

## Educating Engineers for Sustainability. Why? What? How?

El desenvolupament sostenible (DS) és un procés en què s'han d'involucrar tots els actors de la nostra societat per aconseguir la fita d'un món sostenible. Les persones que treballen en l'enginyeria, que són una de les parts interessades d'aquest camí cap al DS, hi han de jugar un paper clau. Aquest article analitza la funció de l'educació superior en la formació dels i les professionals que han de liderar el canvi cap a un futur més sostenible. En concret, s'hi analitza el paper que haurien de tenir-hi les universitats tecnològiques i **PER QUÈ** haurien d'integrar l'educació en sostenibilitat com a valor central dels plans d'estudis d'Enginyeria. Posteriorment es presenta el **QUÈ**, quines competències, àrees de coneixement i comprensió, capacitats, habilitats i actituds hauria d'aprendre l'estudiantat d'Enginyeria a les universitats. En darrer lloc, s'hi analitza **COM** es pot fer que sigui possible adquirir aquestes competències en DS a través de la millora pedagògica necessària a les institucions d'educació superior.

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El desarrollo sostenible (DS) es un proceso en el que se han de involucrar todos los actores de nuestra sociedad para conseguir el objetivo de un mundo sostenible. Las personas que trabajan en la ingeniería, que son una de las partes interesadas de este camino hacia el DS, han de jugar un papel clave. Este artículo analiza la función de la educación superior en la formación de los y las profesionales que han de liderar el cambio hacia un futuro más sostenible. En concreto, se analiza el papel que deberían tener las universidades tecnológicas y **POR QUÉ** deberían integrar la educación en sostenibilidad como valor central de los planes de estudios de Ingeniería. Posteriormente se presenta el **QUÉ**, que competencias, áreas de conocimiento y comprensión, capacidades, habilidades y actitudes debería aprender el estudiantado de Ingeniería en las universidades. En último lugar, se analiza **CÓMO** se puede hacer que sea posible adquirir estas competencias en DS a través de la mejora pedagógica necesaria en las instituciones de educación superior.

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Sustainable development (SD) is a process which all actors of our society must be involved in to achieve a sustainable world. Those in the engineering profession, who are among the stakeholders involved in this path towards SD, have a key role to play. This paper analyzes the role of higher education in graduating professionals that should lead the shift to a more sustainable future. Specifically, the role technological universities should play is studied and **WHY** they should integrate sustainability education as a core value in the engineering curricula. Then **WHAT** competences, in the domains of knowledge and understanding, skills and abilities and attitudes, should be learnt by engineering undergraduates at the universities are presented. Finally, **HOW** to make the acquisition of these SD competences possible is analyzed through the pedagogical improvement needed in existing higher education institutions.



# Educating Engineers for Sustainability. Why? What? How?

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## I. Introduction

Sustainable Development (SD) is recognized to be the path to amend unsustainabilities, one that creates a society in which all present and future humans are healthy and whose basic needs are met. It is a society where everyone has fair and equitable access to the earth's resources, a decent quality of life and where all current and future generations are able to pursue meaningful work and have the opportunity to realize their full human potential, both personally and socially. It is a society where communities are strong because they celebrate cultural diversity, encourage collaboration and participation in governance and emphasize the quality of life over material consumption, and globalization is humanized by solidarity to support democracy, human rights, and economic opportunity for everyone.

Nowadays there is a large number of verified signs which highlight that our society is leading the planet to its collapse; environmental burden, wealth imbalances, ecological footprint, people who cannot cover their basic needs, etc., all are increasing year after year. (PNUD: Human development reports<sup>1</sup>, World Watch Institute reports<sup>2</sup>). For the first time in history, humans are pervasive and dominant forces in the health and well-being of the earth and its inhabitants. We are the first generation capable of determining the habitability of the planet for humans and other species. Engineers have played a key role in the unsustainabilities of our society. Therefore there is a need to shift the focus of engineering education to the kind of education that graduates the engineers our society needs: change agent engineers that lead and encompass the SD process.

