

## **Sustainability in Engineering Education – is PBL the answer?**

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### **INTRODUCTION**

Engineers design not only our world of today but also our grandchildren's world of tomorrow, since many engineering constructions last several generations. But in order to secure the world for future generations, mankind needs to work towards a situation of global sustainability. Higher education in general and engineering education specifically has an important role to play in instilling in future engineers a sustainability mindset, enabling them to fully integrate sustainability concerns in their professional work as well as in their private lives.

This important role has not gone unnoticed and a number of declarations on education for sustainability<sup>1</sup> have been written and signed by universities throughout the world. One such declaration is the COPERNICUS Charta which was written in

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1993. Aalborg University (AAU), Denmark which is well known for its problem based approach to teaching and learning, is one of the signatories.

Following the many declarations, a number of scientific reports, articles and papers have been written, discussing principles of education for sustainability. A review of literature on education for sustainability revealed a number of educational characteristics some of which are the following: Contextual; inter- and transdisciplinary; participative; democratic; action research; critical reflection; experimental learning; emphasis on learning, not on teaching [4], here quoted from [5].

Interestingly, the problem based learning approach applied at AAU is often described by characteristics coinciding with the above list of characteristics of education for sustainability [6].

In this paper we will describe a recent research project carried out at Aalborg University to investigate to which extent the COPERNICUS Charta guidelines have been implemented within the Faculty of Engineering and Science and which role the problem based learning approach has played in such implementation. Thus, the research question guiding this paper is:

*To which extent is problem based learning a suitable approach to achieve integration of sustainability in engineering education?*

In this introductory section of the paper we have outlined the background for the research question guiding the paper. In section 1 the research project undertaken at the Faculty of Engineering and Science, Aalborg University, is described, including objectives, research questions and sub-questions as well as the methodology applied and the definition of sustainability used in the project. The second section details the results of the research project relevant to the above research question and in the third and final section we discuss these results, leading to a conclusion concerning the research question.

## **1 THE RESEARCH PROJECT**

### **1.1 Introduction**

The research project “Sustainability at Engineering and Science, Aalborg University – Practice and potential” (PBL-SUS) was initiated in February 2012, funded by the Dean of the Faculty of Engineering and Science (FoES) and hosted by the Centre for PBL and Sustainability, under the UNESCO Chair in Problem Based Learning in Engineering Education, AAU. The project has been overseen by a Steering Committee representing faculty departments and carried out by an interdisciplinary working group. In this section is described the objectives and the research questions, followed by the research design, including methodology. In the last sub-section the definition of sustainability applied in the project is described.

### **1.2 Objectives and Research Questions**

The overall objectives for the research project were:

- 1) To map existing practices and interpretations of sustainability in engineering and science education programmes at the Faculty
- 2) To point at strategies for implementing sustainability adjusted to the specific programmes.

Research questions and sub-questions for the project were as follows:

- 1) What has been achieved so far in terms of integration of the concept of sustainability in the educational programmes of the Faculty of Engineering and Science at Aalborg University?
  - a) How is the concept of sustainability integrated, interpreted and delimited in relation to the different educational programmes and contexts?
  - b) What are the existing strategies for integrating sustainability in the educational programmes at both strategic and staff level?
  - c) Which role does problem based learning play in designing and carrying out engineering and science activities that integrate key aspects of sustainability?
  
- 2) How can a better integration of sustainability in the educational programmes be ensured?
  - d) How can the potential for further integration of sustainability in projects and courses in engineering and science education be enhanced?

Taking the point of departure in the above objectives and research questions the research project design was prepared, including methodology.

### **1.3 Research Design and Methodology**

The project has been carried out in two phases and at two different levels:

- 1) Phase 1: Programme and management level
- 2) Phase 2: Course and staff level

In Phase 1 the first research question and the three related sub-questions were guiding the research. Three methods of data collection were applied: 1) A document analysis of all existing curricula at FoES; in total 111 curricula were analysed. 2) Interviews with 16 out of 18 possible educational managers. The Dean and the Deputy Dean for education, the three school leaders and 11 out of 13 chairpersons of Study Boards were interviewed. 3) A seminar for educational managers and study board members, students as well as staff members. The seminar featured round table discussions and a panel debate about possibilities and strategies for integration of sustainability into the FoES curricula.

Phase 2 addressed the second research question and the related sub-question. Data collection in this phase was partly via a questionnaire sent out to a representative sample of teaching staff at FoES, asking staff members to detail good examples of integration of sustainability into their courses and/or project supervision, partly via interviews with staff members who via the questionnaire had agreed to deliver in-depth information about their good example.

This paper will mainly deal with Phase 1 of the project while also results from Phase 2 will be included in the presentation at the SEFI Conference in September 2013.

### **1.4 Representation of Sustainability**

In the PBL-SUS project it was important to have a shared understanding of the concept of sustainability amongst the researchers, in order to be able to communicate this shared understanding to the respondents in the project.

