Development education and engineering

A framework for incorporating reality of developing countries into engineering studies

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Abstract

Purpose – To show the key points of a development education program for engineering studies fitted within the framework of the human development paradigm.

Design/methodology/approach – The bases of the concept of technology for human development are presented, and the relationship with development education analysed. Special attention is dedicated to the role of case studies in engineering courses. After that, the development education program pushed by the Civil Engineering School of Barcelona and Engineering without Borders is explained, focusing on two major contributions: two optional courses about international aid and development and nine classroom case studies about different technologies used in real co-operation projects.

Findings – This work provides a conceptual basis for incorporating development education into engineering studies, a general overview of different activities promoted in Spanish technical universities and practical information about optional courses and classroom case studies.

Research limitations/implications – The proposal is based on the experience in Spanish engineering curricula (mostly in five-year degrees). Some of the topics covered by the courses and the case studies can be better adapted at postgraduate level in three- or four-year degrees.

Practical implications – It is shown that development education can be incorporated into engineering studies through different specific non-expensive activities.

Originality/value – This work presents and puts in context the development education activities pushed coordinately between a non-governmental organization and an engineering school. Thus, it can be of major interest for both teachers and workers of the international development field.

Keywords Economic development, Education, Higher education, Sustainable development, Industrial engineering

Paper type Case study

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1. Introduction

During the last years, the role of technology in the international development sector has increased in visibility, and probably in importance. As an example, two recent annual reports of international organisms highlight the role of engineering when analysing the state of the world from a development perspective (UNDP, 2001; World Bank, 2004). Similarly, Unesco's (2003) "Engineering for a better world" and the InterAcademy Council's (2004) "Inventing a better future", seem to support this trend. Moreover, specific international civil society organizations related with the technological sector, both development non-governmental organizations (DNGO, such as Intermediate Technology Development Group (ITDG), and the International Engineering without Borders network) and professional ones (such as the World Federation of Engineering Organizations (WFEO)), are also increasing their work promoting human development and poverty reduction and their interconnectivity. Capacity development is a key point in all proposals (Baser and Bolger, 1996). Following this trend, engineering schools and engineering curricula should aim at developing individual, institutional and societal capacities, apart from technical ones, and should include integral learning processes framed within a human development perspective. This trend can be understood as an evolution from the environmentally and sustainability centered engineering education proposals. Human rights and development should be urgently integrated in higher education in order to face the requirements of the actual globalized international socio-economical context (DEA-AUT, 1999).

The different engineering approaches on poverty reduction and human development can be grouped and reinterpreted using the concept of Technology for Human Development (THD), which has recently grown in popularity in the international development sector. It is based on the human development (HD) paradigm extended during the 1990s and the questioning of the use of the appropriate technologies (AT) term in a too reductionist way. Here, in Section 2, the framework and actual tendencies of THD are presented (Pérez-Foguet, 2004; Pérez-Foguet and Saz-Carranza, 2004). Moreover, the key working lines on THD in international co-operation are described, focusing in the promotion of civic-value ethics through integral development education (DE) programs for engineering. DE is a recognized tool of the international development system. It can be defined as "an active learning process, founded on values of solidarity, equality, inclusion and co-operation (which) enables people to move from basic awareness of international development priorities and sustainable human development, through understanding of the causes and effects of global issues, to personal involvement and informed action", extracted from the on-working definition of DEEEP (Development Education Exchange in Europe Project), pushed under the auspices and in co-ordination with the DE Forum of CONCORD, the European NGO Confederation for Relief and Development. The links between ED and THD are highlighted and, in order to illustrate an ED programme related to THD, a program implemented by Engineers without Borders Spain (ISF-Spain) is presented. ISF-Spain is an average size DNGO, for Spanish standards, with an annual budget of around one million and a half euros (of which approximately 15 per cent is dedicated to DE activities), 1,500 members, and 400 volunteers scattered along the 11 regional associations (data of 2004). It has strong links with universities and engineering schools, as well as with engineering associations, business, and other

civil society organizations. Remarkably, ISF-Spain's network connects most of the Spanish DE experiences in engineering.

DE is closely related to other value-based educational approaches, such as sustainability, peace, gender, human rights and global citizenship (Polo, 2004). In this respect, since the mid-1990s, engineering education has been incorporating education on sustainability, as Barnes and Phillips (2000), Perdan *et al.* (2000) and Dohn *et al.* (2003) show, and whose experiences are closely related to the ones presented here (cross sector partnerships, case studies and problem-oriented learning activities respectively). Also similar are other experiences related with human rights (Hoole, 2002). Sharing experiences and efforts between different value-focussed educational proposals is becoming ever-more popular in the Spanish engineering sector due to ongoing reform of the higher education area following European Union indications (for a detailed account of the latter reforms see Boni (2004)). Major attention is devoted to case studies given their low cost replication, once supporting materials are prepared. Section 3 focuses specifically on using case studies from developing countries in practice-oriented fields of higher education such as engineering, architecture and planning. A proposal of desirable characteristics of THD oriented case studies is presented.

In order to illustrate the feasibility of implementing DE activities of engineering studies, in Section 4, the programme Promoting DE 1999-2002 of the UPC's Civil Engineering School at Barcelona is described. Among the different Spanish higher education institutions that have, in some sense, included DE in their approach and *modus operandi*, this particular one is highlighted because of its wide scope and its characteristics as an example of cross-sector collaboration. Focus of this work is done on two specific courses pushed within this program, and, with more detail, the nine case studies prepared for introducing development issues in other core and optional engineering courses. Cases presented are based on field experiences, most of them carried out by ISF-Spain in partnership with universities from developing countries. In Section 5, the main difficulties found and some remarks on replicability of the experience are summarized. Finally, main conclusions are highlighted.

2. Technology for human development
2.1 Framework
Benavides (1998), in agreement with Unesco, defines technology as "a system of knowledge and information induced from research, experimentation and experience that allows creating a replicable process to produce goods and services". Hence, technology may be characterized according to three elements: *knowledge*; a human activity to which the knowledge is applicable, *actions*; and a practical end, which then generates results according to a certain desires and *values*. Moreover, from Unesco's international classification it may be concluded that technology is directly related to all engineering and architecture professions and university degrees.

In order to study the relationship between technology and HD, it is useful to refer to the triad made up by science, technology and society (STS) (Moñux, 2000). The study of STS has its origin in the 1960s, after the first nuclear accident in 1957, and it is based on the philosophical and sociological analyses of the role of technology in the Western development model. At present, following the boom of the information and communication technologies (ICT) as well as biomedicine and other new applied

sciences, there is a renewed debate between, on the one hand, the techno-optimists, exemplified by the motto used in the Chicago World Show of 1933 "Science discovers, industry applies, and humans adapt" (Rip, 2000), and, on the other hand, critics of the dependence that the current system has on technological developments, and by the ever-larger role technology is acquiring in society. Promoting social participation in the technological advance is appearing as the response to this tension (López Cerezo et al., 1998; Rojo, 2001).