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<sup>1</sup> <http://hdr.undp.org/>

<sup>2</sup> <http://www.worldwatch.org/>

When thinking of Engineering Education for Sustainability, three main questions arise:

- Why? Why should engineers be educated for sustainability?
- What? What should engineers learn in universities in relation to sustainability?
- How? How can engineers learn the competences required to become change agents for sustainability?

The following sections try to find appropriate answers to these strategic questions for engineering education.

## **2. The WHY? Sustainable Development Education in Engineering.**

This society needs scientists, engineers, and business people who design technology and economic activities that sustain rather than degrade the natural environment and enhance human health and well-being. This means a technology inspired by biological models operating on renewable energy where the concept of waste is eliminated because every waste product is a raw material or nutrient for another species or activity or returned into the cycles of nature. It is also where management of human activities restores and increases the biological diversity and complexity of the ecosystems on which we all depend, so humans could live off nature's interest, not its capital, for generations to come. Thus, a new kind of engineer is needed, an engineer who is fully aware of what is going on in society and who has the skills to deal with societal aspects of technologies (De Graaff et al, 2001)

To follow the SD path we need a fundamental, transformative shift in thinking, values and action by all society's leaders, professionals and the general population. To quote Albert Einstein, "The significant problems we face cannot be solved at the same level of thinking we were at when we created them". (Covey, 2004).

In this context, higher education institutions (HEI) are responsible for educating graduates that have achieved the moral vision and the necessary technical knowledge to assure the quality of life for future generations. This implies that SD will be the framework within which higher education has to focus its mission. (Corcoran et al, 2002)

In relation to SD, so far, there is no direct relation between educated societies with the highest rate of “educated” citizens and the highest sustainability<sup>3</sup>. Sustainability demands a specific kind of learning. To quote 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). In addition, some authors call for a deep change in society to achieve more SD (whatever it is). SD 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).

Stephen Sterling maintains that the nature of sustainability requires a fundamental change of epistemology, and therefore, of education. He writes: Sustainability is not just another issue to be added to an overcrowded curriculum, but a gateway to a different view of curriculum, of pedagogy, of organizational change, of policy and particularly of ethos. At the same time, the effect of patterns of unsustainability on our current and future prospects is so pressing that the response of higher education should not be predicated only on the ‘integration of sustainability’ into higher education, because this invites a limited, adaptive, response.... We need to see the relationship the other way around—that is, the necessary transformation of higher education towards the integrative and more whole state implied by a systemic view of sustainability in education and society (Sterling, 2005)

Many international conferences and meetings have drawn attention to the importance of education for sustainability in higher education. A great number of declarations and agreements have been signed following these events:

- The Stockholm Declaration, adopted in the United Nations Conference on the Human Environment. Stockholm, Sweden, June, 1972<sup>4</sup>
- The Talloires Declaration, approved in the Tufts University European Centre, Talloires, France, October, 1990<sup>5</sup>
- The Halifax Declaration, the follow-up to the Halifax Conference on

<sup>3</sup> Some indicators of environmental sustainability such as ecological footprint even show a direct correlation between the most “developed” countries and their ecological impact.

<sup>4</sup> <http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=97&ArticleID=1503>

<sup>5</sup> [http://www.ulsf.org/programs\\_talloires\\_td.html](http://www.ulsf.org/programs_talloires_td.html)

