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Engineering Education in Sustainable Development

Sustainability from burden to challenge for engineers at Delft University of Technology

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Introduction

This paper will first sketch some basic features of the engineering profession, and the need for change. It will analyse the political process that resulted in the decision at Delft University of

Technology (DUT) to emphasise Sustainable Development in its curricula. Main goal of SD education is to show that SD is an interesting challenge to contribute to as an engineer. It will describe the changes in the engineering curriculum that are implemented and give a preliminary evaluation of these changes. The changes encompass

- a 2 credit point compulsory training module “Technology in Sustainable Development”,
- implementing SD issues in existing courses and design work, and
- the development of a special MSc graduation certificate.

DUT co-operates with several other Dutch institutions on implementing SD in higher education. This co-operation resulted in various joint projects amongst which two recent interdisciplinary student projects (‘Sustainable water management’, and ‘Sustainable industrial areas’). The paper will evaluate these two recent experiments and sketch some lines for the future.

The paradigm of engineering

The profession of scientifically trained engineer came into existence in the 18th and 19th century. It was in fact a product of the Enlightenment. As the Enlightenment implied rearranging political and administrative structures in a rationalist way in order to abandon superstition and injustice, it implied for engineers rethinking traditional technologies in order to rationalise and optimise them.
Training of engineers therefore had to change from merely apprenticeship (in order to learn the traditional methods) to the teaching of science and mathematics (Lintsen, 1979, 1985). This transition first took place in France. Its Grand Ecoles were exemplary for special engineering colleges. These special scientific colleges for engineers were created throughout Europe and North America. The new engineers established institutions to protect their interests. Only those engineers were admitted that were trained scientifically. These institutions became respected, as can be seen from their lustrous buildings and titles.

In various debates, engineers generally took the view that their rational scientific methods were the best means to solve a problem. This scientific approach to technical problems resembled the rationalist approach to socio-economic problems as was propagated by the labour movement. The beginning of the 20th century was the golden age for engineers. Not only were various technological enterprises initiated (electricity, automobility, aircraft, telephone, radio, etc); the dominant mood in politics tended towards more rationalist state planning, in regard to social issues as well as technological infrastructure. In the Netherlands, the State established in those years a coal mining company, steel works, and an organisation to rationalise agriculture. The state took over private railways, private telephone companies and private utilities as competition and private ownership were seen barriers for socio-economic progress.
However, what engineers sometimes failed to recognise, was that the issue at stake was not always a scientifically/mathematically solvable optimisation problem, but a choice between irreconcilable norms and values. For example when engineers were asked in the 1920s on their view regarding preservation of Dutch windmills by technological improvement, they generally argued in favour of demolishing, thereby neglecting the appreciation that many people had for this national heritage (Mulder, 1993).

The Technology –Society gap

In the 1960s new problems emerged. By the growing scale of industrial society, pollution, ecological destruction and exhaustion had become global problems. Fast growing populations and uneven distribution of wealth created new conflicts. Armed conflicts were far more threatening as new technologies had created the means for global destruction. The 'Progress', that was so overwhelmingly present in the reasoning on technology in the 1950s, was stigmatised as a road to collapse in the seventies. The instrumental way in which technologists dealt with nature was held responsible for environmental exploitation and destruction. Especially, the German philosophers Marcuse (1968) and Habermas (1968) criticised the ideological character of science based technology.
Although many technology criticisms left scope for an *alternative technology,* the alternatives they presented were generally to far away, or just too weird to be taken seriously by technologists (Cf. Ulrich 1979, Dickson, 1974).
Unsurprisingly, engineers often reacted rather hostile to technological criticism: no matter what engineers did, their work was condemned anyhow: Every solution that they developed was seen as creating new problems, and 'technological' solutions of environmental problems were regarded as inferior to 'social' solutions. In the seventies, technology assessment was launched as an attempt to assess the merits and impacts of new technologies. This attempt to democratise technological decision-making was often denounced by technologists as 'technology arrestment' or even 'technology harassment' (Cf. e.g. Leon Green of Lockheed Corporation and William O. Baker of Bell Laboratories, quoted in D. Medford, 1973, p. 52.)