Just as the relationship between STS' three components has evolved, the relationship between technology and development has also changed, since the critical decade of the 1960s (Motta, 1996). By the end of those years, several non-governmental organizations were founded to deal with STS in an applied sense, such as ITDG in 1966 and Greenpeace in 1969, as well as the first environmental and technical innovation governmental agencies (Environmental Protection Agency in 1969 and Organic Trade Association in 1972). The term "intermediate technologies" was initially coined, although it deteriorated as different political connotations were ascribed to it and evolved into AT, which became popular during the 1970s.

AT may be understood both in a narrower "micro" sense, as concrete and specific technological solutions to the main problems faced by the poor in developing countries (Hazeltine and Bull, 2003), and in a broader sense, which refers to the coherence and suitability of technology (modern or not, and both "macro" and "micro") to developing countries (Pérez-Foguet et al., 2003). AT in the narrower sense has been evermore criticized due to it being excessively techno-centric and for not taking into account problems and realities present at a macro level in developing countries (i.e. focusing exclusively on community level approaches and technology and leaving aside such problems as, for example, water and sanitation of Mexico City). Hence, new terms have been proposed. Concretely, the HD paradigm emerged during the 1990s to confront the classical economic and technological conception of development. HD "places at its core the human being and understands development as a process by which the options of people are enlarged" (Prats, 2001), emphasizes that the ultimate objective must be the people, and is highly related to Sen's (2000) concept of freedom as the increase in capacities, both at individual and collective levels. In 2001, the UNDP's report demanded explicitly to put the technological advances at the service of HD, and the same idea has been promoted since then by several international organizations. The confluence of these global trends with practical experience at local level serves as a base for the THD approach presented here.

One way of approaching HD is via the Human Development Index (HDI), consisting of three factors: life expectancy; the possibility to lead a life with dignity (by accessing sufficient economic resources); and the access to knowledge (via education). Moreover, HD can be also understood as a set of six dimensions (security, equity, economic growth, cooperation, sustainability and empowerment, see UNDP (1996)) that can be grouped in three couples (in the same order: preconditions, means and ends) following a process-oriented approach (Sellés, 1997).

2.2 Actual tendencies

THD is based on the fundamental idea that technology can be part of the solution to the problems of under-development. It demands a revision of technology's role, in order for it to be redirected towards the achievement of HD. This idea of technology has recently

been incorporated to classical international development strategies. Moreover, it is worthwhile emphasizing that THD is not substitutive of AT, rather it is complementary to it. THD may be approached both from a HD perspective and from a multi-dimensional perspective.

Approaching THD from a HD perspective implies looking at technology from the following three points of view. First, technology should guarantee basic rights and access to basic services with equity and a minimum of dignity (related to the life expectancy factor of the HDI). Second, it should assure minimum production and social participation capacities (related to the HDI factor regarding the access to a minimum of economic resources). Third, it should facilitate sustainability and empowerment (linked to the increase in the education factor of the HDI, understood as the individual and collective capacity to manage the physical, social, cultural and technological environment). The three requirements apply to all technologies, although a particular one may be more related to one technology solution than to the others. One relevant contribution of this approach is the difference between security-based and sovereignty-based technological solutions (secure and equitable versus sustainable and empowering), as, for instance, those in conflict in the agricultural sector.

It is relevant to highlight the complementary characteristics of the THD approach with respect to the sustainable development (SD) approach (especially the SD approach pursued in Western countries). The sanitation field clearly illustrates that improving technology under a sustainable development perspective does not necessary imply development for the poor. As the fourth and latest edition of the famous Metcalf & Eddy wastewater manual (Tchobanoglous et al., 2003) reveals, the latest technological and biotech advances have been adopted by wastewater engineering in order to respect environmental requirements imposed by governments of industrialised countries. Nonetheless, these valuable improvements towards more sustainable management of water resources are not very useful in the case of developing countries (Oliete-Josa, 2004). While in the developed world, the efforts have been primarily devoted to improving treatment and reuse of reclaimed water, in less developed countries priorities are still sewage evacuation and disposal, particularly in urban areas. Unfortunately, wastewater engineering manuals and university textbooks are progressively moving away from low-cost technologies.

A complementary approach to THD is that of analysing a given technological sector from its different scales of application: micro, meso and macro. It is of fundamental importance to keep in mind the diverse nature of the local, regional and global levels, in particular when dealing with technology-intensive solutions that may vary greatly according to the scale they are being applied at. Moreover, the multi-scale approach highlights the diversity of social actors involved in the promotion of THD, namely public and private sector, both profit and non-profit (Vernis et al., 2004). At national and global levels, two features of THD stand out. First, specifically for private sector, THD approach seeks an evolution in the engineering profession in order to improve its capacity to act in contexts with different scales of development. Second, specifically for the public sector, THD implies a change in political and research priorities to allow technological innovations to promote human development. At local scales, a key characteristic of THD emerges, affordability. Today, most technology is designed with high levels of sophistication based on rich standards, resulting in low-income families being unable to pay the price of the goods and services produced. However, as UNDP

(2003) states, technology becomes affordable for poor people when its design takes into account different income levels.

Moreover, THD may be promoted through the three fundamental channels that characterize technological cultures: actions; knowledge; and values (Quintanilla, 1998), which coincide with the three characteristics of technology presented before. The next subsection focuses on this latter approach through the brief presentation of the key working lines of THD in the international development system.

As a summary of the three categories presented for conceptualising THD (focusing on HD, on the level of application, and on the application channel) the cube representation of Figure 1 is proposed.

### 2.3 Working lines in the international development field

The following working lines on THD are, according to our view, the ones that should receive preliminary attention in the international development field:

Operational channel (action):

(1) Carry out development projects that aim at covering the access to basic services, in an equitable, sustainable manner and promoting security and empowerment of the end users;

(2) Define strategies and policies related to development and technological issues in a participative manner and frame technological progress in human rights.

The urgent need to promote HD locates action as the first area of work. Projects and programs have to be carried out at different planning scales, coherently between them. Moreover, participation of all the different stakeholders has to be taken into consideration. In addition, advocacy activities are needed for attracting others to follow these kinds of activities. In this sense, the professional sectors, which require most attention, are:

- land and environment management;
- social equipments and housing;
- water and sanitation;
- energy supply;
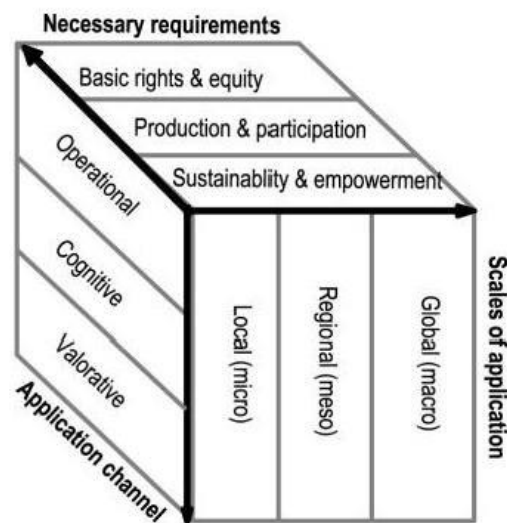
Figure 1.
The three dimensions of
THD

- local production capacity building;
- transport and commercialisation systems; and
- specific ICT for knowledge management.