- University Action for Sustainable Development. Halifax, Canada, December, 1991<sup>6</sup>.
- The Declaration of Rio on Environment and Development, United Nations Conference on Environment and Development (UNCED), Chapter 36 (rtf, 68 kb): Promoting Education, Public Awareness and training of AGENDA 21. Rio de Janeiro, Brazil, June, , 1992<sup>7</sup>.
  - The Swansea Declaration, a declaration released at the conclusion of the Association of Commonwealth Universities' fifteenth Quinquennial Conference, Swansea, Wales, August, 1993<sup>8</sup>.
  - The Kyoto Declaration, the IAU Declaration adopted by leaders from 90 universities that embodies the language and substance of both the Halifax Declaration and the Swansea Declaration. Kyoto, Japan, 1993<sup>9</sup>.
  - The CRE-Copernicus Charter, a charter written by the Cooperation Programme in Europe for Research on Nature and Industry through Coordinated University Studies, whose aim is to bring together universities and other concerned sectors of society from all parts of Europe to promote a better understanding of the interaction between man and the environment and to collaborate on common environmental issues, 1994<sup>10</sup>
  - The Declaration of Barbados, a declaration adopted by the States participating in the Global Conference on the Sustainable Development of Small Island Developing States, Bridgetown, Barbados 25 April - 6 May, 1994<sup>11</sup>
  - The Earth Charter (first version), revised and presented during the Forum Rio+5. March, 1997.
  - The Thessaloniki Declaration, a declaration presented and unanimously adopted by the 83 countries present at the International Conference on Environment and Society Education and Public Awareness for Sustainability, organized in Thessaloniki by UNESCO and the Government of Greece, from 8-12 December, 1997<sup>12</sup>
  - The Earth Charter,, shared values, principles and aspirations on sustainable development compiled by The Earth Charter Initiative. The Earth Charter (final document),, March,, 2000<sup>13</sup>
  - The Lüneburg Declaration on Higher Education for Sustainable Development,

<sup>6</sup> <http://www.iisd.org/educate/declarat/halifax.htm>

<sup>7</sup> <http://www.un.org/documents/ga/conf151/aconf15126-1annex1.htm>

<sup>8</sup> <http://www.iisd.org/educate/declarat/swansea.htm>

<sup>9</sup> [http://www.unesco.org/iau/sd/sd\\_dkyoto.html](http://www.unesco.org/iau/sd/sd_dkyoto.html)

<sup>10</sup> [http://www.copernicus-campus.org/sites/charter\\_index1.html](http://www.copernicus-campus.org/sites/charter_index1.html)

<sup>11</sup> <http://islands.unep.ch/dbardecl.htm>

<sup>12</sup> [www.unesco.org/iau/sd/rtrf/sd\\_dthessaloniki.rtf](http://www.unesco.org/iau/sd/rtrf/sd_dthessaloniki.rtf)

<sup>13</sup> [http://www.earthcharter.org/innerpg.cfm?id\\_page=13](http://www.earthcharter.org/innerpg.cfm?id_page=13)

- adopted by the GHESP partners (IAU, ULSF, Copernicus Campus and UNESCO), on 10 October, 2001, in Lüneburg, Germany, on the occasion of the International COPERNICUS Conference, "Higher Education for Sustainability Towards the World Summit on Sustainable Development (Rio+10)" held at the University of Lüneburg 8-10 October, 2001<sup>14</sup>.
- The UBUNTU Declaration on Education, Science and Technology for the Sustainable Development. September, 2002<sup>15</sup>.
  - The United Nations Decade of Education for Sustainable Development (2005-2014): the overall goal of the Decade is to integrate the values inherent in sustainable development into all aspects of learning. The aim: to encourage changes in behaviour that allow for a more sustainable and just society for all. December, 2002<sup>16</sup>.
  - The Barcelona Declaration was settled at the 2nd International Conference on EESD. The Declaration underlines the importance of Sustainable Development in all technological education, and to stimulate Higher Education Institutions in the engineering field to progressively implement their ESD objectives into concrete actions. October, 2004<sup>17</sup>.

The mobilization of universities started in the nineties. Two declarations and two international organizations can be considered the initial promoters of international coordination of universities in the area of education for SD. Firstly, the "Talloires Declaration" (1991), from which the "University Leaders for Sustainable Future" (USLF) was created. This association acts as secretariat for more than 300 universities in over 40 countries that have signed the Talloires Declaration and promotes education for sustainability with regard to the Earth charter. Secondly, the signing of the COPERNICUS University Charter for SD in 1993 as a response to the Earth Summit in Rio de Janeiro marked a breakthrough in raising consciousness within European universities about the need to work together to preserve the future, signed by more than 320 rectors of 38 European countries.