In the debates on (nuclear) energy in the seventies and eighties engineers often failed to recognise that there was far more at stake than (cost-) efficient electricity supply. Even if they took the issue of safety seriously, they often failed to recognise that disasters in the order of magnitude of a nuclear meltdown were just completely unacceptable for many people, no matter how small the chances might be (Schuuring et al. 1983, Cf. Nelkin 1992). In this light, the enormous engineering efforts to calculate risks, minimise them, control them or play them down appear to be futile.
Developing technology is not a matter of optimising artefacts or systems in regard to a given (set of) demand(s). Demands of society are dynamic, just as technology is itself. Successful technologies generally do more than just fulfilling peoples existing demands; they challenge people and show them new possibilities that they did not even think of before. Developing new and successful technologies can only take place if the technologist has a deep understanding of the motives and desires of people that will be related to the new technology and the effects of his design on society as a hole and nature. This problem orientation is hard to achieve within engineering curricula that are generally composed of disciplinary courses (Cf. Neef, 1995).
A paradigm shift is therefore required in engineering, and it will profoundly affect engineering curricula. Engineers have to learn that not their technology driven concepts are the central issues of society, and that people have to adapt to these concepts[1]. The demands of people (especially the weaker, and unborn) are what counts, and technologists have to be challenged to contribute to fulfilling those demands. If engineering students realise that, they can make invaluable contributions to the environment. It is therefore hopeful that problem

[1] This gap between engineering ideas on 'useful' technologies for society and the ideas of the layman was nicely illustrated by a study of the IEEE (1984). US Engineers valued 12 (electrical) technologies about equal to laymen. However, there was a large gap regarding the usefulness of 'automation' and 'robotics'.

oriented forms of training are of growing importance at DUT. Several faculties adopted problem oriented training methods in the past couple of years.

Sustainable Technological Development, a new paradigm

Nowadays, the air appears to be cleared to pursue technological change to contribute to Sustainable Development. However, the traditional top-down technocratic approach won't work to cope with the challenge of Sustainable Development. Democratising technological decision making and participation of stakeholders will be important to prevent the failures from the past.
Are engineers fit for the job? The basic features of most engineering training programmes (the application of basic science and mathematics to technological problems) have hardly been challenged ever since Engineering Schools were established. However, one cannot expect that this is a solid base to solve society's modern problems, as environmental problems are intimately connected to social and political issues. Major problems are often of a hybrid character: they cannot be solved by a single discipline. To solve these problems, not only scientific rationalism, but also political, legal and economic rationalism is needed (Cf. Snellen, 1987). Especially if the social and political rationalism of public opinion leaders curb the engineer in his science based design praxis, conflicts might arise.
Unsurprisingly, the number of freshmen in engineering schools is decreasing, as is the relative number of engineers that are in leading positions in modern society (Icke et all., 1997). New schools that integrate science and technology with social sciences have emerged.
However, training 'hybrid engineers' does not solve the problem. Specialised engineering knowledge is essential in developing solutions for the Sustainable Development problems that we face. Many engineers hardly feel the need to co-operate with other professionals, and the work of social scientists is often rejected as 'irrationalism'.
Only adapting the engineering curriculum can bridge this gap between engineers and other professionals to enhance mutual understanding. Naturally, the same applies to the social sciences as they often refer to engineers as 'nerds' or 'useful idiots' without any basic understanding of the limitations of the engineers' work. Project based learning could contribute to this goal, especially if these projects are organised as interdisciplinary projects.
Sustainable Development is the great new challenge for the engineer of the 21st century. However, we must admit that engineers also created a lot of environmental problems in the past. What engineer do we need to do a better job? How do we train such engineers?

DUT and its culture

In 1842, DUT was established in Delft as first institute of its kind in the Netherlands. It was intended to train civil engineers (as opposed to military engineers who were trained at military academies). The organisation flourished, as engineers became of key importance for a country that started developing its water, road and rail transport, and mining, metal and electrical industry. Academically, DUT was also successful as its graduates were allowed to use the title "Ingenieur" ("Ir.") and the organisation was allowed to grant PhD's. DUT graduates organised themselves in the "Koninklijk Instituut van Ingenieurs (KIvI)"[2]. Before WW II, Delft graduates were often involved in public policy. The rationalistic approach of these

[2] Royal Institute of Engineers.

engineers often lead to sympathy for socialist planning policies, and several graduates went east to help the development of the Soviet Union.

