Stand-alone and Interdisciplinary Course Design for Engineering Education for Sustainable Development

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ABSTRACT
In order to embed ESD in the EE curriculum, several approaches has been introduced and practiced in higher education institutions. One of the approaches is to introduce a new ESD course as an add-on to the existing curriculum being either compulsory or elective and either designed for a single discipline or to fit across programmes. At Aalborg University (AAU), Denmark, which has a long tradition of problem based learning (PBL), a comprehensive sustainability course has been introduced to fit all students not at least across programmes but also across faculties of engineering, humanities and social science. At this stage the learning objectives and the course content is stated; whereas the experience from practise is yet to be explored. In this paper we discuss the proposed learning objectives and content of the AAU course based on a conceptual framework for characterising ESD courses and reported examples of other ESD courses of the same kind. The presented conceptual framework is put to practice, characterising the AAU course as a stand-alone interdisciplinary course with a consensual approach. The conclusion is that the conceptual framework can provide an awareness of the design features, which can be related to the overall purpose of the course. The analysis also shows that even among the same type of courses there is divergence in the learning outcomes and the content. Therefore, discussion between course developers and stressing the use of the same type of courses across institutional settings is strongly recommended.

Keywords
Engineering Education, Education for Sustainable Development, course design, learning outcomes and content.

1. INTRODUCTION
Technology cannot be deployed as if it had no environmental or societal implications. Engineers must therefore be key players in sustainable development, and exhibit responsibility as part of the social structure – they should not just act as isolated technical experts [1]. In 1989 UK Royal Academy of Engineering started to develop the Principles of an Engineering Design Scheme. This charter points out that a sustainable development will require significant shifts in behaviour and consumption patterns. Often it will be – and should be – engineers who are making the decisions about the use of material, energy and water resources, the development of infrastructure, the design of new products and so on. However, engineers must recognize and exercise their responsibility to society as a whole, which may sometimes conflict with their responsibility to the immediate client or customer [2].

The importance of Education for Sustainable Development (ESD) in the Engineering Education (EE) curriculum was recognised by UNESCO already in the year of 1975 and in 1992 UNCED introduced sustainability as a major principle in supporting human development. The Barcelona Declaration stated that the "world and its cultures need a different kind of engineer, one who has a long-term, systemic approach to decision-making, one who is guided by ethics, justice, equality and solidarity, and has a holistic understanding that goes beyond his or her own field of specialisation". Education can serve as a platform to produce a new generation of engineers and therefore higher education should be committed towards sustainable development [3].

Aalborg University Denmark, a higher education institute well known for its problem based learning environment, an ESD course is presently being implemented. The course is to be offered to all students across the faculties of Engineering and Science, Social Science and Humanities. At this stage the learning objectives and the course content are formulated, whereas the experience from practise is yet to be defined.

Scientists who are experts on sustainability construct the curriculum; however from the perspective of educational research in general and research on ESD in specific, the case offers opportunities to follow an ESD course offered across faculties and within a problem based learning environment.

In this paper will tell the first part of the story, by addressing the following question:

How can an ESD course be characterised based on the content and learning outcomes and to what extend is the AAU course in alignment with other ESD courses sharing the same characteristics?

In the following pages we will synthesise theoretical distinctions of ESD courses considering the content and learning outcomes. After that, we present the course content and learning objectives

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of the AAU ESD course; and discuss the characteristics of this specific course. Besides the case-specific conclusions, we also seek to provide a conceptual framework for characterising ESD courses in general.

Based on the characteristics from the AAU ESD course, we have selected two cases of ESD courses for comparison focusing specifically on the learning objectives and course content. These cases are based on a literature review of two articles with the same characteristics as the AAU course. The articles are selected through a screening of 25 articles on EESD. As the articles are chosen for exemplification, they by no means are to construct statistical validity for the dominant EESD practise of courses of that kind. Instead the articles are chosen primary to show the variety of learning outcomes within the same category of courses and secondary to provide feedback to the suggested course content and learning outcomes of the ESD course at Aalborg University.

2. CHARACTERISING ESD COURSES

The strategy for design of ESD differs from one institution to another, but however may share some of the same characteristics. In the following we present three theoretical distinctions to characterise an ESD course.

2.1 Stand-alone versus embedded models

Salih has pointed to two types of models to integrate SD; (i) a stand-alone and (ii) embedded model [4].

