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Integration of Sustainable Development at Dutch Universities for Professional Education: the CIRRUS approach

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Abstract. *The paper describes the results of a pilot project for a novel approach to introduce sustainable development in engineering eduction. That concerns a full integration in the study with the goal that all students develop a basic understandingt and are trained in the specific aspects of sustainable issues and the tools to handle it that belong to their specific field. The pilot project has been ended a year ago. The lessons learned during the project and in the further implementation of the reults are discussed. It forms part of a larger program to instroduce sustainable development in Dutch higher education.*

1. INTRODUCTION

If sustainable development is to become an essential aspect of society and economical development, it has to become as well an essential part of education. In the Netherlands various initiatives have been taken to reach that aim. Different approaches exist on the various universities and UPE's [1]):

- ✓ separate courses on sustainable development and specific issues as energy and building.
- ✓ multistudent projects involving different studies on a specific sustainability issue
- ✓ complete integration of sustainability in the engineering study.

The approaches differ also in the size and the time spend on it. It can be an only small part of the curriculum, such as an introductory course. Courses can be made obligatory or not.
In several studies however extensive time and attention is paid to sustainable development and the consequence it has for engineering. In some case it has also become a specialization

1 UPE : Universities of Professional Education are the Dutch institutes of higher education for applied sciences

within a specific engineering study.

The Dutch development program “Sustainable Technological Development” (STD) [1] has defined the basic characteristics of the most likely and feasible routes towards real sustainable development. The essential feature of such routes is based on a paradigm shift in developing, designing and implementing technology. Asked for are ’system innovations’ and ‘transitions’, aimed at satisfying needs and less at ‘just optimisation’ of the isolated performance of products and processes’. It is often not so much the character of technologies that influences ‘sustainability’ as the way they are used. [2, 3]
Defining how a sustainability oriented study and curriculum should look like, requires also fundamental insight in the way society, industry and the professional requirements will develop in the future. Students must be trained to handle such a ‘systems-approach’ for finding solutions and implementation options for the short and for the long term. It requires multidisciplinary and ‘lateral’ thinking. The attitude and the competencies to do that are essential aspects for any engineerstudy that calls itself ‘sustainable’.

2. SUSTAINABILITY IN ENGINEERING EDUCATION ON DUTCH UPE’S

Sustainable development has become an essential subject in most of the Dutch Universities for Professional Education. Often the engineering departments take the lead in that. The newly set up expertise centres with the ‘lector’ (UPE professor) for the field sustainable development that have been formed on most UPE’s, play a major role in this.
A charter is made by the UPE’s, the UPE Council and the government departments involved on the introduction of sustainability in the UPE curricula. It describes the necessity and the actions to be taken. It has been signed already by over 170 studies/schools/academies from 31 UPE’s.
The schools/academies that start introducing sustainability into their curriculum can apply for a certification, on different levels. As audit tool for that the AISHE method has been developed [4, 6]. Presently on 7 UPE’s 30 studies have been certicified with 1 or 2 stars. 22 of those are engineering studies. The number is growing rapidly.
Attention for sustainable development will also be taken up as a criterion during visitation audits of studies in the future.
Since a few years socalled ‘knowledge-centers’ are being established on the Dutch UPE’s. A ‘lector’ (UPE professor) is in charge. Their role is to introduce new knowledge on specific fields into the studies. 12 of those are in the field of sustainable development. In several occasions they elaborate on developments that are already going on for some years.

The result is that a substantial number of students in UPE engineering studies become familiarized with sustainable development. As an indication of that see table 1 showing the progress on three different UPE’s based on a short questionnaire. The progress is clearly thanks to the presence of a ‘knowledge-center’ in the field of sustainable development. On the other UPE’s with such a knowledge-center the situation is comparable.

case	number of engineering studies	students in these studies	approach			students 'exposed' to sustainability	docents directly involved
			intro-duction	separate course or specialisation	full integration		
UPE Den Haag	5	2400		-sustainable energy		~ 40	5
UPE Zeeland	8	800	X		being developed	400	10
Avans UPE	18	3400	X	- green chemistry - sustainable building	in 8 studies	900	20

Table 1 : Progress in introducing sustainability in the engineering curriculum of three Dutch UPE's, for example