In the year 2000 the Global Higher Education for Sustainability Partnership (GHESP) was formed by the two organizations mentioned above and

- the International Association for Universities (IAU), the international centre of cooperation between 800 institutions of higher education and

<sup>14</sup> <http://www.lueneburg-declaration.de/>

<sup>15</sup> [http://www.unesco.org/iau/sd/rtf/sd\\_dubuntu.rtf](http://www.unesco.org/iau/sd/rtf/sd_dubuntu.rtf)

<sup>16</sup> [http://portal.unesco.org/education/en/ev.php-URL\\_ID=27234&URL\\_DO=DO\\_TOPIC&URL\\_SECTION=201.html](http://portal.unesco.org/education/en/ev.php-URL_ID=27234&URL_DO=DO_TOPIC&URL_SECTION=201.html)

<sup>17</sup> <http://congress.cimne.upc.es/eesd2004/frontal/Declaration.asp>

- universities, which developed and adopted the Kyoto Higher Education Declaration; and
- UNESCO, responsible for implementing Chapter 36 of the agenda 21 "Education, Awareness and Training" and the program of education of the UN Commission for SD.

The GHESP represents over 1000 universities which are committed to placing sustainability as the central goal of their education and operation. In 2001 the members of the GHESP signed the Lüneburg Declaration committing themselves to carrying out the following actions:

- Promoting the subscription and implementation of the Kyoto, Talloires and Copernicus Declarations;
- Creating a performance tool addressed to universities, business agents, administrators, teachers and students, designed to go from commitment to action;
- Improving the development and networking of regional centres of excellence in developed and developing countries.

It is also important to highlight the international association "Organización de Universidades por el Desarrollo Sostenible y el Medio Ambiente" (OIUDSMA) created in 1996 by Latin-American universities.

The existence of this type of institution brings to light the interest within the university community towards education for SD, an interest that has led to the celebration of numerous conferences like Engineering Education in SD (EESD), European Networks Conference on Sustainability in Practice (ENCOS), International Symposium IGIP/IEEE/ASEE Local Identity, Global Awareness, Engineering Education Today, Environmental Management for Sustainable Universities (EMSU), Congreso Iberoamericano de Educación Ambiental, Encontro Latino Americano de Universidades Sustentáveis, etc. Moreover, this interest has promoted the publication of books and scientific articles, and the establishment of units at universities that watch over sustainability in higher education.

### **3. The WHAT? Engineers qualified for Sustainable Development**

To quote the Barcelona Declaration (2004) "It is undeniable that the world and its cultures need a different kind of engineer, one who has a long-term, systemic approach to decision-making, one who is guided by ethics, justice, equality and

solidarity, and has a holistic understanding that goes beyond his or her own field of specialization”.

Some questions arise as to how this role should be played. What is a sustainable engineer? What implications will this have for engineering education institutions? In other words: which competences in relation to SD should a graduate in engineering have? How should these competences be acquired at engineering HEIs?

The SD competences that engineers should acquire have been proposed by several stakeholders like Accreditation Agencies, declarations, governments, engineering associations and HEIs. The following paragraphs show examples of each of them.

The Accreditation Board for Engineering and Technology (ABET) in the 2007-2008 Criteria for Accrediting Engineering Programs state that for an engineering program to be accredited, it must demonstrate that students attain (ABET, 2007):

- An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety constraints, manufacturability, and sustainability;
- An understanding of professional and ethical responsibility;
- The broad education needed to understand the impact of engineering solutions in a global, economic, environmental, and societal context.