After WW II, Delfts engineers were part of the establishment of Dutch society. Technology became overwhelmingly important for several reasons:

- WW II was won by the superior technology of the Americans
- Dutch infrastructure was ruined
- The Netherlands lost Indonesia and therefore had to transform its economy.

The need for technology was seen as such, that the DUT could not fulfil it alone. In 1956, a second Technical University was founded in Eindhoven, and in 1964 a third was founded in Twente. Meanwhile, the establishments of the DUT were enlarged and renewed. As the University of Twente was shaped in years of reform, its curricula were often rather experimental as compared to those at Delft. At the DUT, various people regarded their institution as being the only real engineering school, while they denounced Twente as a 'camping-site' and Eindhoven as the 'company school of Philips'. Curricula at DUT generally contained a negligible share of humanities and many people were proud of that. In the 1960's, the department of mechanical engineering wanted to abolish its professorship in management, because part of it was 'organisational psychology', which was branded as 'pseudo-science'. The chair was only saved by the support of the KIvI and 4 large corporations (De Jong, 1992, p. 86).

DUT made itself known as the institution of the 'hard core technologists': while at Twente and Eindhoven engineering students had about 10-15 % courses in social sciences and humanities, an engineering student at DUT was generally not 'bothered' by these subjects. All engineering studies in the Netherlands characterised themselves as 'tough'. At the welcoming address, freshmen were told to look at their neighbours; if the freshman was convinced that he would become an engineer, his neighbours would not, because half of the students failed. This attitude ('we are the best and therefore many students will fail) was part of the institutional pride of the Technical Universities. Within the faculties, there was hardly any attention for students that had fallen behind or had run into problems. The loss that resulted in human terms was taken for granted[3].

DUT remained by far the largest Technical University in the Netherlands. Nowadays it employs about 5000 people. There are about 13.000 undergraduate students.

Two Waves of Environmental Awareness

The uproars of the seventies affected the DUT considerably. By the introduction of new legislation in 1972, students and assistants could participate in the university decision-making processes. Many students spent much time for various left wing political purposes. Political debates in regard to technology and environment were focussed at:

- (nuclear) energy and energy consumption,
- industrial pollution
- soil pollution by toxic wastes
- supply of energy and raw materials

By the end of the seventies, environmental issues had affected some engineering curricula:

- In the department of Architecture, a working group on town planning and environment was established. This group developed and introduced several activities within the curriculum of the department of architecture (this curriculum is based on multidisciplinary

[3] For a general history of DUT, see Baudet, 1992.

blocs of 2 months, one bloc in the second year of study was completely focussed on the environmental aspects of buildings and their surroundings)

- environmental issues were introduced in within some specialisations of Civil Engineering. In this faculty, sewerage engineering and drinking water purification had been a specialisation before. Control of the quality of surface water fitted to this subject. Marine ecology was also added as a specialisation course.
- At the department of Chemical Engineering, some basic courses were introduced. All students had to participate in 'Chemistry and Society' courses in which environmental issues, in their social contexts, were the main subjects. Health and Safety effects of chemical processes also became integrated in the curriculum (Lemkowitz, 1992, 1996).

However, environmental issues only marginally affected most other engineering curricula at DUT.

A second wave of environmental awareness was triggered by the Brundtland report (World Commission on Environment and Development, 1987) and the first National Environmental Policy Plan of the Netherlands (NEPP, 1990). This renewed interest in environmental issues resulted in some new initiatives:

- The faculty Mechanical Engineering established a part-time chair in Environmental Technology. Dr.ir.J.L.A Jansen and Ir. H.P. van Heel[4] jointly fulfilled this new task. They introduced a successful course in 'Environmental Technology'.
- The faculty of Industrial Design Engineering established a part-time chair in Design for Sustainability. This became the core of a research group.
- The faculty of Mining had established a chair in recycling. Thereby it more or less redefined its 'core business': from 'mining' to 'raw material supply'.
- In 1990, four faculties established the joint research institute 'Interduct', the Delft University Clean Technology Institute. Later, three more faculties participated in Interduct.