Moreover, the different sectors share operative characteristics according to where they are found along the three continuums: security-sovereignty (see previous subsection), urban-rural (density of population), and relief-development (Christoplos *et al.*, 2001).

Cognitive channel (knowledge):

(3) Generate knowledge regarding AT for HD and promote reflection on the proprietary rights and copyrights of it.

(4) Transfer of information, technology and knowledge, both between North and South as between South and South.

Power belongs to those who generate and use their own knowledge, thus it is necessary to incorporate knowledge generation and management capacities into development processes in order to avoid creating dependence (Souza Silva and Cheaz, 2000; Carrión and Palacios, 2003). These capacities become more central as intellectual technologies take over material technologies in the post-industrialist society. Moreover, given that creativity increases more due to working groups' interaction, rather than individual action, social technologies, those that allow a participation of different social actors, are also gaining importance. Therefore, from the cognitive channel point of view, creating ICT-related capacities is a high priority. On the other hand, both knowledge itself and the practical research process through which it is generated should promote and enhance freedom and autonomy both at an individual and collective level. Rather than focusing on "learning" (Senge, 1990), it is necessary to focus on "knowledge generation adapted to a changing context" (Nonaka and Takeuchi, 1995) in order to actually increase the transformation capacities of the participants. Therefore, based on a constructivist paradigm, knowledge transfer must be understood as a co-generation of knowledge aimed at endogenously developing the participants, as opposed to the positivist paradigm where, from an authoritative epistemological stance, reality is objectively observed, described, explained, predicted and controlled and no ethical commitment exists (Souza Silva and Cheaz, 2000). Hence, real networking is the basis of technology transfer, and all the different actors involved in knowledge generation should be proactively coordinated.

Valorative channel (values):

(5) Adopt ethic based educational programs (as DE) within the techno-scientific area, in particular within the higher education area.

(6) Raise awareness regarding the role of technology in both situations of inequality and exploitation, as well as in situations of equality and fairness.

A change in attitudes and values worldwide is necessary if a sustainable development of communities is to be reached. DE and awareness raising is based on the basic premise that the people and communities from North and South must be made consciously co-responsible of the common future. DE, which must not be confused with awareness-raising activities or independent educative activities regarding international development, combines different methodologies that aim at tri-dimensionally developing the participants of the teaching-learning process (Balsega *et al.*, 2004), which can be related to the three application channels of THD as shown in Figure 2.
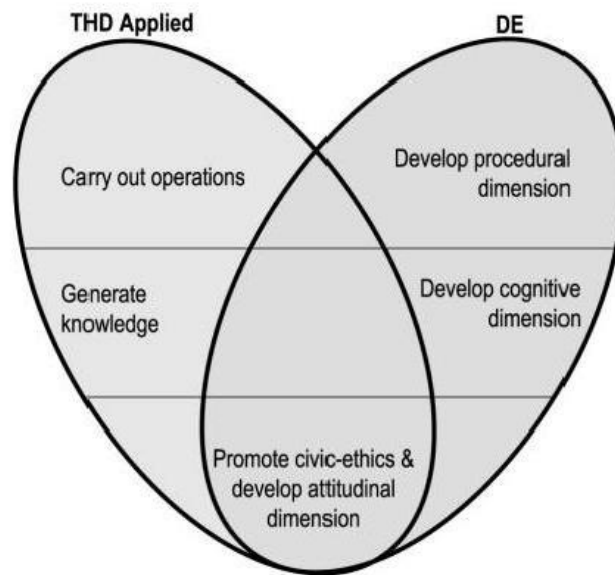
Figure 2.
The fit between THD and
DE

As commented before, DE is close to other value-based educations. All of them push for including social and political reasoning in engineering practice and education, which is one of the major priorities of THD. Moreover, in its recent World Development Report on services for the poor, the World Bank asserts that the "lack of knowledge about the right technical solution is probably not the binding constraint. What is needed is a set of institutional arrangements that will give policymakers, providers and citizens the incentives to adopt the solution and adapt it to local conditions" (World Bank, 2004). Still today, however, many engineers do not have an education that allows them to manage problems with a comprehensive approach beyond technical and economic aspects.

Significant studies propose combining social, political and technical sciences in order to build a more comprehensive engineering field. For example, Forester (1987, 1989, 1999), currently one of the most prominent planning theorists, argues that planners must think politically, as well as technically. According to him, planning is not only a technical practice, but also an effort to build consensus towards commonly perceived goals, emphasizing democracy and participation. Prados (1997), former editor of the *ASEE Journal of Engineering Education*, notes that "[being an] engineer requires [an] understanding of the non-technical forces that profoundly affect engineering decisions". Tarjanne (1997), former secretary-general of the International Telecommunication Union, warns about the digital gap between developed and developing countries and claims that human rights will not be achieved without universal access to basic communications and information services. Finally, Vasconcellos (2001), the director of the National Association of Public Transport in Brazil, reviews the disappointing results of classical modelling procedures for urban transport in the case of developing countries. He suggests that these techniques are not neutral, on the contrary, "they have been used as decision tools in closed arenas" in favour of wealthy social groups.

THD in engineering education is not only addressed at students aiming to work in the international development sector. Recent publications, such as *Doing Business with*

the Poor of the World Business Council for Sustainable Development (WBCSD, 2004) and *Unleashing Entrepreneurship: Making Business Work for the Poor* of the United Nations Commission on the Private Sector and Development (UNDP, 2004), underline the increasing importance of clients from developing countries for private corporations, most of them in the field of engineering.

In the case of the Spanish engineering higher education, first experiences in promoting DE during the early 1990s were presented in the 2001 Congress "DE in the University", organized by the University of Valladolid and ISF-Spain. However, support for such DE initiatives is still, in general, insufficient. Moreover, there is some confusion regarding the different institutional approaches (Freres and Cabo, 2003), and some actors, which are supposed to be central due to their role in pedagogical issues, such as the institutes of education sciences of Spanish universities, do not include DE in their agendas except in very rare cases.

2.4 An example of DE in THD

The network of ISF-Spain has been one of the major promoters of DE in technical higher education, mainly around Engineering Schools of A Coruña, Barcelona, Madrid, Malaga, Sevilla, Valencia and Valladolid. However, it was not until 2002, after the congress cited above, when a unified frame for action at a country level was defined between the different regional associations ISF-Spain. A brief description of the major lines of action of ISF-Spain's 2004 Program of Education for Development follows.