The Barcelona Declaration approved during the celebration of the EESD conference in 2004 declares that (EESD, 2004) today’s engineers must be able to:

- Understand how their work interacts with society and the environment, locally and globally, in order to identify potential challenges, risks and impacts;
- Understand the contribution of their work in different cultural, social and political contexts and take those differences into account;
- Work in multidisciplinary teams, in order to adapt current technology to the demands imposed by sustainable lifestyles, resource efficiency, pollution prevention and waste management;
- Apply a holistic and systemic approach to solving problems and the ability to move beyond the tradition of breaking reality down into disconnected parts;

- Participate actively in the discussion and definition of economic, social and technological policies, to help redirect society towards more SD;
- Apply professional knowledge in accordance with deontological principles and universal values and ethics;
- Listen closely to the demands of citizens and other stakeholders and let them have a say in the development of new technologies and infrastructures.

Since February 2006 the Swedish Law for Higher Education has included a requirement that all higher education in Sweden should contribute to promoting SD.

The United Kingdom Engineering Council in the “UK Standard for Professional Engineering Competence” declares that (ECUK, 2005) Chartered Engineers must be competent throughout their working life, by virtue of their education, training and experience, to undertake engineering activities in a way that contributes to SD. This could include the ability to:

- Operate and act responsibly, taking account of the need to progress environmental, social and economic outcomes simultaneously;
- Use imagination, creativity and innovation to provide products and services which maintain and enhance the quality of the environment and community, and meet financial objectives;
- Understand and encourage stakeholder involvement.

In Spain, through the Spanish Rector’s Conference, the Ministry of Education is trying to create some demand from the legislation and available resources in that direction (CRUE, 2005) and states that today professionals undoubtedly have to be able to:

- Understand how their professional activity interacts with society and the environment, locally and globally, in order to identify possible challenges, risks and impacts;
- Understand the contribution of their work in different cultural, social and political contexts and also how this work affects these contexts and the environmental quality of the surroundings;
- Work in multidisciplinary teams, in order to provide solutions to the demands imposed by the socio-environmental problems produced from the sustainable styles of life, including alternative professional solutions that contribute to SD

- Apply a holistic and systemic approach to the resolution of socio-environmental problems and the capacity to go beyond the tradition to disturb the reality in unconnected parts;
- Participate actively in the discussion, definition, design, implementation and evaluation of policies and action, both in the public and the private sector, to help to re-direct the society towards a higher degree of SD;
- Apply professional knowledge in accordance with deontological principles and universal values and ethical principles;
- Pick up the perception, demands and proposals of citizens and to allow them to have a say in the development of the community.

Finally as an example of an HEI, in its “UPC Sostenible 2015”<sup>18</sup> Plan (UPC, 2006), the UPC declares that: “All UPC graduates will apply sustainability criteria to their professional activity and to its area of influence”

When evaluating learning outcomes and SD competences required of engineering graduates, a recent study (Segalas et al., 2008) of most SD-pushing technological universities shows that there’s a consensus on which competences are more important in the three domains of learning:

- Knowledge and understanding
  - World current situation
  - Causes of unsustainability
  - Sustainability fundamentals
  - Science, technology and society
  - Tools for sustainable technology
- Skills and abilities
  - Self-learning
  - Cooperation and transdisciplinarity
  - SD Problem solving
  - Systemic thinking
  - Critical thinking
  - Social Participation
- Attitudes
  - Responsibility/ commitment/ knowledge
  - Respect/ethical sense/ peace culture
  - Concern/risk/awareness

<sup>18</sup> <http://www.upc.edu/mediambient/Pla%20UPC%20Sostenible%202015.pdf>

#### **4. The HOW? Pedagogical strategies for sustainable development engineers**

In relation to how SD competences should be acquired, many approaches have been developed in technological universities. These follow a similar pattern (Segalas et al. 2006):

- To offer a basic compulsory/elective course for all (or most) students;
- To embed SD in the 'ordinary' courses;
- To offer the possibility of specializing in SD – Bachelor or Master degrees.