3. DEVELOPMENT OF THE CIRRUS APPROACH

Since 1998 a pilot project has run at the technical faculty of the Avans Hogeschool (formerly UPE/Hogeschool Brabant) aiming for complete integration in all technical studies: the CIRRUS project. Models, tools and educational materials have been developed to make that possible.
The project was part of the Dutch program on introducing Sustainable Technological Development in higher education. The CIRRUS project was set up as one of the earliest projects, to demonstrate the feasibility of a novel approach towards integration of sustainability and education and to develop the experience, knowledge, tools and methods other UPE's and universities can apply.
Over the years the results have been published and discussed on Dutch and International forums to test and disseminate the ideas and approaches developed [5, 6, 7, 8, 9, 10, 11, 12, 13, 14]. In 2001 it has won an award for the innovative approach to introduce STD. It ended in 2002 and in 2003 a symposium was held to present the results and at the same time bring together the other experiences in this field on all Dutch UPE's and compare results.

In the still novel CIRRUS approach sustainable issues are fully integrated in the courses, projects and practical training throughout the engineering studies. It starts with a short separate course to introduce and explain the background and main issues. For the remainder sustainability issues and tools are treated in the course of the normal modules and projects where they logically fit in. Such far-reaching integration is an ambitious goal and poses many practical and educational complications. Nevertheless the fundamental idea behind this is that when we consider sustainable development to be essential for all activities within society and all sectors of economy, it cannot remain an isolated field of expertise but must form a 'mind-set' for everyone.

3.1 Sustainable competences for an engineer

'Sustainable thinking and doing' must be fitted in 'competence focussed learning', a new approach with growing importance in Dutch higher education.
A main issue for engineers regarding sustainability concern *the methods* to define feasible and acceptable solutions, also in the long run, to understand how resources, technology, materials and products are to be used and and implemented to satisfy the needs of present and future generations still leaving room for nature.

A formulation of the competence fitting that is:

- *Being able to define the influence (positive and negative) on the "critical sustainable conditions" regarding human quality of life, environment and ecology on the short and the longer term of existing and new products, processes and/or activities.*
- *Being able to develop and use approaches that substantially contribute in decreasing negative influences and increasing positive ones, which eventually must lead to a better quality of life and to an economy and society that can be sustained in the long run.*

Therefore, the educational conditions set for the CIRRUS project approach have been:

- a paradigm shift in developing, designing and implementing technology, aiming at 'system changes' and not on 'only developing and applying innovative technologies.
- attention for attitude and insight as essential components for a really sustainable development oriented engineer.
- interdisciplinary and 'lateral' thinking which are needed to handle a 'system-approach'.
- backcasting as a part of developing a vision and a path for development.
- making students experts in their respective fields but with 'an extra', being the competences mentioned in the points before.

Criteria are developed to define what a study must cover for being 'sustainable' and the staff involved is being trained to understand the relation of their respective subjects with sustainability.

3.2 A model

The educational approach developed to come to real integration has three components:

1. Each course, project and other activity in the 'normal' curriculum takes care of the issues relevant for sustainability connected with its own subjects such as materials use, energy, design approaches, economics, business operation methods, etc.
2. An introductory course on an early moment elucidates the concept, sets out the 'line of approach' sustainability needs and creates the general framework for issues and details treated elsewhere.
3. Throughout all activities in the study attitude, lateral thinking, interdisciplinary ability aimed at sustainability get much attention, increasingly towards the end. Learning by doing the various tasks, practical work and projects offer the best opportunity for this.

The goal must be: students will still become experts in their respective fields, but with 'an extra': those specific knowledge, competences and attitude needed for ' sustainable thinking and doing'.

Figure 1 visualises this approach, from a basis of in depth and mostly specific 'narrowly' profession related knowledge and skills, building up towards broad capabilities and attitude for 'real sustainable thinking and doing' based on having broad view and working with an interdisciplinary system approach. It is dubbed the 'T-model' for integrating sustainable development into curricula.