Supporting the inclusion of DE approaches in degree programs:

(1) Training of faculty (specific courses for faculty, such as that presented in Boni *et al.* (2004), and the seminar "Value-based education in technical fields: the challenge of the Higher Education European Space" co-organized in June 2004 together with the Institute for Education Sciences of the Technical university of Catalonia, UPC).

(2) Resources and diffusion mechanisms for DE activities and specific courses (supporting over ten specific courses regarding international development, THD, and development project management).

Promoting volunteering and social participation in Spain:

(3) Volunteering work and internships in ISF-Spain itself and other DNGO.

(4) Promotion of volunteering and social participation programs by co-founding the offices for Social Action at the A Coruña University and the UPC (Pérez-Foguet and Peña, 2003).

Offering internships in developing countries:

(5) Short-term internships for small groups of volunteers, of around two months with a strong technical and applied component and which allow us to experience the living conditions of the communities with whom ISF-Spain and its working partners collaborate;

(6) Final year projects related to technical studies and long-term development programs of three to six months in length at DNGO and international organizations.

Offering complementary education on THD:

(7) Pushing three postgraduate distance-learning degree programs on THD in collaboration with the Open University of Catalonia, and participating in several other postgraduate degrees;

(8) Organization of an annual international conference in THD (together with the technical universities of Madrid and Catalonia), and several seminars and minor conferences in different schools.

Supporting research in THD:

(9) Editing the Spanish-written international journal in THD and coordinating the national awards for final year projects and PhD theses on THD, together with professional engineering associations.

(10) Creating documentation centres on THD, as the one established jointly with the UPC.

3. Use of case studies in engineering courses: a proposal for THD approach

Case studies have been identified as a privileged way for DE dissemination in formal education systems. In the following, the proposed main characteristics of THD related case studies are presented.

The use of case studies in engineering education is still far from becoming as widespread as it is in business schools around the world. Nevertheless, it is a cost-effective means of bringing real-world problems into engineering courses (Raju and Sankar, 1999). As stated by Yin (1994), a case study may be defined as an empirical inquiry that investigates a contemporary phenomenon within its real-life context. Johansson (2003) argues that in practice-oriented fields such as engineering, architecture and planning, a case study methodology may contribute to improving the capacities of professionals. According to Johansson, the ability to act in a professional framework is based on knowledge of a repertoire of cases, which are based either on personal experience or are model cases established within the profession. Nevertheless, Raju and Sankar lament the lack of case studies that bring sufficient real-life engineering challenges to the classroom. Evaluation instruments to measure the effectiveness of using case studies in engineering classrooms are also not sufficiently available.

Regarding the history of case study methodology, we can understand some of the reasons for its slow introduction into engineering education. Over the last two decades, case study methodology has merged qualitative field study methods with quantitative methods of data analysis. Additionally, as Johansson (2003) mentions, Yin (1994) has transferred experimental logic into the field of naturalistic inquiry and combined it with qualitative methods. In contrast, logical positivism and quantitative methods are still almost exclusives in engineering education. There is a resistance from many teachers to integrate qualitative approaches, which some of them still consider less scientific.

Raju and Sankar (1999) suggest a list of features that should be present in case studies that emphasise technical education. In the following, this list is adapted to the THD channels presented previously. Note that some elements are specifically designed for stimulating students and teacher active participation.

3.1 Operational channel (actions)

Within this channel and under a THD approach, an engineer must be able to carry out development projects and programs, as well as to define strategies and policies. On the other hand, from a DE approach, activities have to develop the procedural dimension.

In order to reinforce these capabilities, case studies should present the following features:

- *Based on a development project or on field research.* Each case study has to be self-contained so that the student has all the information needed to identify alternatives and make decisions.

- *Include development issues.* A national and local overview of the case-study country, as well as an introduction to the environment in which each project takes place, needs to be provided.

- *Include technical issues.* Detailed technical information relevant to the case studies has to be provided to the students. The students must understand clearly the technical issues and be able to make technical decisions.

- *Use engineering software to show the links between engineering education tools and real-life situations.* This software should be free or affordable, as well as being capable of integrating quantitative and qualitative data.

- *Include multimedia interactive educational resources so that the connection between theory and practice is explicit.* Student learning is enhanced as they analyse the written case study, read the supporting documentation, work with the provided software and consult the audio-visual materials.

3.2 Cognitive channel (knowledge)

As mentioned above, knowledge of a broad range of cases enhances an engineer's capacity to confront new situations. In the generation of knowledge through case studies, research and teaching must not be separated, especially when talking about development issues. A research case study can be very useful in engineering education, while at the same time, discussions in the classroom can enrich engineering research. Thus, case studies should incorporate the following features:

- *Tell a real story of a project or research that has actually been identified, planned, prepared, executed, monitored and evaluated.* Case studies used in educational settings should be prepared with the same rigour as those with research purposes.

- *Bring out the human and sustainable development issues.* Videos, photographs and multimedia technologies can be utilised so that the students can get a good understanding of the social, political, economical and technological issues involved in each case study.

- *Test and evaluate the effectiveness of each case study in the classroom.* The evaluation instruments must help the students and the instructor to develop new ideas that may improve the results of the project or research. Moreover, the instructor can send these ideas back to the people running the actual project.

- *Include an instructor's manual that is thorough and detailed.* The instructor's manual needs to include a synopsis of the case, educational objectives, definition of the intended field for the case, possible format for class discussion, theoretical basis of research, and short and detailed answers to questions for class discussion. In addition, the manual must include complementary readings so that the instructor can understand the environment where the example was implemented. Frequently, the length of the instructor's manual is as much as the case study itself.

3.3 Valorative channel (values)
This channel emphasises ethical issues of professional practice. Hence, engineering education needs to contribute to the enhancement of students' attitudes and values. Case studies are a useful tool to achieve this objective because they highlight the human dimension of real-life situations. Linked to this channel, case studies should have the following characteristics:

- *Portray the situations accurately.* The case study reports the reality of what happened in an unbiased and non-judgmental manner.

- *Have a focal problem or logical framework structure.* This enables students to consider alternatives and make non-technical decisions.

- *Generate conflict among the teams.* Each case has more than one viable option for the decision makers. The students' learning experience is enhanced as they identify criteria and weigh the advantages and disadvantages of each option.

- *Have real characters to identify so that the student can role-play one of those characters.* This helps bring out the subjectivity of decisions while demonstrating how the credibility of a person influences decisions.

4. DE in engineering studies: experiences of the Civil Engineering School of UPC

In order to illustrate DE in practice, we present the case of the Civil Engineering School of UPC at Barcelona (ETSECCPB). The strategic plan for 1999-2002 of the school was a result of the negotiation between the school, the UPC (the university to which the school belongs) and actors from the civil society. The strategic development and its subsequent implementation are good examples both of inter-organizational and cross-sector collaboration and of the implementation of an integral plan of DE covering both degree programs and non-formal education. This initiative was rooted in the previous experiences of supporting isolated international development activities within the school, as well as the institutional pushes of sustainability and environmental activities in the overall university (Capdevila, 1999; Didac, 2004). The inclusion of these aspects in the strategic plan gave the ED-related activities institutional and economic support from the school. Useful details on possible extension of the experience are explained before.