Most approaches focus on the curriculum content and syllabus, but not much attention has been placed on the pedagogical strategies that can facilitate the acquisition of the attitudes, values and ethics needed to become an SD engineer. A reorientation of pedagogy and learning processes is a must to achieve an effective education for SD. In this sense, experts have recently begun suggesting different schemes and actions to facilitate and promote this needed didactical transformation in higher education institutions and in engineering education specifically.

Examples of the required pedagogical revision are found in Fenner et al. (2004) where it is stated that “changes need to be made in the way engineering education is conceived and delivered, so that graduating engineers can become proponents for the implementation of sustainable practices in their organisations. What is required is the stimulation of self-reflective learning, in which students are exposed to a range of differing views, and continually encouraged to challenge their own assumptions”. Wals and Jickling (2002) also declare that “teaching about sustainability requires the transformation of mental models. Teaching about sustainability presupposes that those who teach consider themselves learners as well and that students and other concerned groups of interest are considered as sources of knowledge and feelings too. Teaching about sustainability includes deep debate about normative, ethical and spiritual convictions and directly relates to questions about the destination of humankind and human responsibility. Sustainability in educating demands serious didactical re-orientation”.

Lourdel (2004a), as well, emphasizes the need for a directed innovative pedagogical reflection for an education that aims at integrating SD. More recently, Kagawa (2007) asked for a change in pedagogy, too: “There is no universal formula for ESD. In order to make students’ learning more relevant to a specific content, it is indeed vital to create a curriculum change process within

which students' needs, aspirations, and concerns for sustainability are addressed".

Some authors (Sterling, 2004; Canadell, 2006) point out that most learning/education is functional or informational learning, which is oriented towards socialization and vocational goals that fail to take into account the challenge of sustainability. This has been reinforced by the introduction of managerial and instrumental views of education in industrialized nations' educational systems, which derive from a fundamentally mechanistic and reductionist social and cultural paradigm. This mechanistic education model blocks the holistic vision of reality which is needed to solve problems (Canadell, 2006).

When referring to learning and pedagogy, Sterling (2004) highlights the need to shift from mechanistic to ecological thinking in three dimensions and proposes the change needed in learning and pedagogy in four areas (Table 1):

- Perceptual: the need to widen and deepen our boundaries of concern, and recognize broader contexts in time and space;
- Conceptual: the disposition and ability to recognize and understand links and patterns of influence between often seemingly disparate factors in all areas of life, to recognize systemic consequences of actions and to value different insights and ways of acquiring knowledge;
- Practical: A purposeful disposition and capability to seed healthy relationships, recognizing that the whole is often greater than the sum of the parts; to seek positive synergies and anticipate the systemic consequence of actions.

	<b>Mechanistic view of education</b>	<b>Ecological view of education</b>
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 recognized
	Valuing intellect	Intellect, intuition, and capability valued
	Logical and linguistic intelligence	Multiple intelligences
	Teachers as technicians	Teachers as reflective practitioners and change agents
Teaching and Learning Styles	Learners as individuals	Groups, organizations and communities also learn
	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 cooperative 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 1 – Shift needed in ESD: from mechanistic to ecologic view (Sterling, 2004)

We can describe a didactic strategy as the set of procedures, supported by educational techniques, which aim to be pedagogically successful, that is, attain the learning goals (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 that aims to orient student learning. The technique focuses on a specific sector or on a phase of the course or subject that is taught, such as the presentation at the beginning of the course, the analysis of contents, the synthesis or the criticism of itself. The didactic technique is the particular resource that the teacher uses to attain the purposes brought up from the strategy.

In the process of applying a technique, different activities may be necessary to achieve the desired learning goals. These activities are still more partial and specific than the technique itself and can vary according to the type of technique or the

type of group we are working with. The activities can be isolated and described in consonance with the group's learning.