The stand-alone ESD model provides opportunities for students to develop sustainability skills through specific courses that are carefully planned for this purpose. To put it in more general terms:, stand-alone ESD courses usually do not affect other courses in the programme nor the institution or the educational paradigm [5]. Erdorgan and Tuncer in their article entitled Evaluation of a Course "Awareness for Sustainability" outlined five objectives of the course, characteristics of the stand-alone model [6]. In their stand-alone course, they define sustainability in terms of skills, knowledge and affection [6]. The course provides understanding of sustainability in daily life and work, as well as awareness of environmental issues, acquisition of social values, and personal views on sustainability and the natural life circle [6]. Other examples of the stand-alone ESD model can be found in the following references [7-11].

By contrast, the embedded ESD model integrates SD issues in the teaching and learning activities across the curriculum. This model does not require the student to take a specific course as in the stand-alone model. Instead the students are trained to relate traditional aspects of the disciplines to SD. The learning outcomes related to the SD will thereby be integrated as a part of the learning outcomes of the respective courses. A clear example of an embedded ESD model is reported in Boks and Diehl "Integration of sustainability in regular course: experiences in industrial design engineering" [12]. Another example is the course offered in TU Delft, labelled Technology in Sustainable Development, which is introduced as elementary ESD course integrating SD [5].

2.2 Disciplinary versus interdisciplinary oriented

Another distinction, which may be made in the design of ESD, is whether they are disciplinary-oriented or interdisciplinary-oriented.

A clear characteristic of a disciplinary-oriented curriculum is the focus on a strict interpretation of the disciplines with separate subjects and that no attempts are made for integration [13]. On the contrary an interdisciplinary-oriented curriculum deliberately brings together the full range of disciplines [13].

A disciplinary-oriented ESD course can be viewed as an add-on with a particular disciplinary focus, whereas the choice of content is decided by the relevance for a specific engineering profession as mechanical, civil, electrical or chemical engineering. The difference between disciplinary-oriented and interdisciplinary-oriented ESD courses is important in relation to understanding the course learning objectives. An example of a disciplinary-oriented ESD course is offered to ecological engineering programme by Arabaev Kyrgyz State Pedagogical University (KSPU) [7]. The course contents focus on ecological and environmental aspects including local problems, a code of ethics and nature disasters as most important elements and emphasized these aspects when discussing issues and topics regarding to the environmental impact [7]. Other example of disciplinary-oriented courses may be available in reference [9].

An interdisciplinary-oriented course curriculum is instead demanding cross-discipline implementation without changing or rearranging the course according to one specific discipline. In other words, an interdisciplinary-oriented course is compatible to a wide range of disciplines.

Sometimes course developers are able to design a course that serves all disciplines available in a University [6]. This approach demands a certain level of cooperation among course developers to work together in designing a course that is suitable and achievable for students from different disciplines. However, the interdisciplinary group of students might make it possible to address the complex and interdisciplinary nature of SD.

Course developers might also cope with the diversity by clustering disciplines in larger groups like Social Science, Technology, Engineering and Science. There are several universities that applied this approach to design an interdisciplinary course. This opportunity presents an easier way to select course content and deal with the experience that interdisciplinary content of ESD does not easily fit into a disciplinary-oriented educational process [14]. An example of this interdisciplinary-oriented course opens to students from all engineering disciplines can be found in the study of Hollar [8]. This course has adapted an active learning approach by grouping students across disciplines and assigning them with an interdisciplinary design project [8]. In this project, teams established network relationships among engineering faculty, university engineer and others parties [8]. The students were to propose and design a solution to reduce the CO2 emission from the university to reduce the impact on environment [8]. See the original publication for details [8].

2.3 Singular, dialectic or consensual approach

The case presented by Lourdel et al, shows that sustainable development can be represented by various approaches [15].

Table 1,0 presents an overview of the different approaches applied. Expanding on Lourdel's representation of the diversity of approaches to sustainable development, we would like to propose three dimensions of ESD:

1) pure economic, social or environmental approaches. These three approaches we will term *singular* approaches to ESD.
2) economic approach with either an environmental or social perspective, social approach with either environmental or economic perspectives, and environmental approach with either economic or social perspectives. These approaches we will term *dialectic* approaches to ESD.
3) a holistic approach combining economic, social and environmental aspects, where the three pillars of sustainability are fairly presented and included [15]. For this approach we will adopt Lourdel's notion of a consensual approach.