The principal actors that participated in the 1999-2002 DE program included in the strategic plan were (Pérez-Foguet, 2001):

- The school, which is in charge of the five-year degrees in Civil Engineering and Geological Engineering, the three-year degree in Public Works Engineering, as well as the postgraduate degree and PhD in Civil Engineering.

- Two NGO strongly rooted in the university with specific volunteering programs for university students: ISF-Catalonia (which is a member of ISF-Spain) and WAFAE (university-based DNGO dedicated mainly to promote cooperation between Spain and Northern Africa).

- The different departments of the school.

- The International Cooperation for Development Centre (CCD) of the UPC, which is mainly devoted to financing international development and awareness-raising projects.

Other actors were involved later on, such as the Victoriano Muñoz Oms Chair, which promotes the teaching of humanistic values in engineering, and the Social Action Office "Univers", dedicated to promote cultural and sports activities, and recently also social participation.

The strategic plan was divided into four themes:

(1) improvement and flexibilization of studies;
(2) integration with the labour market;
(3) personal and institutional quality of life; and
(4) future needs and social integration.

The latter theme included the program of DE, which had as its main goal "To incorporate into the school awareness-raising and teaching regarding international development and appropriate technologies". The strategic plan was implemented via general agreements between the school and UPC, which defined 46 different lines of action. Seven of them were directly related to the DE program, and it was via these that the program was actually channelled and implemented.

The school led directly the necessary activities to fulfil three objectives of its own strategic plan: O1 – offering optional courses on THD and related topics; O2 – transversally incorporate THD issues by carrying out specific sessions and documenting case studies; O3 – leading the creation of a documentation collection on THD. The other three objectives of the strategic plan were led by different DNGO, primarily ISF-Catalonia, with the help of the CCD and Catalonia's autonomous government, and, to a lesser extent, the school's assistance; O4 – support awareness-raising campaigns and related activities; O5 – promote technical studies regarding international development; and O6 – promote the inclusion of trained students in DNGO and international organizations. The more relevant contributions related with objectives O1 and O2 are presented in following subsections. The other four are briefly summarized in following paragraphs.

Objective O3 was limited to purchasing reference books and to subscribing to specialized journals during the program under consideration. However, the integration into a single collection of all THD and ED related works held by the university's library was also promoted and achieved once the program finished. This objective also counted on external actors for its implementation. ISF-Spain transferred its own documentation center to the library and the CCD partly financed the expansion of the collection.

Regarding the consecution of O4, an average of one single-session seminar was organized per month during the three years of the program. The sessions were related to THD issues in general, including not only technical issues, but also political issues such as the role of the public administration in development or the role of business. They were coordinated with the two optional courses that are described below. Moreover, the Second International Conference on THD of ISF-Spain was organized within the school around the key themes of water and infrastructures (Pérez-Foguet et al., 2003). Finally, seven awareness-raising campaigns were carried out by this DNGO and co-financed by CCD.

With respect to O5, an average of four to five studies by year has been fulfilled by the end of the program, in particular in the thematic areas of rural water distribution,

urban services, construction materials, small-scale infrastructures and public works. These studies, which are mostly final degree projects or theses, have been carried out in partnership mainly with DNGO, assisting its programs, and with the CCD, which has financed them. Two students from the school were awarded the National Awards for Final Year Projects on THD. However, the fit between the academic requirements and the needs of the specific programs of the DNGO do not allow for a straightforward generalization of such initiatives.

Finally, with respect to O6, although the collaboration of engineering students with DNGO has not been monitored and the role of the school has been limited to informing the students about possible vacancies, the overall impression is positive. The overall number of students that got involved with DNGO is approximately 30 per year, about 8 per cent of the total annual student entrance in the school. Regarding this issue, at the end of the program, UPC included the specific volunteering program FormaPart within the services to university community of its Office for Social Action. The principal task of the program is to centralize volunteering vacancies of NGO and match them with volunteering offers, as well as doing the selection, follow-up and evaluation of the volunteers. On the other hand, the professional involvement of graduated students in DNGO and international organizations has been verified, but the exact number is not known.

4.1 International development, engineering and development courses
Two optional courses related with THD were offered from academic year 2000-2001 directly in line with objective O1: "International aid, engineering and development" and "Development projects: concepts and methodologies". They were based on a previous course "Introduction to international development projects" given twice. The new courses had good acceptance among the students (averaging 31 and 22 students respectively, from 2000-2001 to 2002-2003; which are relatively high numbers in that particular context). Both were 45 hours long, 36 of which were classroom hours, delivered in 12 three-hour sessions, with the other nine hours representing the work associated with take-home exercises and essays.

The three-hour sessions were usually divided into two parts. The first part was dedicated to lectures on the theoretical aspects of the subject taught. The second part included both participatory practical exercises and external speakers; usually engineers active in the international development field or in developing countries. These latter conferences were occasionally opened to all university students, irrespective of whether they were registered to the course or not. The practical participatory exercises underscored the importance of opening up the analysis to all major stakeholders, and proved to be highly interesting and appreciated given the lack of such activities in Spanish engineering schools.

Given the need of such education in engineering schools in Spain, and the almost total lack of them, a general all-inclusive 13 theme conceptual map was specifically designed and adapted, from other academic fields, to engineering (Pérez-Foguet *et al.*, 2005). The specifics of both courses are presented in the following.

International aid, engineering and development course. This course, taught during the autumn term, aims at introducing the role played by engineering in international development and human development. The sessions had usually a first part dedicated to the theoretical framework of a given subject, followed by a participatory case or

invited lecture in the second part. The evaluation of the students was based on attendance, essays and a final exam.

The course is composed of 11 themes, structured in two parts plus a final evaluation session. The first theme introduces the state of the world and in particular the growing inequalities and their possible causes. The next three themes cover the concepts of globalization, governance and development and introduce the mesh of international organizations, such as the World Bank, the United Nations, and The World Trade Organization. The fifth and sixth themes are dedicated to the role of technology and infrastructure in development processes. In these themes, the UNDP and World Bank positions are presented. These first six themes constitute the first of the two blocks of the course, which is the most conceptual and general in nature. The second block of themes has a more concrete approach and focuses on specific organizations and development strategies. The seventh theme covers international aid based on the UN Millennium Development Goals, while theme eight introduces the principal actors in international development, differentiating among governmental, non-governmental, international and business organizations. The Spanish international development aid is overviewed in the next theme, while the tenth theme is dedicated to the role of the Spanish private engineering sector in international development, including the effects of public policies aimed at favouring the internationalization of Spanish enterprises. The final theme goes through basic concepts in business ethics and corporate social responsibility and promotes reflection among the students regarding their personal future position in the private engineering sector.