Students learn in many ways— by seeing and hearing; reflecting and acting; reasoning logically and intuitively; memorizing and visualizing and drawing analogies and building mathematical models; steadily and in fits and starts. Teaching methods also vary. Some instructors lecture, others demonstrate or discuss; some focus on principles and others on applications; some emphasize memory and others understanding. How much a given student learns in a class is governed, in part, by that student's natural ability and prior preparation, but also by the compatibility of his or her learning style and the instructor's teaching style (Felder et al., 2000; Felder and Brent, 2007). People tend to learn in different ways. Most of us have preferred learning styles that influence how successfully we interact with different forms of the learning experience. A widely used inventory of learning styles, developed by Honey and Mumford (1992), suggests that there are four broad learner types: activists, reflectors, theorists and pragmatists.

Felder et al. (Felder and Silverman, 1998; Felder and Brent, 2007) defined four dimensions of learning styles and the teaching styles that adapt to them (see Table 2).

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

Table 2 – Dimensions of learning and teaching styles

The conventional teaching approach used in engineering education emphasizes 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 and Silverman, 1998; Straka, 1997). Table 2 shows that there are 16 (24) 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 usual 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 (Felder and Brent, 2007).

From the literacy analysis, Table 3 describes the general characteristics of pedagogical strategies and techniques and how they can contribute to ESD.

Strategy	Description	Contribution to ESD
Lecturing	Lecturing consists of the presentation of a subject in a structured way, where the main resource is oral language, even though it can also be a written text.	Regarding ESD, lecturing is a good method to introduce students to sustainability concepts (Azapagic et al., 2005).
PBL	PBL can be described as a set of learning experiences that involves students in real complex projects through which they develop and apply skills and knowledge [10].	PBL, especially PBL that is organized as interdisciplinary projects, could contribute to adapting engineering curricula to enhance mutual understanding of science and technology with social sciences (Mulder, 2006).
Case study	Case study consists of providing a series of cases that represent diverse problematic real-life situations so that they can be studied and analyzed.	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 problem-based learning a small group of students meets, with the support of a tutor, to analyze and to solve a problem designed to attain certain learning goals.	Problem solving prepares students to be "people". 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 (Knowlton, 2003).
Backcasting	Backcasting 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, backcasting approaches are much better suited (in reference to forecasting) to address long-term problems and provide sustainability solutions (Quist, 2007).
Role play	Roleplay can be defined as a learning process in which participants act out the roles of other individuals in order to develop particular skills and to meet particular learning objectives.	Roleplay is an approach which combines complexity, the setting in situation, group work, autonomy and action of the student. It is particularly relevant for ESD (Lourdel, 2004b).

Table 3. Contribution to ESD from different pedagogical strategies

The literature review done so far suggests that, in relation to ESD, the use of a specific learning technique that would be optimal cannot be sustained. Instead, using a wide range of pedagogical tools and strategies seems the optimum. In that combination of methods, more student-centred and interactive-based pedagogical approaches are needed, where experiential, real, multidisciplinary, multicultural, controversial and creative activities are worked out, without forgetting the role of the teacher as a model.

