global Dimension into the process referring to the Adaptive Pluralism characteristic of using ‘fitting practices’ rather than ‘best practices’. Table 1 is suggested as a starting point for identifying issues and skills. Table 2 is suggested as a starting point for competencies.

Stage Two: Matching

Having understood and identified these skills and competencies, they can then be compared to the list of learning outcomes determined by the course as well as the overall learning outcomes for the discipline of engineering being taught (as may be defined by engineering institutions or engineering accreditation bodies). In their Global Engineer report, Bourn & Neal map the Global Dimension against the UK-SPEC learning outcomes to demonstrate how the outcomes are linked to the issues and skills they have identified and which are reproduced in this chapter in Table 1. Table 4 is a reproduction of this mapping based on the second edition of the UK-SPEC (to see an updated version based on the third edition of the UK-SPEC 2014, see the GDEE course *Mapping the Global Dimension within Academia*).

Stage Three: Opportunities

The third stage in the process for embedding skills and competencies focuses ways that the Global Dimension in Engineering can be increased where there is an existing presence and implemented where there is no presence. Some suggestions from Bourn & Neal (2008) are:

- **Ethos and Core Values:**
  Engineering practice often deals with complex contexts and difficult global problems, technical, financial, social and environmental which may be unfamiliar to the engineers. Addressing the ethos and core values of engineers gets to the nub of addressing the skills and competencies for the Global Dimension in Engineering and is central to any attempts to embed it into the curriculum. Using materials such as case studies where the theory is encased in a real world example through which the Global Dimension in Engineering can be presented and discussed in direct relation to the technical engineering theory is as an opportunity to move engineering teaching from the black and white of theory, into the increasingly complex global environment engineers have to be competent to operate in.

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

Table 4 *Mapping 2nd edition UK-SPEC learning outcomes and GDEE* (Bourn & Neal, 2008)

- **Visiting Lecturers:**
  Similarly, to bridge the gap between academia and engineering practice, university relationships with companies and alumni can be leveraged to bring external perspectives and experience into courses, in the form of guest or visiting lecturers. Many non-profit organisations have speaker lists, with experts in particular fields or countries who are willing to share their knowledge and experience with students. Care must be taken to ensure that these speakers are within the scope of the course and are not seen as 'extra-curricular' by students.

- **Feasibility and design projects:**
  Projects are an excellent medium to develop the skills and competencies for the Global Dimension as they challenge the student to really assess their technical choices within the framework of comprehending the Global Dimension in Engineering. An example of this is the EWB Challenge where first and second year undergraduates are invited to engage in a for-credit team design competition based on briefs developed with a community partner from across the globe. The students are actively encouraged to consider and include the Global Dimension in Engineering in their design work through the identification of these particular learning objectives in the marking criteria used by EWB to identify teams to present their ideas at a finals day. These marking criteria are complimentary to any institutional marking criteria however in some instances have been adopted as such.

- **Dissertations and Research Projects:**
  Likewise, research projects and dissertations can be an opportunity for students to work on 'real' projects, partnering with local engineering companies or, facilitated through NGO's, developing communities throughout the world. A good example of this approach is the Appropriate Technology Research Programme at Nottingham University which allows third and fourth year students to engage with global design problems, sourced through NGOs such as Tearfund, Engineers Without Borders and Practical Action.

- **Management, business, innovation and enterprise skills:**
  Where project management and business skills are included in the curriculum, there is an opportunity to develop transferable skills and explore global issues such as: Global skills required by employers., the impact of globalisation on engineering employment, global business drivers (such as innovation, poverty reduction and climate change), global futures in the engineering sector, the importance of multi-disciplinary, team working in engineering, the importance of understanding the social, economic, environmental, cultural and political context and finally, global business ethics and corporate responsibility. These can all be explored easily through using case studies, such as those within the GDEE resources or through publications such as the Royal Academy of Engineering's 'Engineering in Society' (see additional reading)

- **Innovative pedagogies and team based working:**
  Active learning methods, such as role play, simulations etc. can be effective ways of surfacing the detail and complexities in global dimensions of engineering and will encourage individual and critical thinking. Through team based working, transferable skills such as presentation, negotiations, conflict resolution, cultural awareness and respect can be learned through doing by students, if this process is carefully managed. However not all students welcome such approaches. Student surveys at Imperial College show some engineering students, particularly those who excel at maths and science, struggle with non-technical subjects and non-lecture based learning. These students mark down such modules which they perceive to be more difficult, despite many acknowledging the value of such non-technical content later in their courses.

Stage Four: New pathways to development

Developing Global Dimension pathways throughout the degree programme is perhaps the most difficult task because it can require a huge amount of coordination of multiple stakeholders, timelines and learning objectives as well as requiring buy-in from those in control of this coordination. It may not be possible in every situation. However, ensuring that the materials within the proposed course(s) builds upon earlier learning is the most powerful way to ensure that the Global Dimension in Engineering is embedded in the curriculum and the associated skills and competencies are cultivated in the engineers being developed.

This may involve delving into preceding courses, and mapping their learning outcomes against Global Dimension skills and competencies to understand the comprehension that students should already have gained. To simplify this process, colleagues could be encouraged to share their thoughts or mapping of Global Dimension engagement in their courses, and once the course design has been completed for your course then your Global Dimensions skills and competencies should in turn be shared with colleagues.

Another approach is to create ‘vertically integrated programmes’. This approach is being used to great effect at the University of Strathclyde though the David Livingston Centre for Sustainability. The University of Strathclyde has had a long-standing partnership between its engineering department and a group of government, community and non-governmental organisations in Malawi. Many of their engineering courses are now designed around this partnership, and so students can work on solutions to real problems in Malawi throughout their time at the University. For example, undergraduate design and research projects are used to prepare students for the context and technical differences of working in Malawi, and undergraduate final year projects are linked with postgraduate researchers in Malawi. This vertically integrated programme approach has created a Global Dimension pathway throughout an undergraduate’s studies at the university. A later chapter in this course, entitled ‘*Teaching and Assessment Methods*’ outlines another GDEE example of a vertically integrated programme at Coventry University.

Stage Five: Monitoring and Evaluation

Through student surveys, peer review or other monitoring and evaluation methods that are appropriate to a particular university context, it is possible to gain feedback on how the learning outcomes are being achieved in the class and how the Global Dimension is being learned. By reflection on this data, and through an iterative process including the preceding four stages, courses can be continually updated to increase the cohesion between the learning outcomes and the Global Dimension. Revising the course content is also an opportunity to keep abreast of current trends, technologies and thinking globally. The GDEE course entitled '*Monitoring and Evaluation*' goes into this in some depth using the example of the Global Engineering Challenge at Sheffield University.

CONCLUSIONS

The skills and competencies for the Global Dimension in Engineering are new, complex and could potentially be seen as being in tension with more traditional views of the skills and competencies of an engineer. However, they have been shown to be necessary, complimentary and directly mapped with the skills and competencies of an engineer. Indeed, developing the skills and competencies of a Global Engineer are meaningless without also developing those fundamental to an engineer – and in any discourse this connection must remain clear. It has also been implied that what it means to be an engineer is not, and never should be, a static definition and that it changes with the times and with global challenges.

It is recognised that the skills of critical thinking, team working (including in multi-disciplinary teams and with non-engineering experts), the ability to work across cultures and contexts, systems thinking and strong inter-personal and communication skills will need to be an integral part of all engineering education. These skills can perhaps be readily addressed through tweaks to curriculum and changes in teaching methods. The competencies or mindsets that accompany them are, however, harder to bring into a curriculum and require a much deeper understanding and a broader change that more fully embraces and embeds the Global Dimension.

By designing courses from this deeper understanding, and by planning the implementation of learning outcomes that map to the Global Dimension as part of pathways throughout an engineering student’s university education, the change in skillsets and mindsets will prevail. Students will gain a greater appreciation of engineering and of its global role, and they will have the ability to apply their new skillsets and mindsets towards the development of humanity and the future sustainability of our planet.

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FURTHER/SUGGESTED MATERIAL

- Book: The Medici Effect: What Elephants and Epidemics Can Teach Us About Innovation
- Report: Engineering in Society – Royal Academy of Engineering. Available from: www.raeng.org.uk/news/publications/list/reports/engineering_in_society_ebook.pdf
- Report: The 2006 Hinton Lecture, Redesigning African Economies - The Role of Engineering in International Development. Available from: www.raeng.org.uk/news/publications/list/lectures/Hinton_Lecture_06.pdf
- Report: Striving for Humanity, 2013 Failure Report. Available from: http://blogs.ewb.ca/failure2013/
- Report: Engineering for Sustainable Development. Available from: www.raeng.org.uk/education/vps/pdf/Engineering_for_Sustainable_Development.pdf

PHOTO: : The school in Yari. N. Greene

CHAPTER 3

Intended learning outcomes

3

CHAPTER 3. Intended learning outcomes

EDITED BY
Global Dimension in Engineering Education

COORDINATED BY
Agustí Pérez-Foguet and **Enric Velo** *(Universitat Politècnica de Catalunya)*
Manuel Sierra *(Universidad Politécnica de Madrid)*
Alejandra Boni and **Jordi Peris** *(Universitat Politècnica de València)*
Guido Zolezzi *(Università degli Studi di Trento)*
Rhoda Trimingham *(Loughborough University)*

WITH GRATEFUL THANKS TO
Boris Lazzarini *(Universitat Politècnica de Catalunya)*
Xosé Ramil and **Sara Romero** *(Universidad Politécnica de Madrid)*
Jadicha Sow Paino *(Universitat Politècnica de València)*
Angela Cordeiro and **Gabriella Trombino** *(Università degli Studi di Trento)*
Emily Mattiussi, Sylvia Roberge and **Katie Cresswell-Maynard** *(Engineers Without Borders - UK)*

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3 INTENDED LEARNING OUTCOMES

Rhoda Trimingham, Senior Lecturer, Sustainable Design Research Group, Loughborough University

EXECUTIVE SUMMARY

This session discusses the importance of Intended Learning Outcomes (ILOs) when integrating the Global Dimension in universities, especially as they relate to the key skills and competencies as discussed in the previous chapter.