These three approaches to ESD show different levels of comprehensiveness in the interpretation of sustainable development.

Table 1. Approaches to Sustainable Development content

Lourdel´s representation	Category
Environmental (Strong sustainability)	Singular
Social	
Economic (Weak sustainability)	
Environmental with social perspective	Dialectic
Environmental with economic perspective	
Social with environmental perspective	
Social with economic perspective	
SD consensual approach	Consensual

2.4 Conceptual framework for characterising ESD content and learning outcomes

When combining the three distinctions of ESD presented above, we have a conceptual framework for characterizing learning outcomes and course content; by asking the following questions:

1) Are the SD learning objectives or content embedded into courses or does it have a life of its own within the programme (stand-alone or embedded)?
2) Are the learning objectives and content focused at supporting a single discipline or a range of disciplines (disciplinary/interdisciplinary)?
3) What are the range of the learning objectives and content in regard to SD as a concept (singular/dialectic/consensual)?

In the following paragraph we will use this three dimensional framework to characterize the ESD course at AAU.

3. THE ESD COURSE AT AAU

In the spring 2011 the president of Aalborg University together with the faculty deans decided to offer an elective 5 ECTS course (corresponding to 150 hours student work) for all nine-semester students at the University. Researchers within the field of sustainability science were appointed as responsible for the course. In the course description it is stated [16]. :

"This course is designed for all master level students, regardless of academic discipline. The course is interdisciplinary in nature and will take its point of departure in students' backgrounds, their current studies and their future careers and professional life and how they can incorporate sustainability in their coming professions. Emphasis is therefore on creating an understanding of how different professions relate to and impact on the core aspects of ensuring quality of life and creating environments in which sustainable development is possible".

The course has several learning objectives; whereas it is stated that after students have completed the course they [16] :

- Have thorough knowledge of professional responsibility and accountability
- Understand personal roles and responsibility (e.g. as consumer)
- Understand professional and/or organisational roles (e.g. as engineer, manager or policy maker)
- Have thorough knowledge about developments in the environmental discourse (past – present – future), including environmental regulations
- Have thorough knowledge and understanding of relevant concepts, theories and models in relation to sustainable development and its inherent complexities
- Can understand and reflect, with a scientific basis, on the causes and consequences of un-sustainable development, as well as the ability to identify scientific problems in relation to these
- Can from her/his own professional perspective identify, analyse and assess sustainability related problems and consequences
- Can communicate and discuss broad themes that have particular relevance for sustainable production and consumption
- Can relate to work and development situations that are complex, unpredictable and require new methods of solving
- Can reflect on relevant sustainability metrics used for valuing sustainability
- Can independently take responsibility for own professional development and specialisation in relation to sustainable development

In the specification of content the following keywords are mentioned: Fundamentals of environmental, social and economic development; practical challenges and theoretical underpinnings of sustainable development and responsibility: individual, professional, and organisational responsibilities; global-problems/crises (climate change, biodiversity, food, economy), as well as national and local cases; the relationship between ethical and political assumptions; social cohesion and justice [16]. .

We will argue here that the learning outcomes and content of this course can be characterized as an interdisciplinary, stand-alone course with a consensual approach.

In the following, we will compare the learning outcomes and contents from this course to two courses of the same kind, which is reported in [10, 11]. This we will do to provide feedback to the suggested course content and learning outcomes for the ESD course at Aalborg University, and on a more general level to elaborate on the theoretical founded characteristics of this kind of ESD course.

4. IMPLEMENTED STAND-ALONE INTERDISCIPLINARY COURSES WITH A CONSENSUAL APPROACH TO SD

Analysing two cases, based on the literature review offers insight in the implementation of EESD stand-alone interdisciplinary courses with consensual approach. The examples have been selected from a screening of 25 articles within the field of EESD. The two examples show that learning outcomes and course content might differ within same type of courses.

The first case is the Climate, Sustainability and Society course adapted by developers from La Trobe University, Australia. The stated learning objectives for the course are that students will [11]:

- Develop a vocabulary of contemporary definitions and theories relating to climate, sustainability and society.
- Be able to synthesise provided information and deliver a reasoned view.
- Recognise and use the semantic base from each of science, social science and economics.
- Respond to contemporary news media and appropriate peer reviewed research literature to convincingly argue a point of view and convey arguments to peers.
- Use a variety of resources to research a topic and construct an analysis relevant to a given context, and
- Work in a team to develop a summary of this research, and to present it to peers.