Development projects: concepts and methods course. This second course aims both at introducing some basic decision-making and at planning tools for managing development and humanitarian projects, and at introducing the humanitarian continuum. The course, which is taught during the spring term, covers first the logical framework approach and emphasizes both efficient management and participation. The course goes through the project cycle, emphasizing the requirement that the project objectives to be identified based on stakeholder analyses and grounded in the needs of the beneficiaries. Indicators, necessary to evaluate and monitor interventions dealing with intangible social issues, are also highlighted. Second, the course covers the humanitarian continuum and the linkage between relief, reconstruction and development. By showing the humanitarian aid's long-term effects on development, the importance of including strategic long-term criteria in the decision-making process is highlighted, along with technical and managerial criteria. Methodologically speaking, the course uses case studies, concrete practical experiences and role games for more than half of the classroom hours, which is rare in Spanish engineering higher education.

This course, together with the last theme of the previous course, business ethics and corporate social responsibility, provides the three fundamental pillars that should serve as a basis for the future professional careers of the students: ethics, management skills and participatory and team skills. Concretely, the course makes two main contributions. In the first place, it attempts to enlarge the number of factors that must be taken into account when making decisions in the engineering sector, decisions that are all-too-often based exclusively on technical factors. A managerial dimension and a strategic dimension are added to the technical dimension in order to cover the three basic dimensions involved when making decisions regarding

organizational interventions (Serra, 1998). These two additional dimensions become of even more importance in intangible sectors, such as poverty reduction or social inclusion (Serra and Saz-Carranza, 2002). In this sense, from a THD perspective, not only must an intervention involve appropriate technologies, but must also have a strategic objective that aims at building capacity for the beneficiaries in the long term and must be managed efficiently and in a participative manner. The second contribution is that it introduces engineering students to intangible results and, in particular, to the social impact of engineering interventions. Hence, social criteria are added to the purely technical criteria during the planning and the evaluation stages of engineering projects.

4.2 Teaching THD case studies in the UPC

A set of case studies related with THD has been developed directly in line with objective O2. This initiative arises from the need for training new volunteers participating every summer in ISF-Spain internships. Therefore, most of the cases are based on field development projects. Since 1999, the authors have been collecting the principal data of ISF-Spain projects in the South in order to provide case examples to be used in engineering courses. Final degree projects or theses, often made by ISF-Spain volunteers, have been a valuable source of information.

A pilot phase started with the elaboration of three case studies during the 1999-2002 DE program. The cases have been extended to nine during 2003-2004. Recently, a publication of a guide with a CD containing all nine cases has been launched with the aim of disseminating the experience (Oliete-Josa and Pérez-Foguet, 2004, 2005). Some case studies have already been used in engineering courses at the Technical University of Catalonia.

Teachers can use these materials to prepare theory classes, to arrange practical exercises and to supply supporting readings to the students. The structure of the case study materials provided is the following:

(1) *A brief introduction of the case.* This introduction is generally accompanied by the essential theoretical considerations needed to solve the technical issues of the case. This information is predominantly for the teachers' use.

(2) *Set of presentation materials.* In order to reinforce the textual descriptions, the presentation package contains several audio-visual resources. There are two kinds of slides. The first is addressed to the teachers and it contains a broad explanation of the case. The second is for class use and the information is summarised. In both presentations, the slide sequence is the same: it starts by describing the general issue and presenting the theoretical concepts, and continues setting out a particular project. The slides finish by asking questions to generate discussion among the students.

(3) *A class discussion guide for teachers.* This guide suggests instructor's remarks to encourage students to participate. In addition, it includes prepared answers to frequently asked questions. Finally, it proposes some alternatives, such as creating opposed discussion groups or organising role-plays.

(4) *Two practical exercises.* Using real data, exercises aim to show how engineering, and particularly engineering software, can be applied to development projects. The first exercise is solved and arranged to be explained in the classroom. It

also includes some practical suggestions for teachers. The second exercise is proposed to be solved by the students at home. To resolve both exercises, specialised software is needed. Usually, each case study uses different software. Criteria for software choice are:

- appropriate technical specialisation;
- free access or affordability;
- learning time needed to run it; and
- capability to integrate quantitative and qualitative data. Where necessary, the software manuals are also supplied.

(5) *Supporting readings and online references*. Most slides contain notes with recommended readings. Some documents are provided and others are available on the web. Additionally, bibliographic references are supplied.

The case studies currently available are outlined in the rest of this section. Topics covered are surveying, water supply, urban services, sanitation, rural electrification, information and communication technologies, reinforced concrete small structures, rural water resources and urban transport. Note that cases are related with six of the seven points of the THD action channel cited before.

It is important to highlight that DE and sustainability education (SE) strategies can differ significantly, especially teaching engineering. In general, SE shows facts closer to the reality of the student. Instead, DE usually deals with situations less familiar to the students. These differences can be illustrated by comparing the case studies here presented and the ones of Perdan *et al.* (2000). The last are based on issues centred in the social and cultural context of the student, whereas THD case studies relate to a wide range of situations from developing countries. In any case, sustainability is implicit in development actions, even if the temporary scale of priorities is not necessarily the same as in the industrialised world.

Surveying. This case study is based on a four-year land tenure legalisation program in a rural area of El Salvador. This action started in 1999 in response to a demand made by the community-based organisations from the mountainous north of the country. Technical issues were undertaken by the Department of Structural Mechanics of the José Simeón-Cañas Central-America University (UCA) and ISF-Spain. The UCA Human Rights Institute (IDHUCA) monitored legal aspects.

The case study describes the work carried out by a group of volunteer engineering students, supervised by surveying teachers. This project was developed in two rural communities where the traditional plot limits had been established generations ago. Therefore, the main challenge was to identify, and sometimes negotiate, the plot limits in order to execute the surveying project.

The practical exercises provided are planimetric representations. Usually, the concepts used are already taught in classical surveying courses. For its resolution, students can use any calculation software, such as Microsoft Excel, and any graphical representation software, such as AutoCad or Microstation. By solving the exercise, students can realise the complexity and the inequities of land distribution in poor rural areas.

Water supply. Since 1999, ISF-Spain has been undertaking a water supply program in rural areas of El Salvador. This case study describes one of their first completed projects. The project promoters were ISF-Spain and the Salvadorien DNGOs, who worked closely with community representatives.

Technical design was carried out by a civil engineering student who was working on his master's thesis. This work resulted in the collection of a large quantity of detailed information. In addition to general technical water quality and supply issues, the case presents considerations about the water and project cycle, community participation and technical alternatives.

Exercises are to be solved using EPANET. This public domain software, developed by the Water Supply and Water Resources Division of the US Environmental Protection Agency, models the hydraulic and water quality behaviour of water distribution piping systems, and it can be freely copied and distributed. The student is asked to argue conclusions about supply, pressure and speed distributions in the network.