ILOs are the "*statements of knowledge, understanding and competencies which...engineering programmes are designed to develop in...students*". They inform teaching methods selected in engineering programmes through teaching theories such as constructive alignment. Therefore, it is important for academics interested in developing modules related to the Global Dimension to have a clear idea of the ILOs for students in order to inform the rest the module development.

At the end of this chapter, participants will be able to construct a set of ILOs for their Global Dimension programmes in accordance with the curricular frameworks their programmes are embedded in.

LEARNING OUTCOMES

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

- Understanding of the importance of a clear set of ILOs in the development of new module structures.
- Developed capacity to construct a set of ILOs for Global Dimension related programmes.

KEY CONCEPTS

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

- How Intended Learning Outcomes inform teaching methods through the identification of the knowledge, skills and values a student should gain through studying the course.
- Understand the link between ILOs and key skills and competencies for GDEE.

GUIDING QUESTIONS

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

- What are ILOs?
- What are relevant/important ILOs for Global Dimension related programmes?
- How do you link ILOs with key skills and competencies?

INTRODUCTION

"*Organising teaching is really about designing learning*" (D'Andrea, 2006, p26). Designing learning makes the intentions of the teaching activity explicit for both academics and learners, which improves the learning experience. Defining ILOs requires academics to make conscious choices regarding teaching and learning and focusses attention on the learning experience (D'Andrea, 2006). D'Andrea highlights the benefits of developing ILOs as being:

- Makes learning focussed and achievable
- Gives direction to student learning
- Provides a 'contract' between academic and learner
- Allows for flexibility and intervention if outcomes not met
- Helps focus essential concepts and skills
- Suggested increase in learning (ibid).

Defining Intended Learning Outcomes

ILOs should describe what students should know, understand and/or be able to do at the end of the course or programme. They should be centred on student performance. Each individual ILO should support the overarching aim of the course.

HOW TO CONSTRUCT INTENDED LEARNING OUTCOMES

There are a number of differing views on how intended learning outcomes should be developed, and many higher education establishments have their own rules – so it is always a good idea to ask about these in the first instance.

You may wish to construct ILO's through the identification of the 'knowledge' (what they should know and understand), 'skills' (what they should be able to do) and 'values' (also referred to as 'attitudes' which refers to the students opinions) that you wish a student to gain throughout the course.

Many academics also refer to learning taxonomies to construct ILO's. A famous example of these is Bloom's Taxonomy (1956, although also see Mackenzie and Pritchard, 2008 which connects nicely with ILOs) which categorises cognitive tasks and suggest action verbs to use when construction ILO's. These help in developing ILOs that are appropriate for the level of achievement intended (D'Andrea, 2006). Bloom (and colleagues, though they're often ignored!) refers to three overlapping domains, which relate to the knowledge, skills and values domains that we often refer to today:

- Cognitive domain (knowledge)
- Psychomotor domain (skills)
- Affective domain (values)

He proposed that knowing was composed of six successive levels arranged in hierarchy; from simple fact recall at the bottom, to evaluation at the top (see Figure 1):

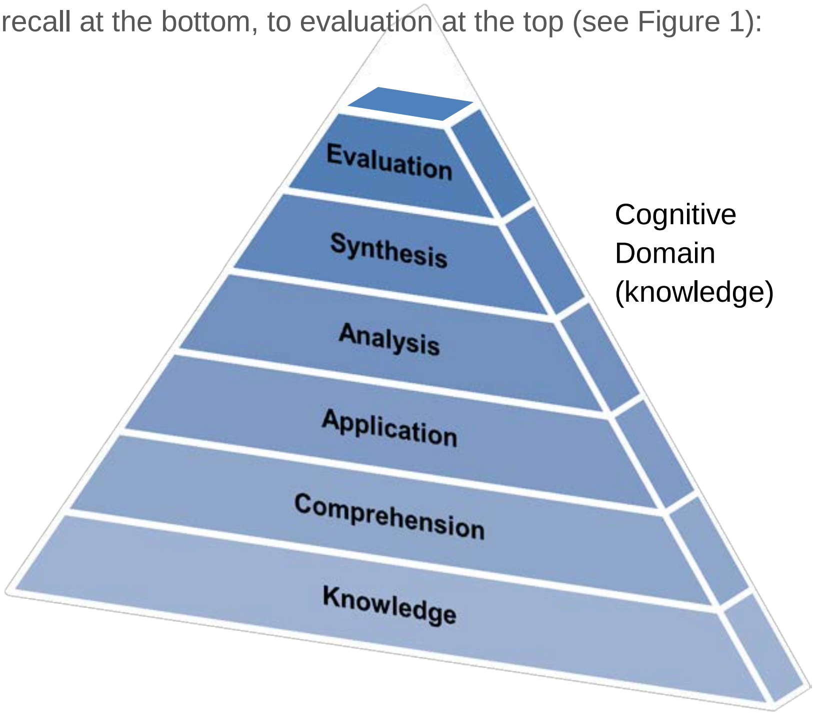

Figure 1 *Bloom's Cognitive Domain hierarchy*

Bloom presents a number of action verbs that can be used to construct ILOs at a given level, from ‘surface learning’ to ‘deep learning’ (or bottom to top of the hierarchy). Surface learning refers to students’ intention to complete a task, and memorising information. Deep learning refers to students who intend to understand and relate evidence to conclusions (Atherton, 2005). A good overview of the complete taxonomy and associated verbs is given by Kumar (2011) (although not an academic website, this presents the work very clearly). He also presents this interpretation of Bloom’s wheel (see Figure 2):

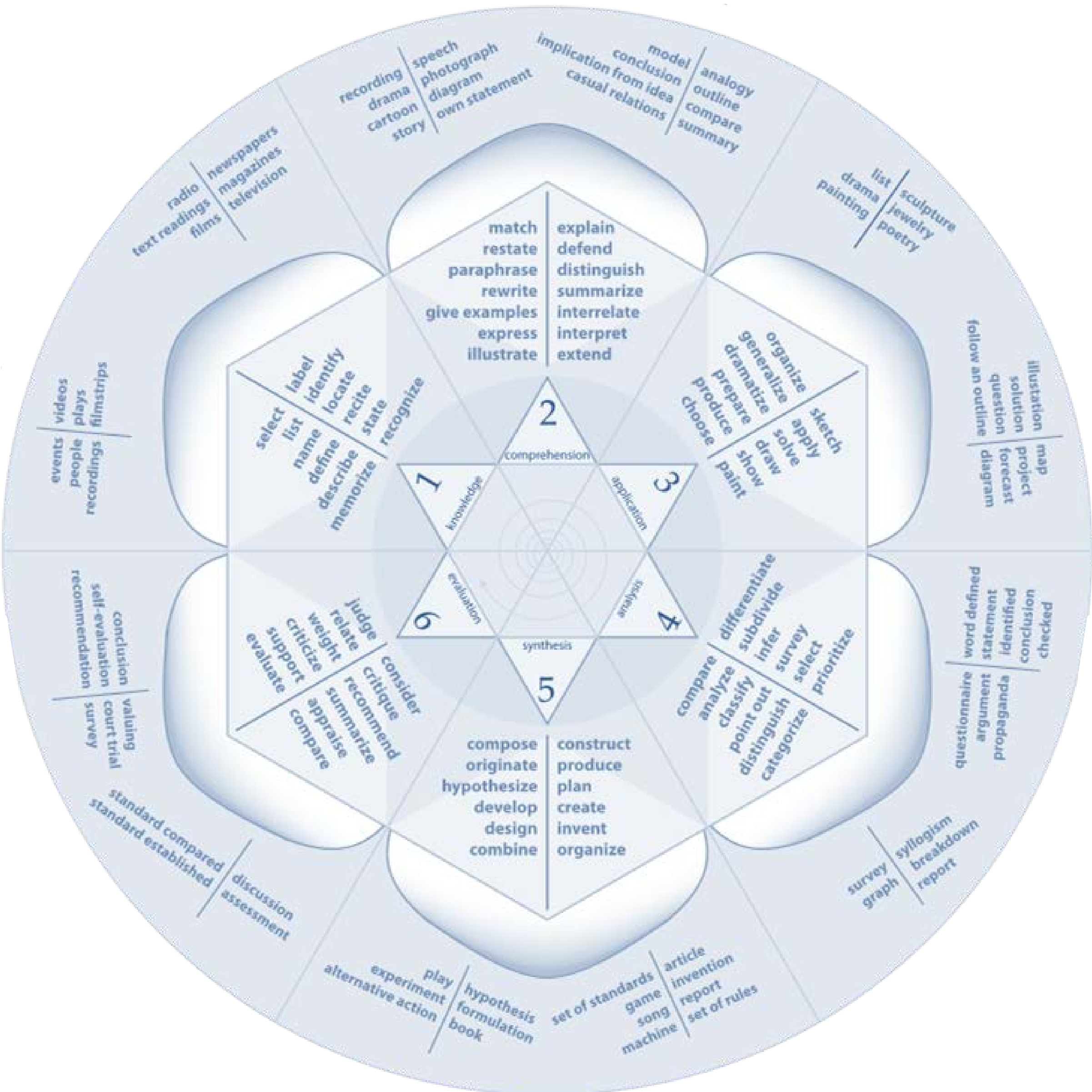

Figure 2 *Bloom’s wheel* (Kumar 2011)

Whilst the cognitive domain is the most widely referred to, it is important not to ignore the affective (values) and psychomotor (skills) domains – particularly for the Global Dimension.