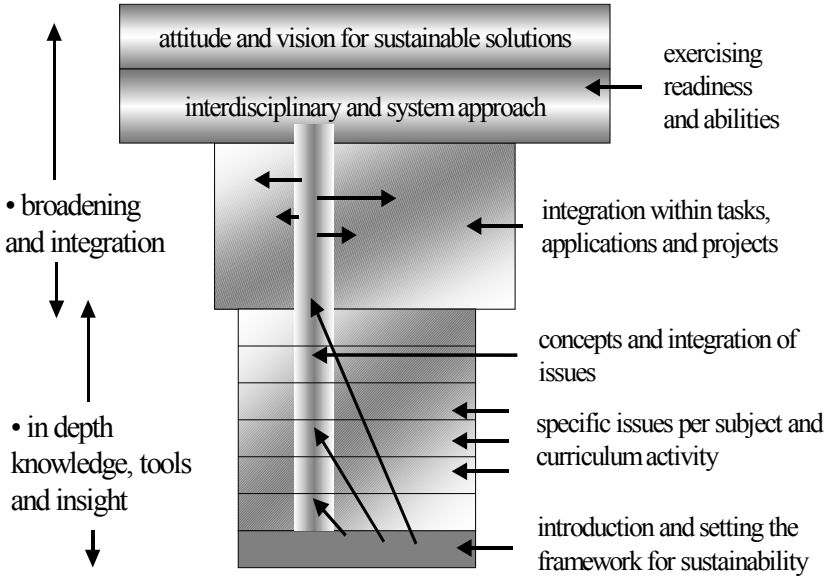

Figure 1 Integration model for sustainability in a study: the T-model
(The shading indicates that attention for sustainable aspects is really spread through all of the curriculum and not a well-defined and separate issue. The horizontal beam of the 'T' signifies the broader view including the 'systems approach' needed as well as the inter- and multidisciplinary understanding needed to work with other experts from other fields, technical and non-technical.)

3.3. Characteristics of an integrated sustainable curriculum

To attain a sufficient level of sustainability in a curriculum requires:

- definition of a minimum set of issues to be treated over the years, which together lead to a total coverage of all essential knowledge and insight, together with the tools and capability to use them
- attention for 'general' competences and capabilities which are essential for being able tot work in a sustainable manner;
- regular 'moments for integration' of the varied knowledge and capabilities learned;
- a minimum amount of time that has to be dedicated to 'recognisable' aspects of sustainable development and covering the specified learning goals. That amount of time is presently set on 5%, which signifies 80 study hours.

A series of issues is selected as being essential for the 'sustainable competence' as defined. Those have to be covered and learned to a 'sufficient' level. They form the 'learning goals' for a curriculum intended to include sustainability and the criteria by which the extent sustainability is covered can be measured. They fall into three main themes' which each has its own role and shows a specific angle to look at sustainability.

- ✓ environment, ecology and socio-economic oriented issues as degradation and depletion, poverty and social disruption, for understanding the basic causes, policy development, history etc. It gives the 'WHY' of sustainable development.
- ✓ system oriented issues, as product chains and technology development. It gives the specific knowledge for methods, technologies, the overall approaches to be able to come to sustainable solutions and development routes. It gives the 'HOW'.
- ✓ human and society oriented issues, as need and function, cultural aspects, ethical issues, human behaviour etc. It gives the context that has to be taken into account and determines the gap between desirable and feasible. It gives the actual 'SCOPE' that counts.

During the study there is a shift in attention for the three themes. In the first phase much attention is paid to the background: the environment, ecology and socio-economic oriented issues. That shifts in the later years towards the system and the human and society oriented issues. Understandably, during the last phase of a study, during practical work and the final project the system approach gets most attention.

Defining the detailed criteria and learning goals of 'sustainable competence' for the separate studies also necessitates that to each of the issues a level must be assigned: from knowledge, understanding, skills to attitude. For the different studies / professions such 'thinking and acting in a sustainable way' the required level and extent of coverage will of course be different for various issues.

Knowledge is required regarding the basic facts and concepts, for instance environmental pollution issues, scarcity of resources, possible technological solutions but also the present policies and history of the field, laws and regulations.
Understanding is required for how 'things work' (technical but certainly also socio-economical and cultural), what problems can occur and how sustainable options might function. For instance one must understand the different angles to look at options and constraints as:

- o consumer-needs and preferences and the requirements of society;
- o background of rebound effects, business management issues;

Skills are required for assessing effects, positive and negative, and designing, for instance the use of 'practical tools' as LCA and design methodologies. It concerns also the handling integrated system oriented approaches.
Attitude goes beyond it all. It is deemed essential not just to understand but also to be committed to sustainability. Only then knowledge, insight and skills are used 'automatically'

and effectively. Table 2 gives an example how that could be filled in for a specific study (chemical engineering in this case).