## References

- ABET. (2007) CRITERIA FOR ACCREDITING ENGINEERING PROGRAMS. Effective for evaluations during the 2007-2008 Accreditation Cycle. ABET. Baltimore. 2007
- Azapagic, A.; Perdan, S. and Shallcross D. (2005). How much do engineering students know about sustainable development? The findings of an international survey and possible implications for the engineering curriculum. *European Journal of Engineering Education*. 30(1) pp. 1-19
- Barcelona Declaration. (2004) Engineering education in Sustainable Development Conference Barcelona
- Canadell, A. (2006) Educació Sostenible. Criteris per a la introducció de la sostenibilitat en els processos educatius. Càtedra Unesco de Sostenibilitat. UPC. Terrassa.
- Corcoran P.B.; Calder W.; Clugston R.M. (2002). Introduction: Higher education for sustainable development. *Higher Education Policy*. Volume 15, Issue 2. pp 99-103
- Covey, F. (2004) *The 7 Habits of Highly Effective People* (1st ed.) New York: Free Press. pp. 42
- CRUE. Comité Ejecutivo del Grupo de Trabajo de Calidad Ambiental y Desarrollo Sostenible de la CRUE (2005). *Directrices para la Sostenibilización Curricular*. Valladolid.
- De Graaff, E; Ravesteijn, W. (2001). Training complete engineers: global enterprise and engineering education. *European Journal of Engineering Education*. Vol. 26. N° 4, pp. 419-427.
- DIDE. (2004) Dirección de Investigación y Desarrollo educativo. ITESM a "Capacitación en estrategias y técnicas didácticas".
- Engineering Council. (2005). "UK Standard for Professional Engineering Competence".
- Felder, R. M.; Silverman, L.K. (1988) Learning and teaching styles in engineering education. *Engineering Education*, 78 (7) pp. 674-681 Felder, R. M. (1996) Matters of style. *ASEE Prism*, 6(4), pp. 18-23.
- Fenner, R.A.; Ainger, C.M; Cruickshank, H.J.; Guthrie P.M. (2004) Embedding Sustainable Development at Cambridge University Engineering Department. International Conference on Engineering Education in Sustainable Development. EESD 2004. Barcelona.
- Kagawa, F. (2007) Dissonance in student's perceptions of sustainable development and sustainability. Implications for curriculum change. *International Journal of Sustainability in Higher Education*. 8(3). pp. 317-338

Knowlton, D.S. (2003) Preparing students for educated living: virtues of Problem Based Learning across the higher education curriculum. *New directions for teaching and learning* 95. pp. 5-12.

Lourdel, N. Gondran, N. Laforest, V. Brodhag, C. (2004a) Introduction of Sustainable Development in engineer's curricula: problematic and evaluation methods. *International Conference on Engineering Education in Sustainable Development. EESD 2004. Barcelona.*

Lourdel, N. (2004b) *Méthodes pédagogiques et représentation de la compréhension du développement durable : Application à la formation des élèves ingénieurs. Projet de Thèse.*

Mulder, K.F. (2006) Engineering curricula in Sustainable Development. An evaluation of changes at Delft University of Technology. *European Journal of Engineering Education*. 31 (2). pp 133-144.

Quist, J. (2007) Backcasting for a sustainable future. The impact after 10 years. PhD dissertation. Technological University of Delft. Eburon academic publishers. Delft

Segalas, J.; Mulder, K.; Ferrer-Balas, D. (2006) Embedding sustainability in engineering education. Experiences from Dutch and Spanish Technological universities. *Conference: Higher Education for Sustainable Development: New Challenges from a Global Perspective. Luneburg.*

Segalàs, J.; Ferrer-Balas, D.; Svanström, M.; Lundqvist, U; Mulder, D.F. (2008) What has to be learnt for Sustainability? A Comparison of Bachelor Engineering Education Competences at three European Universities. *Journal of Sustainability Science. Tokyo (in revision).*

Sterling, S. (2004). *Sustainable Education. Re-visioning Learning and Change.* Schumacher Briefings. Green Books. Bristol.

Sterling, S. (2004), "Higher education, sustainability, and the role of systemic learning", in Corcoran, P.B., Wals, A.E.J. (Eds), *Higher Education and the Challenge of Sustainability: Problematics, Promise and Practice*, Kluwer, Boston, MA, pp.49-70.

Straka, G. A. (1997) *European views of self-directed learning: historical, conceptual, empirical, practical, vocational.* Gerald A. Strada Ed.

UPC (2006) *UPC Sustainable 2015*, UPC

Van Der Veer, Jeroen. (2006) *Reengineering the engineers. The Observatory. Status of engineering education for sustainable development in European higher education.* pp. 7-8 Available on-line: <http://www.upc.edu/eesd-observatory/>

Wals, A.E.J. and Jickling, B. (2002) "Sustainability" in higher education. From doublethink and newspeak to critical thinking and meaningful learning. *International Journal of Sustainability*