Bloom developed five categories within the affective domain (see Figure 3 for these five areas and associated action verbs):

Figure 3 *Blooms' Affective Domain hierarchy and verbs* (Kennedy, 2006)

The psychometer domain has been less well discussed, and Bloom did not complete a hierarchy for this domain. However a number of authors have suggested a hierarchy for this domain including Dave (1970, cited Kennedy, 2006) as presented below (see Figure 4):

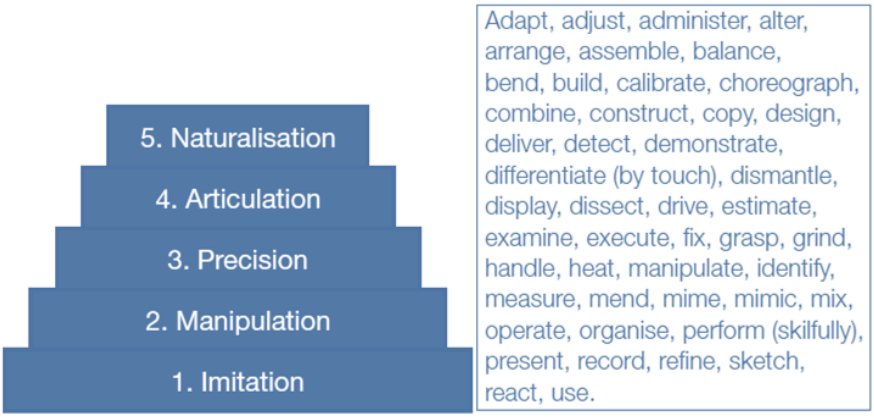

Figure 4 *Dave's proposed Psychometer Domain hierarchy, and verbs* (cited Kennedy, 2006)

A module with about six well-written ILOs is ideal to specify the essential learning for that module. If you have more than ten ILOs then you have gone too far! (Kennedy 2006).

ILOs should always be linked with measurable outcomes so the student understands how they will be asked to demonstrate that they have achieved each ILO. Rubrics (criteria for success) should be developed so students can understand what is expected of them. ILOs should always be assessable (Moon, 2002) and there should be alignment between teaching methods, assessment techniques, assessment criteria and ILOs (ibid).

INTENDED LEARNING OUTCOMES AND GLOBAL DEVELOPMENT

A paper by Svanstrom et al discusses the commonalities that can be found in ILOs for successful Education for Sustainable Development programmes. The commonalities include systemic or holistic thinking, integration of perspectives, skills such as critical thinking, change agent abilities, communication and different attitudes and values (Svanstrom et al, 2008). These commonalities also resonate with priorities discussed in the Global Dimension.

The following is taken the Svanstrom et al paper, which has been developed through looking at the Tbilsi Declaration, the Barcelona Declaration and a number of successful Sustainable Development programmes:

- **Systemic or holistic thinking:**
  Systemic thinking aids the acknowledgment of complexity and finding balance between different dimensions. It relates to interactions and relationships. It combines the skills of analytical and synthetic thinking (p342).

- **Different perspectives:**
  Inter- and multi-disciplinary are also terms often mentioned here and refers to bringing in other views and disciplines in order to build a holistic and balanced perspective of a problem or solution. This also includes the importance of local, national and co-operation (p342).

- **Skills:**
  Skills that are often mentions are problem solving, critical thinking, creative thinking, self-learning and communication, teamwork and becoming an effective change agent (342).

- **Attitudes and values:**
  Awareness, attitudes and values are also important ILOs for the Global Dimension. Addressing attitudes is seen as a way to create commitment and concern that motivates active participation (343).

CONCLUSIONS

This chapter has introduced Intended Learning Outcomes (ILOs) as a method of making educational intentions explicit. ILOs focus attention on the learning experience and forces academics to make conscious choices about course content. ILOs are commonly developed through the identification of the knowledge, skills and values a student should gain through the course. Often learning taxonomies are used to construct ILOs and a popular example by Bloom has been presented above.

Academics embarking on the development of Global Dimension in Engineering Education programmes should take note of the successful Engineering for Sustainable Development programmes discussed in the chapter – alongside the conclusions from the GDEE course chapter entitled ‘Key Learning Theories and their Relationship with GDEE’ – that call for active, student-centred learning and a focus on the skills and values required by learners. These sections of learning taxonomies are often overlooked but stand as the lynchpins of effective GDEE courses.

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FURTHER/SUGGESTED MATERIAL

A good example of ILOs that relate to the Global Dimension can be found from the Engineers Without Borders Challenge. Available from:
www.ewb.org.au/explore/initiatives/ewbchallenge/learningobjectives/learningoutcomes


PHOTO: Good Aid vs. Bad Aid. A. Elias

CHAPTER 4

Teaching and assessment methods

4

CHAPTER 4. Teaching and assessment methods

EDITED BY
Global Dimension in Engineering Education

COORDINATED BY
Agustí Pérez-Foguet and **Enric Velo** *(Universitat Politècnica de Catalunya)*
Manuel Sierra *(Universidad Politécnica de Madrid)*
Alejandra Boni and **Jordi Peris** *(Universitat Politècnica de València)*
Guido Zolezzi *(Università degli Studi di Trento)*
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4 TEACHING AND ASSESSMENT METHODS

Rhoda Trimingham, Senior Lecturer, Sustainable Design Research Group, Loughborough University

EXECUTIVE SUMMARY

This session introduces some teaching and assessment methods that support the key learning theories presented in Chapter 1.

Innovative teaching and assessment methods that are more suitable or adaptable to Global Dimension related programmes will be introduced. Participants will be exposed to a variety of innovative methods that could improve student experience within their programme. Case studies to illustrate these methods are derived from the first round of the 'Global Dimension in Engineering Education Teaching Awards'.

LEARNING OUTCOMES

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

- Understand the application of appropriate teaching methods.
- Understand the application of appropriate assessment strategies.

KEY CONCEPTS

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

- Teaching methods that support key learning theories
- Assessment methods that support key learning theories
- Inspirational case studies

GUIDING QUESTIONS

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

- What would work at my university?
- What teaching methods would best match the materials I teach?
- How can I add transformational learning to transactional learning?
- What are the most interesting aspects of the examples given?
- What will I do to ensure that I stay informed and my teaching is relevant?

INTRODUCTION

The scale of adaption required by engineers to enable them to produce globally appropriate outcomes is large. Engineering students (and academics!) need to be made more aware of the issues and given the skills with which to deal with such change.

All of the educational themes and studies of best practice that you have seen so far throughout this course follow the same pattern. They begin by introducing concepts of global development and building global development knowledge, and they then move to supporting learners who are expected to be working on real projects. This approach promotes learning that emphasises independence of mind and the ability to make sense of, rather than reproduce information (Khan, 1995).

Engineering for global development must involve the key characteristics of a transformative (discussed below) educational approach. It involves creative, solutions-focused learning; self-directed teamwork; learning-by-doing (commonly referred to as ‘real’ or ‘live’ projects); iterative refinement and reflection; and drawing from a range of disciplines to inform outputs.

To date, engineering for global development has been viewed as an additional subject to be addressed. But to reach conceptually different solutions, one has to begin to see engineering-focused thinking in a context of global development (Sterling, 2001, Bourn & Neal, 2008).

In 2004, academics from Loughborough University developed the ‘toolbox for sustainable design education’ (Bhamra & Lofthouse, 2004) which included key learning objectives for sustainable design education. These were later used, among many others, by Bourn and Neal during the development of ‘The Global Engineer’, and Chapter 2 of this course has outlined their five-stage process for embedding the Global Dimension (Bourn & Neal 2008).

However, this process can be developed further, as summarised below. Five new stages have been added by the author to reflect new understandings of effective education for global development. The additions have been developed by drawing upon the outcomes of case studies that reflect best practice for GDEE (taken from the GDEE Teaching Awards). It also embeds learning from a recent publication ‘Internationalising Higher Education’ from the UK’s Higher Education Academy (HEA, 2014).

The ten key stages for embedding the Global Dimension in Engineering Education can now be summarised as:

1. Develop a faculty-wide philosophy and base of knowledge and understanding.
2. Identify areas within the curriculum where global development can enhance current teaching.
3. Introduce students to global development.
4. Integrate the idea of systems thinking in relation to global development.
5. Convey an appreciation of the commercial, institutional, legislative and social motivations for implementing global development.
6. Demonstrate knowledge and understanding of the concepts of global development and how it exists within discipline-specific contexts.
7. Advance practical understanding of the pressures facing industry in terms of integrating global development.
8. Acquaint students with the current range of tools and resources available for integrating global development, and understand how to use the most common.
9. Allow students to generate solutions through active learning.
10. Develop a view of future directions for global development engineering.

This chapter now looks at each of these ten key stages in greater depth, and presents the case studies from the GDEE Teaching Awards that demonstrate their use.

TEN STAGES FOR INTRODUCING GDEE IN TEACHING AND ASSESSMENT

1. **Develop a faculty-wide philosophy and base of knowledge and understanding.**
In order to integrate the Global Development within Engineering Education, you will need to get people on board. This starts with your own faculty to build impetus and enthusiasm. One of the best ways to start is to develop awareness, highlight benefits and present of examples of best practice (all of which can be found in these courses). It is crucial to get the buy-in and commitment of the engineering department leadership.

2. **Identify areas within the curriculum where global development can enhance current teaching.**
It is often beneficial to begin with a review of the current situation. In a number of the case studies presented below, academics have been surprised to discover how much GDEE teaching already exists and can be aligned. The next step is to identify areas in which learning for global development can be integrated into the curriculum. The mapping of skills and competencies to the relevant discipline requirements is essential. The challenge here, as highlighted by Bourne and Neal (Bourn & Neal, 2008) is to protect the teaching of 'core engineering' whilst bringing in the benefits of a Global Dimension curriculum (as discussed in Chapter 2 of this course).

