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CHAPTER 1

Key learning theories in GDEE

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1 KEY LEARNING THEORIES AND THEIR RELATIONSHIP WITH GDEE

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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)

There is, therefore, a strong correlation between the challenges that Engineering for Sustainable Development and the Global Dimension in Engineering Education.

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, and by corollary the Global Dimension in Engineering Education?

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:

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.

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

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):

	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

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

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):

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

Table 3 Dimensions of learning and teaching styles

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):

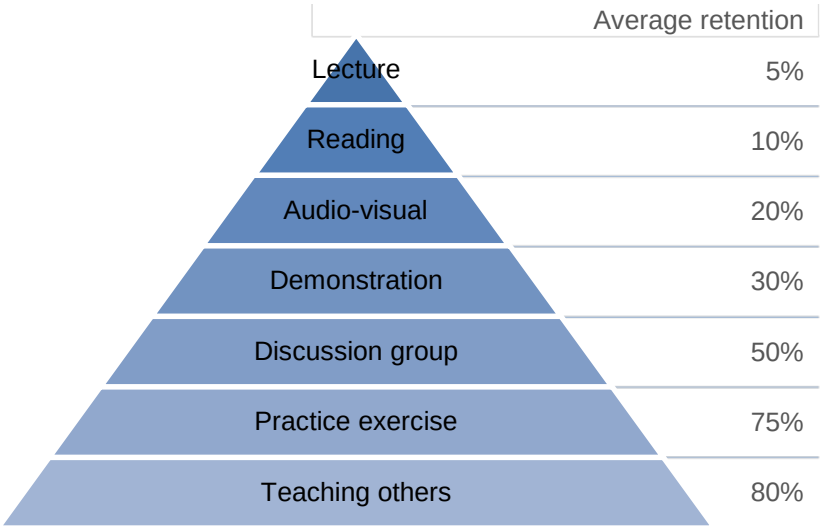

Figure 1 Bales pyramid of learning average retention (Bales, 1996)

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).

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 4 Classification of didactic strategies and techniques according to participation

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

Table 5 Classification of didactic strategies and techniques according to reach

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.

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).

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

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.

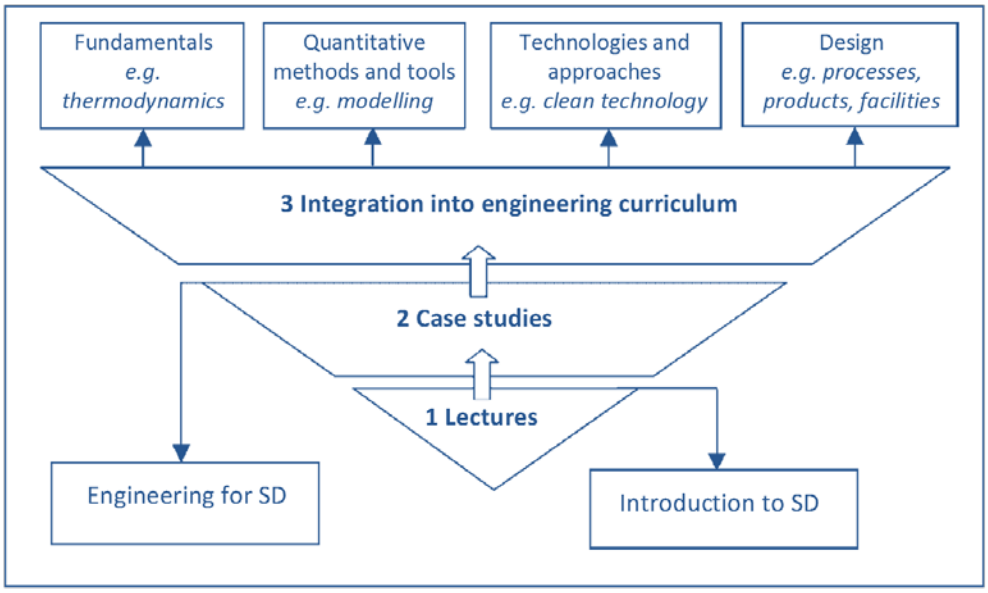

Figure 2 The three-tier approach to teaching sustainability (Azapagic et al., 2005).

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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