Urban services. This case study stems from the FOURMI I programme in Cameroon, funded by the European Union. The Upgrading Program in Yaoundé 6 seeks the empowerment of slum populations by means of infrastructure micro-projects. Capacity building is attained due to a high degree of community participation in all stages of the programme. It started in 1998, with the execution of a pilot project in Melen IV. This neighbourhood had been previously undertaken as a field of study by the urban planning researchers at the Technical School of Yaoundé. ISF-Spain has been providing assistance on technical and social issues.

Slides present different micro-project investments. The goal of these micro-infrastructures is to improve urban services by enhancing accessibility inside the neighbourhoods, upgrading rain drainage networks, protecting traditional water supply points (springs and wells) to ensure a diversified supply to low-income families, and to provide improved on-site sanitation systems to protect groundwater and preserve public health.

One main problem hindering the improvement of urban services in African cities is the heterogeneous and fragmented land use. Exercises seek to characterise an urban drainage basin in order to identify different settlements and uses. Students work for this purpose with a geographical information system (GIS). Detailed descriptions of each kind of land use are provided so that students can recognise the different areas on the map. Presently, most GIS software on the market is quite expensive. However, some free applications such as SPRING or GRASS are available. Since exercises are not very complex, another option is to work in class with free demo versions.

Sanitation. This case study is based on a research project coordinated by the Water Sciences and Environment Laboratory of the Technical School of Yaoundé. It aimed to analyse wastewater management in planned urban zones and their surroundings in Cameroonian and Chadian cities. Two ISF-Spain volunteers, both of whom were civil engineering students in the Technical University of Catalonia, did their master's theses as a part of this research project.

Physical, socio-economic and infrastructural conditions of some neighbourhoods are presented in the slides. At the same time, several sewage evacuation and treatment systems are proposed in order to discuss the best alternatives for each situation.

Similarly, exercises try to determine the best technical solution. The software used in this case is a learning application distributed with the URALITA wastewater manual for small communities. After the system has been chosen, students use the software to calculate the dimensions of the treatment plant. Sometimes, dimensions do not suit the space available. Given that space is an important issue concerning sanitation in poor urban areas, students are then obliged to start again using another system.

Rural electrification. The information for this case was collected from energy projects in Ecuador, Peru and El Salvador; particular attention is paid to a photovoltaic project executed in El Salvador. It was carried out by ISF-Spain in collaboration with the Department of Hydraulics and Energetic Sciences of the José Simeón-Cañas Central-America University (UCA). The goal of this project was to provide electricity to an isolated rural community of 300 inhabitants.

Like in the other case studies, the slides begin with an overview of the difficulties found in developing countries in supplying electricity to rural areas. They continue by describing the main features of clean and sustainable energy and finish with a detailed characterisation of the system implemented in El Salvador. Students are encouraged to discuss the final solution adopted.

Technical exercises use the software DIMENSIONA developed by the Spanish Solar Energy Institute (IES), a research centre of the Technical University of Madrid. This software can determine the dimensions of autonomous photovoltaic systems by means of probabilistic models.

Information and communication technologies (ICT). This case study is based on a feasibility study for the creation of an intranet network in Santiago del Estero, a northern province of Argentina. It also uses support information from the EHAS programme in Latin America, which aims to provide low-cost communication tools and telemedicine services to health centres in rural areas. Both programmes are backed by ISF-Spain and several Spanish, American and European organisations.

The project in Santiago del Estero plans to connect rural communities through a wireless network. Slides begin by introducing the concept of digital gap and the main difficulties in providing universal access to ICTs. Then, they present technological alternatives, as well as some projects that have already been developed. In class, students discuss the alternatives, paying close attention to the technical limitations of each one.

In the exercises, students are expected to calculate the cost of a wireless network to connect remote communities; they have to take into account a possible network extension. For designing wireless antennas, WLAN Design Tools are proposed. This software can be downloaded free of charge.

Ferrocement structures. Ferrocement water tanks are used in many countries for the collection and storage of water for drinking, washing, animal needs and irrigation. With this very low-cost technology, water tanks of $350\,m^3$ and above can be built. Nevertheless, very often this technology is not taught in concrete structures courses. This case study explains the construction of one of the tanks executed by ISF-Spain in El Salvador for a water supply project.

There are not many non-technical issues to discuss concerning ferrocement structures. Nonetheless, this case study triggers students' interest because of the problems regarding tank's location. Indeed, in addition to technical aspects, students

are required to think about issues such as land ownership, difficulties with volunteer work, etc.

Exercises are solved by numerical methods. The modelling software is based on the finite element method Castem3M. This software is free when used for teaching purposes. The objective of the exercises is to model a tank with a given geometry.

Rural water resources. In 2001, the Salvadorian NGO CORDES and ISF-Spain agreed to develop a master plan in order to achieve a more comprehensive management of water resources in La Libertad district. This plan establishes the order for the execution of water projects. Priorities are not only determined by the lack of water resources. In addition to the urgency criterion, other features are used to classify the rural communities; these include the level of participation, the existence of previous experiences in similar projects and the economic feasibility of the project.

The class presentation starts by explaining the concept of the master plan and its application in water resource management. It also describes the critical situation in Central America caused by a lack of water resources. Finally, the master plan of La Libertad is presented emphasizing the work done in collecting information and the principles used to prioritise the interventions. Class discussion is focused around these principles.

Exercises analyse the final order proposed by the master plan. Using a multi-criteria analysis method, students are expected to propose alternative decisions. The method used is ELECTRE III. This method is able to classify the different alternatives of a problem from the best one to the worst based on a defined set of criteria. A demo version of this software is available on the web.

Urban transport. The last case study is based on a research project on urban transport in Cameroon. The goal of this study is to investigate the correlation between the access to transport and the human development of the inhabitants of dense informal settlements in the city centre. A civil engineering master's thesis has been done as part of this research. One important feature of this case is the integration of both quantitative and qualitative data.

The teacher's presentation explains the different research methodologies used to analyse transport reality in developing cities. Starting with the classical demand simulation models, slides present new approaches based on concepts such as sustainability, democracy and equity. The presentation emphasizes the importance of non-motorised transport modes. It also highlights the links between access to transport and housing programmes for the urban poor.

Exercises are to be solved by using qualitative comparative analysis (QCA). These tools may be used when there is a lack of statistical data. They are also appropriate because of their capacity to manage human development variables. By means of real data from surveys carried out in some neighbourhoods of Yaoundé, students are asked to establish conclusions about human development of its inhabitants and their accessibility conditions.