3. **Introduce students to global development.**
The student now becomes the focus of attention. The aim of this stage is to provide students with the necessary understanding (and knowledge) of how engineering can play a role in the move towards global development. The emphasis should be on the ability to understand and apply theory to real problems, and to develop the learner's ability to use technical engineering knowledge to help solve complex problems.

Traditionally, building knowledge about a subject area is seen as a transactional or transmissive activity (where an academic transmits knowledge of how to do something to a learner, in order that they might then go and do that thing). However, it is important to introduce a transformational or transformative activity into teaching (Sterling, 2001) – for example, by having activities where students can be asked to engage with faculty staff and respond to a number of questions, discussions etc (see Table 1).

By moving from transactional/transmissive teaching (where information is passed to the learner) to transformational/transformative teaching (where the learner constructs meaning) (Sterling, 2001) or 'learning-by-doing' (Kolb, 1984, cited in Fry et al, 2007), students are empowered to become deeply engaged with the subject. It has been noted that when a teacher takes a purely transactional/transmissive approach to teaching, students are more likely to adopt a more surface approach to their learning where their intention is to complete the task by memorising the information (Atherton, 2005); but when a teacher engages students through transformational/transformative activities, the student is more likely to adopt a deep approach to learning (ibid) and this approach emphasises "*independence of mind and the ability to make sense of, rather than reproduce information*" (Khan, 1995). With this in mind, it is also essential to make use of Bloom's taxonomy when developing Intended Learning Outcomes (ILOs) to ensure that the teaching and assessment methods fall into deep learning zones (as discussed in Chapter 3 in this course).

Table 1 *Examples of the differences between transactional/transmissive and transformational/transformative paradigms in education* (Sterling 2001)

Transactional/Transmissive	Transformative/Transformational
instructive	constructive
instrumental	intrinsic
training	education
teaching	learning
communication of message	construction of meaning
information focus	appropriate knowledge
central control	local ownership
product oriented	process oriented
problem solving	problem reframing
linear	iterative and responsive
facts and skills	concepts and capacity building

Teaching methods include traditional lectures (with transformational/transformative elements of course!), individual and group study, search and analysis of information, debates, student-led seminars, invited speakers, workshops, wider reading, research projects, thesis, case studies and examples from around the world, videos or international partnerships.

4. **Integrate the idea of systems thinking in relation to global development.**
Systems thinking provides a way of looking at the scale of the problem and the ways in which change can occur. It provides new ways of thinking that focuses on studying elements in terms of their connection, context and relationships to the whole. In terms of global development, a systems perspective reflects the complexities involved and whole life analysis required to tackle global development issues, and also the relationship between solutions and their context.

Teaching methods include life cycle thinking or whole life analysis, and understanding complexity. It also includes the understanding of contexts, through case studies and making connections with people around the world and wider issues.

5. **Convey an appreciation of the commercial, institutional, legislative, and social motivations for implementing global development.**

   This stage reflects the need to put global development into a real context, and the importance of business, innovation and enterprise skills.

   Teaching methods include work placements, guest speakers/tutors and strong links with industry, NGOs and community organisations.

6. **Demonstrate knowledge and understanding of the concept of global development and how it exists within a specific discipline.**

   This stage reflects the importance of developing a network of key strategic relationships within your specific discipline, both for review of courses and for the delivery of subject specific content. It also reflects an understanding that global development solutions need to be multi-disciplinary.

   Teaching methods include the use of case studies and partnerships with business and community organisations.

7. **Have a practical understanding of the pressures facing industry in terms of integrating global development.**

   It is important to gain an understanding of the specific global skills that engineering industry (including government, business and NGOs) requires within engineering graduates (which, as shown in Chapter 2 of this course, resonates increasingly strongly with the Global Dimension).

   Teaching methods include the exploration of management techniques for global development through project briefs and case studies, the use of management and planning tools, and inputs regarding enterprise and innovation.

8. **Acquaint students with the current range of tools and resources available for integrating global development, and understand how to use the most common.**

   This stage is to provide students with tools and techniques to integrate global development thinking into engineering solutions, both during their studies and through into employment.

   Teaching methods include role plays (and developing role play games themselves), student-led seminars, the use of case studies within new projects, and the introduction of current tools and techniques. Engineers Without Borders organisations, GDEE UK and GDEE Europe are good places to look for current tools and resources for presentation to students.

9. Allow students to generate solutions through active learning.

This stage is to provide the students with the opportunity to put theory into practice by carrying out global development projects. This is essential in order for them to fully understand the challenges & opportunities within engineering for global development. It is also important to remember the importance of critical thinking in education for global development, since it allows learners to challenge assumptions and to analyse problems to find effective solutions. This has been deemed essential to understanding and tackling global issues (Bourne & Neal, 2008 and Khan, 1995).

Teaching methods for critical thinking can be promoted through dialogue, seminars, multi-disciplinary projects, and active learning pedagogies. Active learning methods include real / live projects set by industry, team projects, multi-disciplinary team projects, research projects, thesis and dissertation, active research, global development competitions (such as Engineers Without Borders Challenge), role play and participatory techniques. Popular pedagogical models such as those of Kolb (Kolb, 1984) and Bloom (Bloom, 1956) have also been used to develop effective module content. The Kolb Cycle suggests that students learn through a re-iterative process of concrete experience (doing), reflective observation (reviewing), abstract conceptualising (concluding) and active experimentation (see Figure 1).

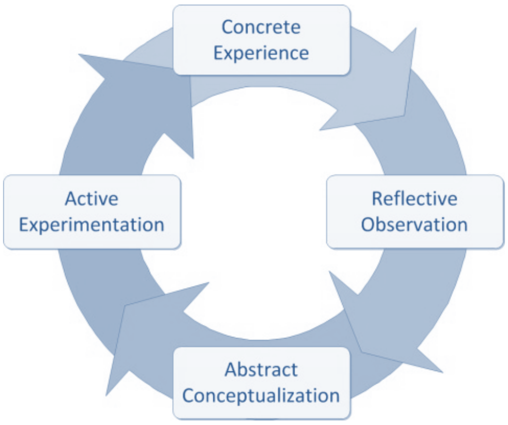

Figure 1 *The Kolb Cycle* as taken from www.envoys.com.

10. Develop a view of future directions for global development engineering.

This is important for both academics and students because it helps to guide current activity through a lens of future possibilities. From an academic perspective, this includes becoming involved in research that is related to global development and keeping up-to-date with current thinking within the GDEE. New principles and understanding, as well as new tools and techniques, can then be integrated into teaching.

Sources to stay informed include the GDEE Teaching Awards, Engineers Without Borders conferences, research groups (such as www.ukcds.org.uk, www.ids.ac.uk and www.steps-centre.org in the UK), websites like www.engineeringforchange.org or www.appropedia.org and some engineering education reform initiatives (such as www.bigbeacon.org and some leading national engineering academies or institutions).

SUMMARY OF BEST PRACTICE

A good place to start when contemplating the integration of the Global Dimension into engineering courses is to have a look at what others have done before!

The case studies shown below are the recipients of the first 'European Award for best practice in the Integration of Sustainable Human Development into Technology and Engineering Education' (known as the 'GDEE Teaching Awards'). The content of these case studies helps to support the ten steps presented above. The following are brief summaries taken from their respective award applications (links to publications written by the academics involved in each of these case studies is provided at the end of the chapter).

Introducing Humanitarian Engineering & Computing at Coventry University – Elizabeth Miles

Miles successfully integrated and embedded the theories and practices of 'Humanitarian Engineering and Computing' (HE&C) into the curriculum in the Faculty of Engineering and Computing at Coventry University. She did this by the introduction of the concept of HE&C as a method to develop the global perspective of engineering and also the ethical and sustainability side to the subject.

Miles began by reviewing existing literature and engaging with staff and students as to what the exact definition of 'Humanitarian Engineering and Computing' would mean to Coventry University. Once this had been defined, time was taken to establish a baseline of understanding of the existing capability within the Faculty that aligned with this HE&C agenda. Then, work was done to develop and execute a strategy for the incorporation of HE&C into the curriculum in a way that aligned with the overall philosophy of teaching engineering at Coventry University.

The overarching objective was to develop a Faculty-wide philosophy through appropriate curriculum development and delivery that allowed all students the opportunity to study the theories and practices of HE&C in a manner that gave them both a broad appreciation of responsible engineering and a deep global perspective of the use of engineering.

This overarching objective was broken down into several smaller SMART (Specific, Measurable, Attainable, Realistic, Time-bound) activities that were as follows:

1. Investigate academics' and students' perceptions of the term 'Humanitarian Engineering and Computing' and to review this in terms of up-to-date literature.

   For staff this was done through a day of activities including key note speakers, curriculum discussions and focus groups. For students this was done through online and paper-based questionnaires, workshops and focus groups.

2. As a result of this, a shared Coventry University definition of 'Humanitarian Engineering and Computing' was developed as: "*using engineering and computing in culturally sensitive and sustainable ways to address social issues in communities that are unable to cope themselves. This can be on a local, national or international level and does not necessarily have to follow a disaster or crisis*".

3. Establish a baseline understanding of existing capability within the Faculty that aligns with this definition and agenda.

   This was done through focus groups, discussions and a senior management discussion about capabilities and activities within each department.

4. Develop a network of key strategic relationships to support and advise the Faculty on the development of their HE&C agenda.

   This involved engaging with key organisations across the UK including Engineers Without Borders UK, Engineers Against Poverty, RedR UK, WaterAid and Architecture for Humanity for advice.