The STD education plans at DUT

However, these initiatives were all add-on; there were hardly any changes in the basic training programs of engineers, nor in research programs. In the framework of the NEPP, important tasks were assigned to universities.

In 1991, DUT adopted an environmental policy plan. This plan included the introduction of an environmental management system, and more scope for environmental issues in training and research. It also stated that guidelines for introducing sustainable development within engineering curricula and research programs had to be formulated within three years. However, as the faculties were rather independent in shaping their curricula, this was a hard task. A high level steering group was formed. In the summer of 1994, the steering group published its report (Stuurgroep Duurzame Ontwikkeling TU Delft, 1994). The steering group aimed at introducing 'Sustainable development' throughout the engineering training programs. This report was rather controversial within the university community. On the one hand, students and various staff members supported it. However, most faculties did not want to support these plans. At that time, the technical universities and the KIvI were struggling to convince the government that undergraduate training of engineers should be prolonged from 4 to 5 years. As the outcome of this debate was still unclear, one did not want to put an extra

[4] Jansen and Van Heel are well known in the Netherlands. Both men are engineers. Jansen was an MP in the seventies (a green party) and held a leading position within the Ministry of the Environment. Van Heel was the director of Hoechst Holland, Vlissingen.

burden on the overfull curricula. Moreover, the concept of Sustainable Development was for many people rather vague, and thereby opposed to the self image of being an institute of hard core technologists. Priority was given to a plan to introduce ethics courses.

Although the steering group's report had not much direct impact, various activities followed that kept the strive for sustainable technological development very alive:

- In 1994, the University Council adopted the strategic vision that was formulated by the University Board 'Towards a new commitment' (College van Bestuur, 1994). The mission statement was formulated as:

  DUT will function as an internationally leading technical university, both in regard to education as well as research. DUT is committed to the main social and technologic-scientific problems and challenges. She contributes to its solutions and holds itself accountable for that.
- The University Council emphasised the importance of Sustainable Development for DUT
- Various activities in relation to Sustainable Development took place. In 1994, a rather small denomination organised a successful congress on sustainable technology and religious acceptance. In 1995, student groups organised a successful conference, 'TU Globaal'.

Clearly, new initiatives were needed. The government had consented to 5-year curricula for engineers, and so there was scope for new courses. This scope was not to be filled by extra technology courses. Social skills of engineers were often regarded to be less than sufficient and therefore developing social skills became important. Moreover, it became politically unacceptable that half of the students failed. Pressure on students had to be eased.

By the end of 1996, a new committee was installed by the University Board to come up with new proposals for implementing Sustainable Development in the engineering curricula. This committee consisted of fewer professors and more lecturers. The intention was that it had to philosophise less, and act more.

The main target of the committee remained bridging the gap between (traditional) 'environmentalism' and 'engineering': sustainable development had to become a challenge for engineers and the engineering profession. In line with the strategic vision of DUT, engineers graduated at DUT had to be prepared for the great technological challenges, especially solving questions related to sustainable development. This implied that DUT has to educate engineers who can operationalise 'sustainable development' in technical scientific designing and in the application of technology and technical systems.

In its approach the committee was inspired by the report '*Our common future*' by the World commission on environment and development (1987) and by the Copernicus declaration (1993). Prof. dr.ir. J.L.A. Jansen chaired the committee. His experiences as initiator of the research program *Sustainable Technological Development*, (STD) a program that started in 1993, and was sponsored by five government departments, gave inspiring examples of new paths to fulfil the needs of people in the next century. This requires a dramatic increase of the so-called eco-efficiency, the efficiency by which the environment at large is used to provide in people's needs. The committee therefore considered that sustainability should be an integral element of the designing process, and of the development and application of technology. In its approach the committee regarded the responsibility for sustainable development as a line-responsibility in the professional practice, i.e. it could not be left to specialised engineers.