Level → ↓ Theme	Knowledge	Understanding	Skills	Attitude
Environment, ecology and socio-economic oriented	- causes of pollution, - resource availability - policies and laws, national and international - history of technological evolution - future scenarios	- cause – effect relations for the various issues	- developing a vision on possible developments and their effects, back casting - finding and assessing relevant information - operate from existing laws and policies	- keep a view on possible and wished for developments - own, critical, opinion on sustainable development
System oriented	- basic facts of various relevant technologies - overview of resource options and their drawbacks - set-up of care systems,	- function oriented character of sustainable approaches - the systems structure of fulfilling human needs - the role of other disciplines - broader 'profits and costs' assessments - relation of short term actions and long term strategies	- LCA - design for sustainability - use of DFA and DFD methods, - exergy analysis - water and energy pinch, - product chain management -multi- and interdisciplinarity - sustainable business operation	- 'automatically' use the knowledge, insight and skills effectively - willing to include inter- and multidisciplinary aspects
Human and society oriented	- relation of the various actors in society	- consumer behaviour and rebound effects - cultural aspects in using technology	- critical assessment of potential uses of technology	- understanding own responsibility as an individual in society - critical attitude

Table 2 Example of learning goals, issues and level, for specific study

Important learning goals are to be 'system thinking', multidisciplinarity and capability to work from a future oriented vision. What is needed is not just knowledge and practical application of technology and methods, but also, and maybe even more, an all-encompassing attitude towards 'sustainability'.
Working in a 'systems oriented way' is seen as essential for a student to be able to really develop sustainable options. It however is one of the hardest to learn and to teach. 'Problem oriented education' and projects in which students, preferably from different studies, work together prove to be a good tool to train a 'sustainable view and attitude' and to develop the capabilities for systems approach and multidisciplinarity that are essential for real sustainable solutions.

Some discussion is going on regarding the moment a complex issue as sustainable development can be introduced to students, when they are ready to become interested able to

understand it. Consistent with the vision that sustainable development is an intrinsic aspect of all subjects, in the CIRRUS approach sustainable development is introduced in the earliest possible moment. That proved to be quite effective and rewarding. If brought in a 'light and easy way, in a short project students are very interested and early insight is easily gained, on which can be elaborated later on. Such projects were commonly based on issues that concern 'aspects of daily life': own energy use, environmental effects of household products and activities and excursions to 'sustainable building projects'. The latter were done actually already during the introduction weeks for the study.

3.4. Practical implementation

The approach makes it indispensable that much effort is put into 'training' the teachers and developing clear learning goals. There are a large number of lecturers to be trained and only few lecturers had prior knowledge more than just a fleeting idea about sustainable development. A two-step route was taken.

- A core group was formed of about 10 lecturers from all departments involved and trained.
- This was made responsible for training the total of all staff involved (around 250 persons).

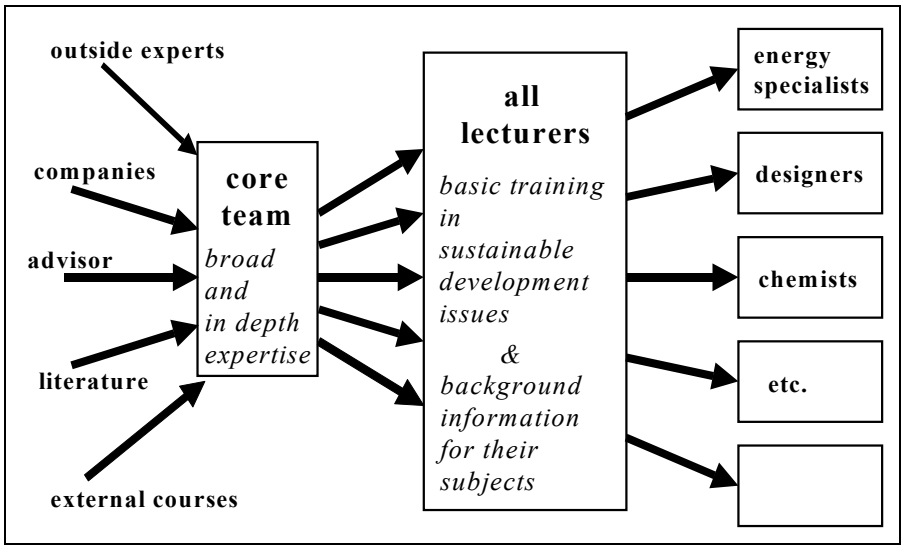

Figure 2. Stepwise training of the whole faculty

The basis of the approach was that lecturers start with their own specific expert knowledge, develop that further with respect to the related sustainability issues and teach one another with what they have learned themselves. The systems approach and the multi and interdisciplinary aspects are learned by the docents too 'hands-on' by doing several projects together.