5. Make appropriate applications to sources of funding and support for enhancing capability.

6. Raise the profile of HE&C within the Faculty and university overall.

7. Identify areas within the curriculum that HE&C could enhance the materials already delivered to the students.

   Through some of the earlier activities, the staff were also able to generate ideas of how to integrate HE&C into their teaching.

8. Develop a 'humanitarian pathway' that students could choose to study to develop their skills and understanding of this area.

   This approach to a 'vertically integrated curriculum' made use of a ten-credit module in each of the three years of engineering study and was also available to all Coventry University students.

As a result, 450 students attended humanitarian modules within the initiative's first three years. Students gave a 98% satisfaction rating for these modules on feedback forms. In 2012, a team from Coventry University secured first place in the national Engineers Without Borders Challenge competition finals. Coventry University hosted the competition finals in 2013 where one of its teams won second place. More than 60 staff attended the activity days and a core team of 20 academics now actively engage with the HE&C agenda.

Introducing Sustainability and Human Development skills at the Barcelona School of Informatics using Service Learning – David Lopez

In order to integrate Sustainable and Human Development (SH&D) into the Barcelona School of Informatics, Lopez used Service Learning within Information and Communication Technologies for Development (ICT4D). Service Learning is a method of teaching and learning that combines an academic classroom curriculum with meaningful service throughout a real community. These service activities are planned to ensure that students acquire the necessary knowledge and training. As a learning methodology, it falls within the philosophy of experiential education. Service Learning enables students to participate in activities focused on human and community needs, which are planned beforehand to assure that students acquire the necessary knowledge and training. Comprehension of real-world problems helps students to develop S&HD skills and provides them with new perspectives.

The objectives of the project were to:

- create a network of students, academic staff and administration staff involved in S&HD activities;
- integrate S&HD skills in several subjects of the study plan and assess the knowledge acquired, whilst developing the tools required;
- design activities with a real impact on the community in the implementation of Service Learning ideas – learning engineering skills while helping develop communities (achieving other benefits, like reducing e-waste);
- develop an increasing number of projects conducted as Bachelor and Master theses that are service projects, and to include all this knowledge in research.

A number of initiatives were implemented including:

1. Introducing the teaching staff to Sustainability and Human Development skills.

   The first step was to create a network of teaching staff committed to introducing these skills in their subjects. These teachers were offered training workshops on the relationship between S&HD and the computing and services industry.

2. Creating support tools.

   This includes a book chapter aimed at providing ICT teachers with theory and examples of S&HD to use in their subjects and an educational knowledge database for S&HD on IT knowledge areas.

3. The Reuse Workshop.

   This is a lab activity shared across several subjects and consists of taking computers discarded by the university and: testing their performance and preparing a report on the ones that still work; repairing broken computers, separating the parts that still work for use in other computers; and installing free software adapted to the requirements of the final projects in which these computers will be used.

4. Other activities throughout the workshop, such as talks, round tables or meetings.

5. ICT4D projects.

   ICT4D projects are used to implement service learning. Most of these projects help local communities and NGOs, but about one-third of the projects (the more complex ones) are aimed at supporting communities in developing countries with ICT access and use in order to contribute to their sustainable development.

6. Integrating S&HD at all levels of teaching and research.

As a result of these initiatives, the awareness of students and staff increased and the University now engages with other universities' globally within this arena. S&HD skills are fully integrated into the curriculum and are assigned and assessed in mandatory subjects. Support materials have been developed to help teachers integrate S&HD, such as eBooks and a knowledge database. More than 60 students have conducted ICT4D projects.

Sustainable Human Development in Mainstream Undergraduate Engineering Education at the University of Edinburgh – Alison Furber

The Institute of Infrastructure and Environment at the University of Edinburgh provides a mainstream civil engineering degree. They are currently engaged in ongoing research to explore ways to help student engineers develop the skills they will need to tackle issues of sustainable development. In particular, they are interested in improving the way students incorporate qualitative factors (for example social and ethical dimensions) into their engineering design solutions, alongside those factors which can be quantified (for example technical and economic dimensions). Current research objectives include finding innovative ways to develop students' abilities to combine qualitative dimensions of sustainable design alongside the quantitative. They are trialling an innovative method of combining 'Case Method' with 'Socratic Dialogue' (which encourages the reflexive thinking where there are no right or wrong answers) in teaching.

Current objectives of the Institute of Infrastructure and Environment include:

1. Continue to integrate and embed sustainability and human development dimensions in undergraduate teaching curriculum.

2. Test innovative ways to develop student ability to combine qualitative factors with quantitative in engineering design.

3. Respond to students' demands for increased course content relating to sustainability and global issues.

4. Increase employability of graduates.

5. Include case studies of an international development nature in engineering courses as an exciting and engaging way to expose student engineers to challenges that allow them to develop the skills they will need during their career. Produce graduate engineers with the skill set they will require during their career to tackle global issues and strive towards a more just and equitable world.

6. Trial Projects. Small-scale trials have been undertaken during a number of advanced level projects. The goal of these projects is to present students with an engineering problem set in a particular context and ask them to develop a solution. The context (which is either described to the students or researched by them) gives the problem a real-world complexity and encourages multi-dimensional thinking. Since the problems are designed such that there is not one correct solution, the students must get to grips with identifying a broad range and types of factors, multi-criteria decision making and coping with uncertainty.

The Institute has recently won a grant from the University to employ an assistant to research and develop additional teaching material with a view to improving sustainability teaching. The aim is to trial innovative ways to educate engineers about broader issues of sustainability and human development and find ways to embed these teaching methods throughout all level of the curricula.

Beyond Traditional Education in Engineering: a systemic approach to strengthen development at Politecnica de Milano – Emanuela Colombo

The challenge of promoting sustainable and human development has become a mission at Politecnico di Milano, led through collaborations with governmental, academic and international institutions. Activities have been tailored to combine the innovative and rigorous methodologies for the performance evaluation of energy conversion systems with a holistic and creative approach that tries to meet the constraints of economic, environmental and social sustainability. Research and teaching are focused on strategies for improving energy access and for impact evaluation. Activities also depend on the effective contribution of PhD students from developing countries.

Objectives include:

1. Broadening Knowledge and Promoting Research for development.

   This aims to build new competences and new attitudes to development and social responsibility. Students are offered work on theses in joint co-operation with universities from developing countries.

2. Curricula innovation.

   Theory and practice have to be linked together to increase the competences of students. Courses are implemented with the direct contribution of other actors of co-operation to development – such as NGOs – and through the presentation of real case studies.

3. Enforcing networking and knowledge sharing.

   The focus on sustainable development also meets the interest of Politecnico to share this mission with other institutions involved in the same pattern of content – within the goal of strengthening the network, especially with universities from developing countries. Staff exchanges and joint projects are being implemented. The staff exchange is tailored to knowledge-sharing among research personnel of the institutions. Incoming PhD students carry out part of their research at Politecnico in order to acquire the tools for effective development of co-operation projects, while outgoing PhD students develop such tools in the field to complete their studies.

Partnership with universities in developing countries has been very positive, with two projects granted funding by the European Commission aimed at upgrading higher education systems on Sustainable Development, Sustainable Energy strategies and North-South co-operation. Two lecturers (from Tanzania and Cameroon) are now developing their PhD research at the Department of Energy.

Hacking and Translating for Social and Economic Development at the University of Trento – Adolfo Villafiorite & Fondazione Bruno Kessler

The ICT4D group of Fondazione Bruno Kessler uses new technologies to foster social and economic development. They have been organising ‘hackathons’ and ‘translathons’ for the last two years at the University of Trento.

There are three main objectives for these activities:

- Expose students to issues related to social and economic development.
- Train students on practical aspects of building applications.
- Build prototypes and solutions which can make an impact.

Hackathons (hacking marathons) are a relatively new format in which volunteers gather and dedicate their time to focus on solving specific problems. Translathons (translation marathons) focus on the localisation of applications; it is a powerful approach to break barriers and give access to information.

One characteristic of the events is the involvement of Computer Science and Engineering undergraduate students who work with professors, researchers and domain experts as peers. The mix provides a new and refreshing approach to learn, teach, and have fun. Presentations by NGO experts offer a unique opportunity to expose students to relevant issues. The innovative aspect of the format is mixing teaching and hands-on, while targeting a focused applicative domain. During the event, researchers and students sit and work together. This allows student to learn ‘in the field'.

A second important aspect to consider is the way the event helps inform and create interest about socially relevant issues. During the event, experts working in NGOs share their experiences and propose challenges; representatives have come from Informatici Senza Frontiere (an Italian NGO focusing on open-source eHealth solutions in Africa), Last Minute Market (an Italian NGO focusing on food waste), Banco Alimentare (the Italian food bank) and the emergency department of the Autonomous Province of Trento

Another important aspect is that the participants build prototypes, and some of these prototypes have been tested in the field.

Integrating Sustainable Development into Engineering Design through the EWB Challenge at Durham University – David Toll

Undergraduate students at Durham University have been educated in Sustainable Human Development through the means of the design course in the second year of the Engineering Masters programme. The focus has been the Engineers Without Borders Challenge.

All design projects undertaken by engineering students within the second year design course at Durham University must take sustainability into account through the choice of materials and the whole-life use of energy. However, projects have been extended to introduce international development and the issues of sustainable use of natural resources and minimising the impact to the local environment. Students are encouraged to consider technologies that are appropriate to developing country contexts while making use of modern engineering methods.

The objective of these projects is to contribute towards the sustainable development of disadvantaged communities in developing countries whilst also educating and familiarising engineering undergraduates and academics in critical 21st Century issues: globalisation, climate change, sustainability and inequality. Students at Durham University study a general engineering programme for the first two years that includes aspects of Civil, Mechanical, Electrical and Electronic Engineering. All students undertake a design course in the second year, equivalent to 10% of the year. Students work in groups of 5 or 6 students on a project brief that is substantial in scale and multi-disciplinary in nature. To introduce the concepts of Sustainable Human Development, the students are given activities relating to the Engineers Without Borders Challenge; for example, tackling real projects to develop innovative and appropriate project solutions to make a contribution towards the sustainable development of the Anh Minh district within the Kien Giang province on the Mekong Delta.