The committee regarded integration of sustainable development into DUT education and research as a challenge, which it had to meet in co-operation with the faculties in a process of 'learning by doing'. For that reason, the committee consulted a lot with various decision-makers within the faculties. This resulted in a plan consisting of three interconnected operations:

1. The design of an elementary course ‘Technology in Sustainable Development’ for ALL students of the DUT.
2. Intertwining of sustainable development in ALL regular disciplinary courses, in a way corresponding to the nature of each specific course.
3. Development of a possibility to graduate in a sustainable development specialisation within the framework of each faculty.

The elementary course ‘Technology in Sustainable Development’ (TIDO).

The objective of this course is:

- To develop consciousness among the students for the challenges that sustainable development poses to engineers,
- To develop understanding by the students of the role technology plays within society at large, and more specifically in the process of sustainable development,
- To develop knowledge of the most relevant concepts, models and tools regarding sustainable development and basic skills for application during professional life.

The course will consist of two elements:

- A general and theoretical part of 40 study hours covering the most relevant concepts, models and practical exercises and
- A faculty specific part of 40 study hours connecting sustainable development to the faculty discipline.

Intertwining of sustainable development in disciplinary courses.

Adequate intertwining of sustainable development in disciplinary courses will depend on the nature of the course. A design course demands another approach than a fundamental natural science course. In order to ‘learn by doing’ how to set up models and methods to intertwine sustainable development in different categories of courses one or two pilot- projects per faculty will be set up. Based on the experiences from these pilots we hope to learn how the intertwining can be managed and how to develop a course for teachers of the university to enable them to meet the goal.

Graduation in sustainable development.

As ‘sustainability and environment’ was considered to be a line responsibility, the committee argued that it required, like other line-responsibilities (finance, quality management, personnel management etc), specialists to support line management. On the other hand some students may desire to specialise themselves in the art of technology in sustainable development (1 % would already entail some 10 to 15 graduating students per year). The committee wanted to offer those students the possibility to specialise on sustainability in relation to their faculty discipline during the last years of their study. The requirements will be a graduate work which is clearly sustainability oriented and following successful a selection of three to five sustainability oriented courses. The selection has to cover some 800 study hours.

This part of the plan triggered some resistance within DUT. Faculties feared loosing students (although this was denied in the plan) and (probably) feared that the graduates in sustainable developments would be too much social sciences oriented. Discussions with faculties were renewed and obscurities in the proposal were removed. Right now, decision making on the proposal is in its final stage.

Implementation: example Sustainable Development for Aerospace engineers

The first TIDO course will take place between September and November 1999 in the faculty of Aerospace Engineering. To give an impression of the course the following topics will be dealt with:

1 Sustainable development, what is it and what can engineers do about it?
(population growth, underdevelopment, unjustified division of wealth)
Eco-efficiency, as the main challenge for the 21st century engineer. Technology as the cause of the problem or technology as problem solver?
2 the environment as a system: cycles, equilibrium capacities, stability, and exhaustion of raw materials
Degrees of magnitude of effects in time and space. Examples of environmental problems from different degrees
3 atmospheric problems as an example: Ignorance, uncertainty, conflicting interests and the precautionary principle. The greenhouse effect and the ozone hole as examples.
4 what do aircraft contribute to atmospheric problems? Emissions, trends, and possibilities to achieve reductions, with different or less aircraft.
5 Space debris, an underestimated problem for future communications and space flight
6 Man and Environment. Social and cultural backgrounds of mans' use and misuse of the environment.
7 A local environmental problem: aircraft noise near airports
8 sustainable development in global perspective: How do our decisions affect the world's poor? How could we help them to develop their society?
9 Innovation and Sustainable development in corporations: gaining from developing sustainable technologies.
10 Technology in interaction with society: social and cultural factors and the margins for a government technology policy
Social gaming, Sustainable development is not just a mater of acquiring some extra knowledge. Attitude is also important. Moreover, it is often necessary to change social structures. It is our conviction that it is not very effective to teach this by lectures. Social simulations will be used to give students insights in the difficulties to effect social change.
This TIDO course is scheduled for fourth year students. However, TIDO will not be the only element of sustainable development in this curriculum:

- Environmental management will be included in a second year course on aircraft production,
- LCA's are dealt with in a course on materials and design,
- the dynamics of public debates on technology are dealt with in a second year course on the History of Aerospace engineering,
- sustainable development will be an important element in the third year Design & Synthesis exercise assignments
- In the fourth year, there is a course on ethics of technological design.