5. Challenges for disseminating the experience

The initiative presented in the previous section consists of a coordinated set of DE activities led directly by an engineering school framed within a technical university. Two specific courses, nine case studies, and the promotion of a specialized documentation center are the major achievements of the proposal. Moreover, these

three lines of action, together with the institutional support given to three lines led by external actors (namely, awareness-raising, degree theses and volunteering), completed the DE component of the school's strategic plan for the three-year period. In the following, the main challenges for disseminating the initiative, as well as the replicability of the proposal, are discussed.

First, it is worth noting that the inclusion of a DE component in an engineering school's strategic planning may be advisable, since it ensures funding and institutional support and facilitates coordination with other external actors, regarding both operational aspects as project objectives. Synergies at a strategic-objectives level facilitate resource optimization, which is a critical aspect in contexts with very limited resources (as is the context described which includes a medium DNGO and a public university in Spain). In the case presented, synergies were achieved with the DNGO sector and pre-existing university services (CCD). However, some drawbacks did appear during the execution, and these were related, primarily, to project and information management.

Strategic development and planning may be done using different methodologies, which in turn will have different impacts on its final outcome. Thus, the DE activities finally included in the strategic plan and its planned implementation will vary according to the strategic methodology used. As an example, the continuation of the DE program presented here fits with the university strategic plan for the following period, namely 2004-2006. However, a new methodology was used when developing and planning the strategy for this period. The strategic plan produced relied more heavily on developing fixed indicators than the previous one and allowed for less particularization at functional unit levels (schools and departments). This has visibly influenced the new DE program by, on the one hand, creating some difficulties for promoting synergies due to its less participatory implementation approach, but on the other, allowing for greater monitoring and performance measurement capabilities due to the sharing of common indicators between functional units.

Regarding the specific DE courses, these should be concretely ascribed to specific professors and lecturers, just as any other course. Although this was done in the experience presented, it is not common practice in Spanish universities when it comes to non-mainstream courses, which demonstrates the lack of real will to promote DE, regardless of the lip service paid to DE publicly. However, the inclusion of DE courses, such as those described, should be done gradually, starting with a few seminars, if they are ascribed to lecturers with little or no background in participatory methodologies or development project management. Finally, such courses should invite external DNGO, firms or governmental agencies to the classroom in order to present real experiences.

Moreover, since academic year 2004-2005, the courses mentioned were grouped together with other similar ones and offered as an optional curriculum supplement to students throughout the university. Two groups were created in this respect, one dealing with courses related to international development, and another with humanistic values. The grouping allowed for a minimum of coherence between the courses and improved the visibility of such courses among the competitive and substantial offer of optional courses in the university. It is also worth highlighting the importance of these optional courses when modifying the core curricula is improbable.

With respect to the case studies, teachers who have incorporated these case studies underline the importance of educating through a more comprehensive approach and

repeating the experience. Additionally, many of them think that these cases are very useful in demonstrating the real-life application of their field. Nonetheless, incorporating these case studies seems to be more feasible in elective courses. Two major difficulties arise concerning core subjects. First, at syllabus level, changes are implemented very carefully and slowly, and the will of some professors is not always enough to overcome the collective decisions, which validate those changes. Second, at classroom level, some teachers are simply reluctant to incorporate non-technical issues into their courses. They usually argue that they do not have sufficient class hours. Some teachers even disagree with the principle of including these topics and materials in their engineering courses.

Finally, with respect to documentation effort, as commented, the school's initiative was integrated within the general university library. This was because economies of scale, both regarding subscriptions, renewals and the management of bibliography played an important role. Moreover, it was considered that the physical centralization in one section of a library was fundamental in consolidating this specialized bibliographic collection. Nevertheless, the agreement reached between the different actors involved in this effort (school library, university library and ISF-Spain) accounts for temporarily distributing parts of the collection to school libraries in the university to enhance accessibility and visibility of the collection. The centralization turned out to be extremely fruitful with respect to managing the collection, since a common electronic tagging system has been applied by the university library.

6. Conclusions

This work has presented the concept of technology for human development as a particular evolution of and a complement to the concept of appropriate technologies, and in particular as a fundamental concept in the engineering sector in general and, in particular, in the nongovernmental and higher education sub-sectors. Moreover, it has been shown how an engineering school and a nongovernmental organization have been capable of transversally introducing DE in a higher education context, both at the school level and at the national level. This has been based on working on practical experiences, values and specific knowledge. Regarding the latter, not only have technical aspects been taken into account, but also managerial and relational aspects, as well as political and strategic aspects. Moreover, the exclusively technological approach, typical of Spanish engineering schools, has been widened to include a social dimension when evaluating to the impact of technology.

This work has paid especial attention to the case study as a teaching methodology and its potential in DE activities. In recent years, case studies have been the most used method in social and technical analysis carried out by international organisations and NGOs. This can be confirmed by taking a quick look at their reports and technical papers. For example, at the 2003 Urban Research Symposium organised by the World Bank, 32 of the 40 papers presented were case studies. This trend originated in the early 1990s, when the World Bank, as well as other international organisations, started to gain awareness of the disappointing results that their policies had for the poor. Consequently, they decided to include a diversity of practices and the local institutional features into their strategies (Pincus, 2002). In addition, combining quantitative and qualitative data in development analysis is gaining recognition with development agencies (Bamberger, 2000). Engineering education programmes cannot downplay

these facts. Engineers are expected to play an important role whether in the international development sector or in a transnational corporation. Technology is an important driving force that affects the life of citizens around the world. Use of case studies from development countries in core courses is a valuable method to enhance skills, knowledge and values that engineers need to meet these challenges.

These case studies are a good an example of what can be done to incorporate human and sustainable development issues into engineering education. They show that teachers are actually interested in bringing real-life cases to the classroom. Moreover, the production of these case studies is a research activity itself. Indeed, collecting the information, meeting the project managers and teachers, creating a coherent structure to be used for educational purposes, searching for the appropriate software, conceiving of and solving the exercises, etc. are a useful manner to assess and evaluate the projects and likewise to develop new educational strategies. In addition, there is still much work required to disseminate these case study materials. The presentation of this paper is an important step. Institutional procedures also need to be done in order to incorporate this methodology in the teaching strategies of the university. Publishing a textbook and CD-ROM may be a good opportunity to circulate theses materials. In any case, a very useful way of disseminating this method is with teachers, beginning even with collaboration in the preparation of the case studies.

Although limited and incomplete, this experience and theoretical framework may serve as an example and incentive for other schools and initiatives. In order to facilitate the successful replication of the experience, this work proposes some basic recommendations. These have been: to include DE initiatives into the strategic development and planning of the higher institutions; to explicitly ascribe courses to specific lecturers, to introduce such courses gradually as optional courses, and group them thematically; and to look for economies of scale regarding DE bibliographical collections. We hope this work adds to the search for a sustainable development model, since we believe that the triple triad implicit in the THD approach (science, technology and society; knowledge, practices and values; and technical, managerial-relational and political-strategic) together with its multi-scale (macro, meso and micro), multi-disciplinary and multi-sector (private, public and non-profit) implementation may well be a useful building block towards this end.

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