The concepts of sustainable human development were developed through small group teaching. Students worked on these projects supported by a pair of design tutors; one an academic tutor and the other from industry. Students were also supported by the on-line EWB Challenge provision that can provide details of the local environment, availability of different types of materials and the skill sets available among the local community. These internet sources provided the students with the ability to gain effective awareness of the conditions and environment in Vietnam.

Over the last 2 years, over 80 students have been educated in the concepts of sustainable human development through the means of the second year design course. The design course is tutored by 16 design tutors (8 academic and 8 industrial tutors). It has been very successful in educating a large proportion of the undergraduate students at Durham University and a significant number of academic and industrial design tutors in issues relating to sustainability and global development.

In addition, a design proposed by students at Durham University will provide sustainable electricity to 500 typical households in the Anh Minh district of Vietnam.

CONCLUSIONS

It is becoming essential for all engineering graduates to have a good understanding of global development so that they can apply these skills within professional practice. However, one of the major problems in getting to grips with global development is the diversity of the issues that impinge on it; from technical issues to the importance of values in human decision-making.

By developing a number of resources with a number of partners, universities can begin to establish an integrated approach and a clear roadmap for the Global Dimension to be developed. By developing resources, the building of knowledge and skills as a student's education continues is promoted. The approaches used within these resources can also develops a student's problem solving abilities by focusing on understanding and engaging with issues and working on live projects (often through partners).

In opening peoples' minds to the scope of the connection between global development and engineering, it is important that they have the opportunity to translate abstract concepts into language and action that has resonance for them. The main idea behind linking traditional knowledge transfer to active learning is to provide students with a familiar 'zone' (the act of thinking as an engineer) to explore an unfamiliar area; in this instance, the core concepts of the Global Dimension.

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PHOTO: Life in the slum. B. Kunwar

CHAPTER 5

The issue of relevance

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EDITED BY
Global Dimension in Engineering Education

COORDINATED BY
Agustí Pérez-Foguet and **Enric Velo** *(Universitat Politècnica de Catalunya)*
Manuel Sierra *(Universidad Politécnica de Madrid)*
Alejandra Boni and **Jordi Peris** *(Universitat Politècnica de València)*
Guido Zolezzi *(Università degli Studi di Trento)*
Rhoda Trimingham *(Loughborough University)*

WITH GRATEFUL THANKS TO
Boris Lazzarini *(Universitat Politècnica de Catalunya)*
Xosé Ramil and **Sara Romero** *(Universidad Politécnica de Madrid)*
Jadicha Sow Paino *(Universitat Politècnica de València)*
Angela Cordeiro and **Gabriella Trombino** *(Università degli Studi di Trento)*
Emily Mattiussi, Sylvia Roberge and **Katie Cresswell-Maynard** *(Engineers Without Borders - UK)*

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5 THE ISSUE OF RELEVANCE

Daniel Pargman, School of Computer Science and Communication and Centre for Sustainable Communications, KTH Royal Institute of Technology, Stockholm, Sweden

EXECUTIVE SUMMARY

This chapter is a practical text that presents personal experience.

It is written for university teaching staff who want their engineering students to 'get on-board' and care about Global Dimension issues, which are usually perceived (even by some students themselves) to be outside the scope of traditional engineering education. In this chapter, the Global Dimension issues are taken as primarily non-technological issues that impact the engineering profession at a global level[1].

This chapter is particularly aimed at those who are planning and developing a course that includes the Global Dimension, or those in a position to commission such a course (e.g.: a head of teaching or a head of department). Whilst it is good to have GDEE in a course, and better to have it embedded across a number of courses or to shape a whole education programme, this chapter has a more modest goal. Also, because of the nature of topic, it is written from a personal perspective[2].

I teach a course for first year students on a Master's degree in the Media Technology Engineering Programme at KTH Royal Institute of Technology in Stockholm, Sweden. Its overarching challenge is environmental sustainability, so my experiences and many of my examples will relate to environmental sustainability. However, my aim is to reflect on the broader issue of student engagement in a way that allows you to apply it to GDEE.

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[1] The author includes: climate change, ecological crises such as pollution and species extinction, globalisation, surveillance, erosion of freedoms, militarisation, the extent of democracy, over-population, over-consumption, resource depletion, energy scarcity, water scarcity, over-fishing, rate of food production, economic recession or depression, unemployment, social instability, global poverty and inequality etc. The list is long and can be made longer, but can be considered as three broad topics; environmental, social and economic sustainability (Brundtland, 1992)

[2] This chapter is based on two articles I have authored with my colleague Elina Eriksson, entitled: *'It's not fair!: Making students engage in sustainability'* (Pargman & Eriksson 2013) and '*ICT4S reaching out: Making sustainability relevant in higher education*' (Eriksson & Pargman 2014).

LEARNING OUTCOMES

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

- Make informed decisions about various trade-offs that will impact the content and design of our course.
- Consider and possibly re-consider your role as teacher in a GDEE course.
- Enthuse your students about your GDEE course.
- Initiate the process of finding an ‘angle’ on GDEE that will suit your course, students and programme.

KEY CONCEPTS

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

- Sustainability.
- CO_2 emissions, climate change, energy and Information Communications Technologies (ICT).
- The ethics, values and responsibilities of university teachers.

GUIDING QUESTIONS

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

- How do you regard and treat your engineering students? Do you see them as (passive) empty vessels to be filled with engineering knowledge or as materials to be moulded into engineers? Or do you see them as (active) growing plants to be nurtured or as independent travellers who are looking for directions?
- How can you plan a course yet still enable the unplanned to emerge?
- How far does your responsibility as a teacher stretch if your GDEE course raises difficult – and perhaps even painful – questions? What is your responsibility if students become de-motivated, despairing or even depressed by the global challenges covered in your course materials?
- How much should you as a teacher disclose about your own world view, convictions and attitudes?
- How do you assess students’ work where its most valuable outcome might be the unplanned, emergent results of debate, discussion and your students (altered) thought processes?

INTRODUCTION

Everybody knows that engineering students absolutely detest courses on ‘soft’ and ‘squishy’ topics like ethics, justice and sustainability, right? Wrong! I would argue that engineering students can be just as (or even more) interested in these topics as they are in their ‘core’ courses – as long as the ‘soft’ topics are planned and taught in a way that reaches and engages the students.

For an example, I refer to talks by a leading computer ethics researcher Donald Gotterbarn whose interest in computer ethics (and most of his examples) come from his reflections on his own experiences[3]. It is almost impossible for students not become engaged by his humorous way of chiding (and wryly making fun of) his younger ambitious-but-clueless self, who imposed seemingly reasonable restrictions on computer systems that later – in unpredictable ways – sometimes led to serious failures and effects.

Another example is a larger ‘theme’ developed at the School of Civil Engineering and Geosciences at Newcastle University (UK) that focused on global engineering challenges and that incorporated engineering ethics and sustainability as well as ‘*human demands and impacts*’ (Hall et. al. 2013). In partnership with a non-governmental organisation called Raleigh International, undergraduate students worked on the task of providing a cleaner, safer and more secure water supply to a rural community in a developing country by implementing two gravity-fed water systems in a community in the Pitas region of Borneo. Although sending off a class of students to Borneo is hardly realistic in most cases, my point here is to ask: does anyone seriously expect these students to ‘not be interested’ in the global dimensions of engineering?

I would thus argue that the right teacher(s) with the right (personal) experiences and with great teaching materials holds great chances of engaging the most (seemingly) ‘square’ engineering student in almost any topic. Are you that person? Can you become that person?

I hope that I am, and I will describe a few humble suggestions based on hard-won experiences and insights of my own – having struggled with these questions for some years. I will not, however, offer any checklist or guide. Instead, I present a number of ‘tensions’ that are interleaved in the text (in coloured boxes, like the one below). These ‘tensions’ should help you to consider your own personal position on these issues as you develop your GDEE course.

[3] http://csciwww.etsu.edu/gotterbarn/

Tension: Out-source or In-source?
Should the course be out-sourced and taught by external ‘experts’, or should the course be ‘in-sourced’ and taught by an existing/regular teacher at the department? The easy solution may be to out-source, but while there are obvious advantages to having outside experts teach a course, there are also some important disadvantages.

The main problem is that external experts often have only a weak understanding of – and a tenuous link to – core issues in the programme, as well as to the interests of the students. This becomes all the more important if many students hold the pre-conceived opinion that the ‘soft’ topic is, at best, peripheral – and, at worst, irrelevant – to their education. It could easily be that the course becomes just another hurdle, and that its lessons are relevant only up until the examination and no further.

My personal conclusion is that the better solution is to in-source the course. It is not a coincidence that computer-scientist-turned-ethicist Donald Gotterbarn tells captivating tales (based on his own experiences) about the ethics of systems development that spellbind his computer science students. There is hopefully such a person at your department e.g.: someone with an interest in the area in question and who, with some support, would like to develop their expertise in the area further. It may also be possible to invest in such a person – one who shows potential but perhaps has not yet travelled to a developing country and could be persuaded to take a sabbatical to help them realise their potential.

HOW DO YOU ACTIVATE YOUR STUDENTS?

There are, of course, a large number of possible ways to engage students. I might assume that ways to engage students in GDEE do not differ fundamentally from ways to engage students in any other topic. But would my assumption be correct?