All of these courses are compulsory. Students might choose to do some more courses. However, scope for this is rather limited in the curriculum.

Implementation: example interdisciplinary projects

Sustainability is a complex theme that needs to be approached with an open mind and a wide scope. Working in interdisciplinary teams is a method to work on complex societal themes, in an integral and creative way. Changes and innovations often start on the boundaries of different work fields.

Table: Participants on the interdisciplinary IJssel project

DUT	Civil Engineering
Fontys University Eindhoven *(polytechnic)*	Mechanical Engineering, Micro Biology and Chemistry
University of Amsterdam	Philosophy, Social Geography, Political Science and Physics
Van Hall Institute Leeuwarden *(polytechnic)*	Environmental studies

In 1999 the interdisciplinary project on the theme water took place. Teams of four to six students from four different educational institutes (see table) worked together for fourteen weeks on the themes drinking water, water use in industry and agriculture, and river water management. The introductory phase of two weeks took place on board of a boat on the IJssel River. This river has the most beautiful river basin in the Netherlands, but has also severe environmental problems. The boat was the floating work and living area and was very helpful for the integration amongst the group.
Governmental organisations, industrial and environmental groups were invited to lecture on board of the boat. The students travelled by bike on the mainland for visiting various organisations for educational excursions. They learned from each other by being able to discuss topics during their time together.
After the two introduction weeks, the students had to work on the project for a further twelve weeks, but then based at their own educational institute. There was a virtual platform set up by the Open University of the Netherlands, for information exchange during the project. Evaluation of the group work was the final part of the project.

Back casting was the leading method during the project. Back casting is the creation of a future vision, bearing in mind what is necessary to achieve in the future and then working towards that goal from this day forward. Questions such as: '*What will the world look like, in about fifty years*' and '*What will the increased amount of citizens need?*' has to be answered. This leads to the next questions: '*What do we need to do nowadays and in future times to contribute to fulfilling those needs?' 'How can the necessary changes in culture, structure and technology be made?*' See table.

Table: Illustration programme on back casting

A simple calculation has shown that fulfilling the material needs of present and future generations on the basis of equity requires a jump in the environmental efficiency of technology by a *factor of between 10 and 50, say 20*, over the next years (Weterings and Opschoor, 1992). These jumps in environmental efficiency of technology cannot be brought about by technical innovations alone. The social conditions for these leap-frog technologies still have to be determined but will invariably involve significant *structural and cultural change* (Schwarz, 1997; de Meere and Berting, 1996).

The Interdepartmental Research Programme Sustainable Technological Development was undertaken in the Netherlands to explore and illustrate, together with policy makers in government and industry, how technological development could be shaped, by back casting from visions of sustainable futures and to develop instruments for this. The programme was established by five ministries and took place between 1993 and 1997 (Programme STD, 1997).

In the beginning of the interdisciplinary project there was confusion on the theme SD related to the work field of the students. But during the project the students became aware of their specific contribution, based on their different backgrounds. They learned to communicate, without using technical jargon and discovered they could be critical towards persuasive information. The students started to build a network for their final projects and future work field.
The period after the time spent on the boat caused difficulties as the students were based in various educational institutes, throughout the Netherlands. This consumed a lot of time for those who had to travel to the weekly meetings. It was a graduation project for some students and for others it was a general third or fourth years project. The differences in possible workload and the 'culture differences' between the institutes turned out to be tough for some students.