There are four key topics in this course. First is the introduction of the concept of climate and climate change [11]. Second, students are confronted with the impact of society on the environment and of the changing impact of environment on society [11]. Third, students are exposed to three high profile public speakers providing a platform for economist and environmental scientist to discuss the value of water, and a sociologist and engineer contemplating the impact on society of water redistribution [11]. Fourth, the objective is to make students conversant in the debate on SD and enable to develop an appreciation of the complexity of the issue [11].

The second case, concern an EESD course offered at Michigan Technological University, entitled Engineering Analysis and Problem Solving, the course developer stated three learning objectives [10]:

"…students were introduced to the concept of sustainability and its importance in engineering. They learned that engineers need to consider the impact a technology or device will have during design, manufacturing, use and disposal phases of a product. They were introduced to the effect of lifestyle had on the environment by calculating their ecological footprint."

The course developer introduced sustainable development as a holistic concept by incorporating sustainability investigation of four frameworks; that is engineering achievements, ethical decisions, globalization and individual lifestyles [10].

In the engineering achievement framework, students will research one of the greatest engineering achievements of the 20th Century [10]. As an outcome of this research, students will report their study by outlining the history of an engineering achievement as well as the perspectives of this achievement [10]. They also were to report implications of the achievement in terms of social, environmental and economic aspects of SD [10].

In the ethical decision framework, students investigated and evaluated the ethical decisions in engineering by researching a case study [10]. Students are reporting issues of sustainability involved and suggest alternative decisions, which might be more sustainable [10].

For the globalisation framework, students were to introduce a global perspective on engineering solutions in their studies of ethics [10]. Students will investigate the differences between developed and developing countries in terms of sustainable technologies for water treatment [10]. Students will learn that "only technologies appropriated to the culture, skill level and environment of an area would be sustainable" [10].

In the individual lifestyle framework, the course developer incorporated activities of statistics, programming and ethics [10]. By these activities students are to learn to determine the sustainability of their lifestyles, which include calculating personal electricity consumption, carbon footprint and ecological footprint [10].

5. CONCLUSION

In this paper we have presented a conceptual framework for characterising ESD courses based on three dimensions (see figure 1):

1) Stand-alone versus embedded ESD activities.
2) Disciplinary versus interdisciplinary orientation of ESD activities.
3) Singular, dialectic or consensual approach to SD as a concept.

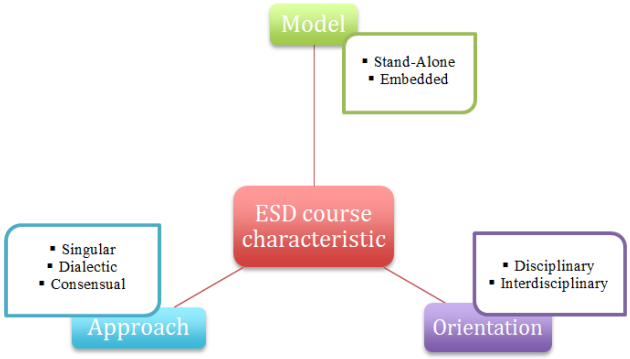

Figure 1. Dimensions to characterise the learning objectives and content of an ESD course.

The presented conceptual framework is brought into use when characterising the AAU course as a stand-alone interdisciplinary course with a consensual approach. In doing that, we have found that the conceptual framework can provide an awareness of the

design features which serves as a platform for seeking inspiration in courses of the same kind.

However, the analysis also shows that even among the same type of courses there is divergence in the learning outcomes and the content.

When comparing the AAU course with two examples of implemented stand-alone interdisciplinary courses with a consensual approach it becomes clear that all though they can be characterised alike there are differences in their perspective. One seems more discursive in approach – focusing on providing the semantics and the argumentations for SD. Another course seems more product-oriented in its approach – focusing on the impact of products/engineering achievements in a life cycle perspective. The AAU course instead seems to take its point of departure in relating SD to the different professions.

Discussion between course developers emphasising the same type of courses across institutional settings is strongly recommended. An association like SEFI could serve as an appropriate framework for this kind of network activities.

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