I personally think that many Global Dimension issues are hot-button issues that have a higher chance of engaging students than traditional engineering content. It is hard to believe that students could not become engaged in discussing and furthering their knowledge about fundamental global dimension questions compared to, for example, learning about structural characteristics of different building materials or different choices of compiler architectures.

I personally try to do whatever it takes to rock my students. Provoke them! Shock them! Challenge them! Deride them (or, rather, use self-deprecation or critique the attitudes of your own generation or your perceived attitudes of their generation)! Do whatever it takes to squeeze out reflective comments from students and to begin a discussion.

There will always be a few students who are willing to be first and have a go at it. If not, play it cool and (literally) wait them out; a long silence that stretches out (no comments or questions from the audience) will invariably become embarrassing to (some of) them if you can brave it yourself.

My experience is that a lot is possible in the classroom as long as you can manage (or save) the situation by resorting to humour or by adopting a certain degree of critical/abstract distance to both the message and to your own performance. I have, in my practice as a university teacher, made great use of courses in rhetoric and improvisational theatre!

Another way to get students to speak up is to provoke them by proxy. Find excellent, provocative texts that can get a discussion going (even if the texts don't have the very best academic pedigree; your students will worry little about this as long as the texts are lucid and engaging). Or initiate difficult discussions by finding and (re-)framing recent news events that are of relevance to the course (e.g.: newspaper articles, podcasts, YouTube videos or TED talks etc).

Personally I have used the 2010 British Petroleum Deepwater Horizon oil disaster in the Mexican Gulf (Tainter & Patek 2011) and the 96% write-down of shale oil reserves in California in May 2013 (which destroyed projections of 2.8 million new jobs and tens-of-billions of dollars in tax revenues)[4]. My students get to ponder whether the risks and benefits of fossil fuels are, for the most part, for better or for worse.

[4] www.latimes.com/business/la-fi-oil-20140521-story.html

Tension: Generic sustainability or Doomsday sustainability?
We have consciously chosen to make the issues clearer and easier to grasp by presenting two fundamentally different and opposing perspectives:

Generic sustainability is the effortless sustainability where our current problems can be solved without any major changes to our political and economic systems, to our current levels of affluence or to our current way of life. Generic sustainability points at a future where mitigation strategies worked. Generic sustainability describes solutions to our current problems as possible, viable and perhaps even inevitable; with high hopes tied to new technologies[5], with increased quality of outcomes in terms of political governance, corporate decision-making, media coverage and increased involvement and/or pressure from the general population etc.

Doomsday sustainability instead points at the folly of believing that our current civilisation is sustainable (i.e.: will continue for a long time). Problems of significant concern are many. For example, current economic models are based on exponentially increasing throughput of (non-renewable) energy and resources – and that, taking a wide diversity of important environmental data points and measurements, we already know that we are heading in the wrong direction, yet there is little effective political action. Doomsday sustainability points at a future where adaptation strategies are necessary (Tomlinson et. al. 2012), i.e.: where we have to learn to live with the uncertainty of altered weather patterns and extreme weather events, as well as decreased human affluence and welfare (Lovelock 2009, Hansen 2009). Doomsday sustainability could work as a call for more fundamental, rather than superficial, action and is thus amenable to initiating ‘interesting’ discussions in the classroom.

I used to think that it would be hard to ‘rock’ our students and was genuinely surprised by their receptiveness to news ideas. In our department, we asked ourselves exactly where our students’ readiness to listen to alternative narratives came from. The best answer we have is that these students are, for the most part, between 22 and 24 years of age – so the financial crisis of 2007-2008 and its lingering effects (e.g. the post-2008 global recession, then the European sovereign-debt crisis etc.) has been with them for all their adult lives. What is considered normal to someone who is a decade or so older (i.e. eternal prosperity and economic growth) is not considered normal to students in their low-to-mid 20’s today. They are therefore much more open to, ready to consider or indeed hungry for alternative interpretations of the state of the world (compared with those of their parents’ generation).

There are of course many more tricks that can be used to engage students – such as inviting external guest speakers or challenging students to establish more sustainable personal habits as part of the course (Axelsson and Nyström 2010). In my own course, we make our seminars

[5] For example geoengineering, carbon capture and storage (CCS), nuclear fusion energy, the hydrogen economy, hydraulic fracking, electric cars, increased efficiency of heating and cooling etc.

more interactive by having each student prepare a question in advance, based on the weekly readings. We then vote for our favourite questions and discuss them at the seminar (i.e. different questions will be discussed in different seminar groups). We also begin our course by having students play a game to get them thinking and discussing issues of sustainability with each other. Some of the discussion questions are in fact seminar questions from the previous year's course, e.g.:

- ICT can help us share physical products, for example by organising car pools. What else can be shared with the help of ICT?
- Should we all adopt cloud computing for sustainability reasons? Elaborate!
- Is it sustainable to have free Internet services (email, Twitter, Facebook etc)?
- Do software developers have a responsibility to consider hardware requirements when they develop software?
- If there are major changes in our world due to climate change or lack of resources, how should we prioritise ICT compared to other infrastructures (healthcare, transport, education etc.)?

The only limitations are imagination and the structure of the course in question (duration, number of lectures and seminars, layout of facilities etc.).

Tension: Delivering facts or Discussing values?
Unlike more traditional engineering courses, facts regarding the Global Dimension are multi-faceted, complex, interdependent and demand action (although what specifically constitutes appropriate action is an open question – that can be discussed in class!). While facts are crucial, a GDEE course based only on facts would quickly become very theoretical and dry. The alternative is to explicitly bring values into the course and into discussions. This calls for more interactive forms of education (as discussed in other GDEE course chapters, and starting with an increased proportion of seminars compared to lectures, smaller seminar groups and/or using parts of lectures to answer questions and to get input from students). Mulder et. al. (2012) have identified nine main challenges in Engineering for Sustainable Development education and one of these challenges is '*how to teach normative content in an academic context?*'. There is no set answer to that question, and you will have to determine what the appropriate balance in your course should be. Leaning too much towards working with values might open the course up for unwelcome critique of a kind that you might not be used to (e.g. '*What exactly are we teaching when we teach the Global Dimension?*' or, '*Is the course based on evidence or ideology?*').

Personally, I have come to the conclusion that I am definitely not just interested in only delivering facts which are only assessed through a written exam at the end of the course. It would be easier, perhaps even natural, to give such a course because it would correspond to the format of many other traditional engineering courses. Such a course would also allow you as a university teacher to retreat into your domain knowledge and would cast you as someone who 'delivers the facts' with dispassionate concern and without personal investment in the issues at hand. However, I think it is very hard to get most students to care about Global Dimension issues if you yourself appear not to care about them.

HOW COMFORTABLE ARE YOU WITH TEACHING THE GLOBAL DIMENSION?

This brings us to an issue that challenges many of us as teachers of engineering. We are not, for the most part, used to bringing human values into our classrooms and into our discussions. I found that it took some effort and practice to become comfortable with (albeit obliquely) stating my own opinions on Global Dimension issues. (This was not helped by the commonly shared Swedish culture of seeking consensus and trying to avoid conflict).

The biggest challenges of teaching Global Dimension issues might, therefore, not be the challenges that the issues pose to students but are rather the challenges that the issues pose to you as a teacher. For the duration of your Global Dimension course, you might have to become a different kind of teacher than for your 'ordinary', more traditional courses.

Tension: Hide your hand or Show your colours?
In the game of Poker you try to hide your hand and reveal as few signals as possible; you try to maintain a 'Poker Face' (Goffman 1959). I strongly believe that the Poker Face strategy would be a serious error if you use it to teach a GDEE course. How can we expect our students to open up and discuss issues and values (including, perhaps, uncertainty and doubt) if we do not reveal any of our own hopes or fears? You will have to think through your own position and determine how much personal information you want to divulge in the classroom, or what to do if a student looks you up after class. Should you or shouldn't you tell your students that these Global Dimension issues keep you awake at night?!

Another main challenge formulated by Mulder et. al. (2012) is to '*practice what you preach*'. While Mulder et. al. referred to issues such as initiating environmental projects and greening the campus, my interpretation of this challenge is more personal. To lead and show the way through self-disclosure probably goes against our instincts as university teachers. As lecturers for an engineering programme, we often concentrate on (or retreat to?) the 'left-brain' aspects of our roles by only being logical, analytical and objective. It can be uncomfortable or even frightening to leave that comfort zone.

But how is it possible to create a considerate, trustful climate in a seminar room if we as teachers are not willing to 'lead from the front'? How do you create a secure environment where students can open up and discuss sensitive topics – including being prepared to engage students who speak frankly about their fears of a future of personal hardships (of decreased respect for human values, of increased strife and unrest or of a bleak future for human

civilisation or life on planet Earth)? These are tasks that we as university teachers are not necessarily prepared for, and they point to the need to rethink not just the engineer's role and contribution in society but also to rethink our roles as teachers of future engineers.
You can prepare by thinking through your own position. Why are these topics important for you, not just as a teacher but as a citizen and as a neighbour, partner and parent? You are and will always be a thought-leader in the classroom whether you like it or not. I suggest you start with the first lesson.

Although discussing values raises the stakes in the classroom, the benefits can also become much larger. Difficult, soul-searching conversation can be extremely gratifying – in terms of engaging students in Global Dimension issues as well as for the students as learners and for you as a teacher. It might well be the case that what makes the biggest impression on your students will be your own frank admission that, say, the possibility of not finding good solutions to Global Dimension issues scares you and fills you with fear. This might well be the only thing that they remember from your course five or ten years later! And it could make a lasting impression on them. The exam and the grade will surely be forgotten before long, so this might in fact be your best chance at having an effect on your students' way of thinking (and hopefully caring) about these issues over the rest of their careers. You can change their minds, and you can change the way that they see the world and the future.