3.5 Teaching materials

Learning materials are needed for:

- The introductory and 'integration' courses, mostly in the form of short presentations and projects in which the students get acquainted with basic concepts and issues.
- The background information which the lecturers must use to integrate the relevant sustainable development issues and aspects in own subjects, courses and learning materials

Essential is that these learning materials are informative and inspiring for the various lecturers. They are therefore made as 'toolboxes' and offer the possibility to implement sustainability in their own subjects, courses and learning materials.
Those toolboxes are based on existing materials and information from all sources. What they offer is a basic amount of information, sufficient to understand the ins and outs of a specific issue and give its position and role within sustainable development as a whole. It supplies also some examples for teaching and ideas to use that information. They can be used also by students as background information.

Only to a minor extent specific materials are made for specific sustainability courses and projects. Those are intended only for introduction of concepts and to act as integration moments for all different aspects.

To make available basic information for the introductory courses a reader was developed that deals with all relevant issues and concepts concisely. It gives the background on the "why and how" of sustainable development and treats the important issues, such as sustainable energy, use of materials building and consumption.

4. LESSONS LEARNED

The approach chosen in the CIRRUS project was ambitious. The results, in our view, support however its feasibility. The first observations show that total integration is possible, rewarding and also can bring a study as a whole to a higher level. However much time and commitment is needed as well as patience and flexibility. Although obtaining acceptance was difficult, the validity of the approach is becoming apparent for most of the lecturers involved. An important factor has be, in our view, finding an optimal combination of the existing educational practice, the own discipline and interests of the lecturers and the relevant sustainability issues and knowledge.

Essential is that a minimum set of issues to be treated and a minimum amount of time to be spent on sustainability issues must be defined, from the start. Good care has to be given that 'erosion' of that does not occur.
As is discussed interdisciplinary projects are excellent tools for integrating knowledge and stimulating a real systems approach. For an optimal result strict coordination of such interdisciplinary projects is then essential. [11]

The two-step structure to train the lecturers, worked very well. Not only because of its efficiency but it created a very competent and motivated nucleus of lecturers that is essential to assure progress of the implementation and future quality. Besides it forms a useful

reservoir of expertise for exchange of information with industry, municipalities and other UPE's.

It is best to involve as many of the teachers as possible from the start on. At least information on what is being done and developed must steadily trickle to them. There must be the possibility for comment and suggestions. In the CIRRUS project that was not the case. It proved more difficult to involve the other lecturers later on because of that. It was felt that they had just accept eductional set-up and materials as was developed in some 'secrecy'. It does not motivate. The workshops to introduce everything later on could only redress that to some extent.

Also because of this it has been decided to develop 'just background information', in the form of an schematic introductory course and a series of 'toolboxes' as described before insteed of complete modules. It leaves the lecturers the choice, responsibility and the challenge to upgrade their own courses and materials. Although it did and still does lead to a sometimes, at least initially, poorer content and level with respect to the criteria set, it took away much discussion, prevented emergence of a 'not my idea' attitude and in fact stimulated involvement. At the end that will guarantee good quality!

Lastly, ongoing implementation and integration is only possible when an expertise centre is kept operational. It must motivate, can supply assistance and guarantee that the level and the time spend on sustainability issues is kept up to standard. Furthermore it is clear that upgrade courses and regular workshops have to be part of the ongoing implementation.

5. FURTHER DEVELOPMENT

New developments offer new opportunities, for instance regarding the bachelor-master structure of studies. A broad bachelor curriculum in the first year makes integration of sustainability much easier. It can act as a stepping-stone for specific paths through the study in which sustainability is a major focus of attention.
Sustainability can provide some of the needed structuring 'leads' through curricula. For instance, in the new bachelor study Technology and Management at the Avans UPE lifecycle approach and end-of-life management of products will become main leads through the study, and function as reference for specialist subjects and projects.
The major-minor set-up of studies makes it possible to set up a minor on sustainability that can fit perfectly with a bachalor major in which the basis of sustainable thinking and doing is given form already. It can be filled in by a student with a focus on hers or his own interests in this fields. Such a personal focus will certainly appeal to students.

The CIRRUS project has been ended, and quite successfully. Its real success has however yet to come when we are able to implement the approach fully in all engineering studies of the Avans UPE. Besides, real success means also that the results inspire others to come to a more integrated approach too. For that we are willing to help.

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