Implemenyation: Graduation on SD

From September 2000 for students at DUT it will be possible to receive an appendix on SD next to their graduation degree. To receive the appendix three different parts have to be completed:
1) Participation on two weeks colloquium on technological innovation for SD
2) Passing eight weeks on courses on SD chosen from four different clusters (see table)
3) Work on a graduation project related to SD (25-42 weeks work). In each faculty, specialised people are selected to advise the students on the content of their work on SD.

Table: Clusters of various topics on SD courses

Design analysis and tools, *in general*	Life cycle assessment, recycling, sustainable energy
Design analysis and tools, *specialised*	Environment and chemistry, photo-voltaic energy, eco-toxicology, sustainable building
Management	Environmental management, environmental law, chain management, risk analysis
Policy and society	Technology assessment, sustainability in global perspective, environmental philosophy, environmental economy

For a list of all SD courses: http://www.odo.tudelft.nl

The colloquium is the main tool to make this special programme visible. It consists of one week intensive course on a boat. The boat is visiting various sites that are interesting for SD. While sailing, lectures, workshops and discussion take place on board. The participants are generally the most critical type of students. We experienced that this pressure cooker idea (being on a boat for a week with students from various disciplines) works out very well.
In the second part of the course, students learn the STD approach, which could offer them a framework for their own graduation project. (Cf., Weaver et all, 2000)
The subject of the graduation project might vary considerable. For example, the Design for Sustainability program (DfS)[6], part of the Industrial Design Engineering studies, offers projects varying from designing environmentally sound products to optimising design methods on environmental issues, to future visions for a sustainable consumer's society

Lessons learnt

- **An academic engineer should also be trained as an 'social engineer'**

Technology revolutionises society and social issues are at stake at every innovation process. For that reason an academic engineer should not be trained as a pure designer of technology but as a 'social' engineer. The future engineer will become the manager of the designers of sustainable technology and therefore must also be able to address social issues. Sustainability should be an integral element of the designing process and of the development and implication of technology.

- **A cultural change in engineering education is needed**

Social issues are easily neglected in engineering. Therefore a cultural change in engineering education is needed. This will take time and persistence for everyone involved in the process of change. Teaching a basic course on Sustainable Development alone is not enough to educate sustainable engineers. SD has to be incorporated in all regular disciplinary courses. The university should stimulate the students to pay attention on the theme during the graduation project.

- **'Hybrid' lecturers are needed**

The message on SD must be pointed out by showing the connection between the theme and the work field of the future engineer. Illustrative and inspiring examples are essential. To raise awareness among technicians by giving examples only from the sociological or economical point of view will not make sense. To address the topic 'hybrid' lecturers with both sufficient social- and technical knowledge are therefore needed.

- **To realise a cultural change both bottom up and top down approaches are needed**

The board of the university represents the organisation to the outside world where issues on SD considered being important. In general they are more sensitive to a proactive attitude towards SD than staff members. Students are not prohibited to address new issues.

- **To realise the cultural change in engineering education both top down and bottom up approaches are needed.**

Personal initiatives are thereby inevitable, but structural agreements are essential to put the theme on a more permanent base on the agenda of the university. People from different levels in the organisation and from all departments should be involved.

- **During changes in the educational systems within faculties all programs are 'under fire'. Therefore communication with all levels of decision making is important to keep what is built up.**

Informal information exchange and network building, for example through lunch meetings, are stimulating to cultural change. Starting the network is often not the bottleneck. Continuation should be emphasised.

Conference October 24th/25th 2002

It might be clear that we are far from where we want to be. However, we feel that we achieved some interesting results. Moreover, we experienced that various colleagues abroad are facing the same problems in their institutions. We are therefore organising an international conference on 'Engineering in Sustainable Development. It will focus on:

- (sustainable) technological innovation practices and the role of engineers in these projects
- what knowledge/abilities the future engineer must have.
- the social implications of (sustainable) technological change
- SD in maintenance, management and design practices
- the content of existing Sustainable Technological Development courses or curricula
- (interdisciplinary) student project work targeted at Sustainability
- organisational and/or political issues related to the introduction of Sustainable Development in higher education
- activities to teach SD to staff members.

We would like to welcome you in Delft October 24th/25th 2002.
http://www.odo.tbm.tudelft.nl/conference

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