One challenge that we have grappled with in our course is that our frank presentation of irrefutable facts can make students feel despair. Several students who took our course described how they, especially around the middle of the course, had felt almost depressed. They said that "*the course gives me a feeling of hopelessness*". Since this reaction was a direct effect of absorbing our lectures and the challenging texts we had given them, we were most certainly responsible for this; and we certainly had some sort of responsibility to handle the situation even though were not prepared for it.

At the University of Limerick, McMahon et. al. (2010) encountered the same issue in a course on sustainable development and their conclusion was that "*positive elements must be the focus of all teaching in the Sustainable Development realm so that students feel empowered and capable of bringing about behaviour change in themselves*". This directly relates to tension between 'generic' and 'doomsday' sustainability (discussed earlier) but it is worth noting that a feeling of hopelessness could signify that our course was indeed successful in engaging our students in sustainability (because it is certainly possible to feel hopelessness after you have been engaged about sustainability!).

I am personally not so sure that censoring the negative content of a course on Global Dimension issues is the best strategy to take. I do believe that we have to help the students feel both empowered and engaged as the course reaches its conclusion (but not necessarily throughout the course). Some of our students have, for example, expressed relief over being able to discuss difficult topics and ‘dark futures’ instead of only concentrating on positive, superficial messages (Ehrenreich 2010).

If a student begins questions their choice of course or programme as a result of the effects of our teaching (which has happened to us), what do you say as a teacher? I believe that we have a responsibility to assure our students that they have made the right choice (e.g.: chosen the right education) and to encourage them to ‘dig where they stand’. If they (and we) apply ourselves, what unique contributions could might they as engineers make to solving Global Dimension issues? Finding some way to contribute to solutions will help them to develop a sense of agency, and hope. Furthermore, to help find a good answer to this question (or any other) you can raise and discuss it in the classroom. This is important because, even on a pragmatic level, you will become very unpopular among both colleagues and the students if some students quit the engineering programme after taking your course. It is very important not to breed disillusionment or disenfranchisement.

I have personally found it much easier to manage the development and delivery of a GDEE course in collaboration with a sympathetic course assistant (for example a colleague or a PhD student) who shares your conviction that the topic is important. Since the course can not only challenge your knowledge of the facts, but also challenge you emotionally, it is very good to have a collaborator to turn to for planning, discussion and reflection.

FINDING YOUR ANGLE

I started this chapter by pointing out my opinion that, where possible, it is probably better to in-source a GDEE course rather than to completely out-source it. Still, how do you relate Global Dimension issues to your students’ interests? What about those students whose main purpose is passing their engineering exams rather than learning about engineering issues (that they may find difficult to articulate well)? These questions are difficult to answer in the abstract, so instead I will describe how we have worked both conceptually and pedagogically to tie climate change and computing together.

In our course, we have chosen to primarily focus on environmental sustainability and climate change (rather than on social or economic sustainability). We assume that the connection between carbon emissions (and greenhouse gases) and climate change is familiar to all students. But how do we rhetorically convince our students that these matters are something that they should care about (as Gotterbarn manages to convince his student that ethics is important for computer science professionals)? More succinctly, how do we relate ICT and CO_2 so that it makes sense for our students? Our answer below might sound simple, but it took us at least two years to find an angle that worked for our students.

We use energy and electricity as intermediary concepts to tie ICT and CO_2 together: ICT uses energy in the form of electricity, and; energy consumption creates carbon emissions and so causes climate change. Or: ICT ← electricity/energy → CO_2/climate change. This conceptual model makes it possible to connect the ICT industry (through its data centres or everyday ICT usage, for example) to energy use and carbon emissions. However that connection remains tenuous for many students, and hard to understand on an intuitive level. Most of our students do not have the same natural or intuitive understanding of energy and power (energy/time) as they have for, say, distance and speed (distance/time).

We have realised that something extra is needed to bring a deep and personal understanding of this conceptual model. We have chosen to use the concept of 'energy slaves' to do so[6]. An energy slave corresponds to the energy necessary to replace the (muscle) power of one human worker. Energy slaves are analogous to the horsepower unit of power (but where a horsepower is approximately equivalent to ten energy slaves). According to Avallone et. al. (2007) a healthy labourer can produce an average output of 75 Watts during an 8-hour day, or 0.6 kWh per day. Such a calculation is compares with that of McKibben (2011) stating that one barrel of oil is equivalent to 25,000 hours of human labour.
If, as the Greek philosopher Protagoas stated, "*man is the measure of all things*" then the concept of 'energy slaves' makes it easier to get a sense of scale in energy consumption. We have found that it allows engineering students to start making calculations about the energy costs of ICT infrastructure (such as data centres), ICT technologies (such as a TV, laptop or smartphone) or ICT activities (such as sending an email, searching the Internet, reading a webpage or playing an online game). The concept of energy slaves can be extended to discussions and calculations not just of energy use but also of the 'embodied energy' of ICT infrastructures and technologies (a term which captures the amount of energy used to manufacture and dispose of something) (Raghavan & Ma 2011).

After we found this angle, we chose to expand it and to make the most of it in our course. Despite it being a somewhat abstract way of bringing the topics of ICT and CO_2 emissions together (since most people have never heard of 'energy slaves'), we have found that it works well for us and for our purposes. Having come to that conclusion, we now suddenly find books and materials that we can build on and use in our education, such as Nikiforuk's (2012) '*The energy of slaves: Oil and the new servitude*' and Homer-Dixon's (2008) detailed calculations of how many real slaves – quite apart from the concept of modern-day 'energy slaves' powered by fossil fuels – it took to build the Colosseum in Rome.

I have outlined the angle we used to bring environmental sustainability into our Media Technology engineering programme. You will have to find your own angle, which will depend on

[6] The term 'energy slave' was coined by R. Buckminister Fuller and used in the 'World Energy' edition of Fortune Magazine, February 1940, cover illustration (see www.fulltable.com/vts/f/fortune/xb/50.jpg). The term 'energy slave' is sensitive or even unsuitable in certain contexts (particularly the USA) or with some students because it de-humanises the human. However it also provides very powerful and provocative way to humanise / conceptualise energy so that students can more easily engage with it.

the Global Dimension topics your course covers, its broader programme and its wider context. Based on my experience, it may be that you have to try your angle out on your students once or twice before you can find an angle that works.

Tension: Global Dimension in general or Global Dimension in particular?

One you have an ‘angle’, a new question arises: what is the best balance between the topic of the course (adapted to your particular engineering programme) and the Global Dimension in general? And what is the relationship between general Global Dimension issues and the particular Global Dimension issues that specifically relate to your topic? For us, the question was of the desirable (or acceptable) balance between general sustainability issues and those sustainability issues that explicitly related to ICT, to Media Technologies and to my students’ future professional careers. For example, we had to decide what emphasis we should put on carbon emissions in general compared to exploring how website designers can decrease the carbon footprints of their websites (Christie 2013). We had no clear-cut answer to that question but, since we chose to engage students in sustainability, we also implicitly chose to frame any ideas of our own about specific knowledge and skills. This means that, at times, it can be a challenge to find and guide seminar discussions towards an appropriate level – rather than allowing for more wide-ranging discussion.

Tension: Pragmatic or Utopian perspectives?

Should we concentrate on the reality of the here-and-now, or on the idealism of how things should be? The more practical approach might be more in line with traditional engineering or computational thinking (Wing 2006), which is to say “*we are here… what is our next logical step?*”. But if the challenges that we discuss in our courses are large or even fundamental, could it not be the case that they cannot be solved within the confines of current political, institutional and economic arrangements? If so, isn’t it right that we spend some time to encourage our students to think ‘outside the box’ in our courses? In our course about sustainability, we faced the typical sustainability question of whether we should praise every incremental step towards sustainability or whether we dismissed small steps as hopelessly inadequate and, instead, focused on the big picture (MacKay 2008). Is it valuable to use our precious course time to decrease the energy consumption of software perhaps even marginally – for example by developing ‘sustainable computer algorithms’ (IEEE Software 2014) – or were we just fooling ourselves that the these marginal changes are a solution?

Tension: Technological solutions or Appropriate solutions?

A major challenge is the ability of the engineer to think ‘outside the box’. The old saying goes that “*to the man with a hammer, everything looks like a nail*”. Well, to the student of an ICT course, everything will tend to look like a problem that can be solved by designing a technological fix in the form of a computer program. How do we get our students to think about low-tech or perhaps even no-tech solutions to hard or wicked problems (Rittel & Webber 1973)?

What if designing a (complex, complicated and perhaps fragile) computer system sometimes is the wrong way to go and, say, some social innovation would provide an easier and better solution (O'Day et. al. 1996, Baumer and Silberman, 2011)? For example, studies suggest that burglars are not necessarily deterred by yet another technological home security system, but are often deterred by evidence of neighbourhood cohesion (Erete 2013)! We would like our students to think about problems with as few prejudices as possible, including the prejudice that every problem in the world by necessity has (only) a technological or high-tech solution (Huesemann & Huesemann, 2011). The key lies in helping students to ask the right questions and to identify the real problems, without making any assumptions.

CONCLUSIONS

I have shared what I believe I know about the issue of relevance and, in particular, of helping students to engage with esoteric or abstract issues. I have presented some of the tensions that I have faced in practice myself as I have tried to engage computer science students in sustainability issues. I have mentioned the value of discussion, provocation, personal conviction, intermediary concepts and finding the right angle to approach the issues.

But I have also raised a number of questions that I currently do not have any clear answers to. I think that these are valuable questions because some will surely emerge in your classroom too. Like sustainability, the nature of GDEE is that it raises many questions whose diverse answers will only emerge slowly through the collective experiences of the GDEE community. Or, indeed, it may well be that there are no clear-cut answers to some questions – and that asking the question is what is important because it keeps us all engaged and relevant.

I wish you the best of luck with your course and with engaging your students with GDEE.

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