Sustainability has been most notably defined in the Brundtland report as ‘*development, which meets the needs of the present without compromising the ability of future generations to meet their own needs*’ [7]. This definition was felt to be too loose to be useful for this study, therefore a more precise understanding was sought. Based on a combination of common core elements of definitions of sustainability as outlined by Vos [8], combined with the illustration of sustainability as three overlapping spheres [9] and with selected aspects from the Global Reporting Initiative reporting guidelines included [10], the representation of sustainability shown in figure 1 was found useful and thus adapted for the PBL-SUS project.

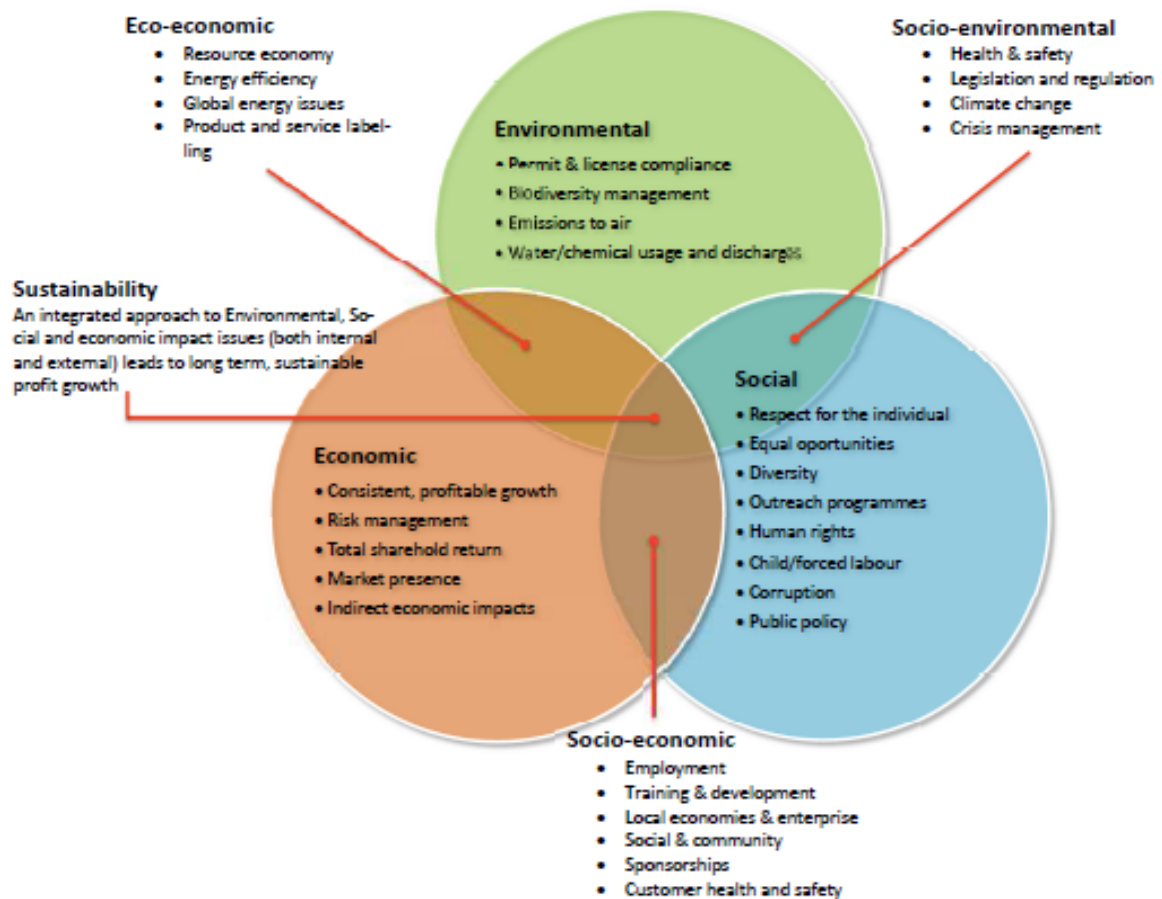


Fig. 1. Representation of sustainability adapted for the PBL-SUS project [9] [10]

This representation was used partly to create the necessary common understanding among researchers, partly to communicate to interviewees the broad understanding of the concept of sustainability applied in the project.

### 1.5 Summing up

After having described the project “Sustainability at Engineering and Science, Aalborg University – Practice and potential”, in some detail, including the objectives and research questions, as well as the research design and methodology, a representation of sustainability, used to create a common understanding of this complex concept, was presented. In the next section the research results will be outlined, with emphasis on the results of relevance to the research question guiding this paper.

## **2 THE RESEARCH RESULTS**

### **2.1 Introduction**

Research results from Phase 1 of the PBL-SUS project are presented in this section. The presentation is structured according to the method of data collection, i.e. in sub-section 2.2 is presented results from the document analysis and in sub-section 2.3 is presented results from the interviews with educational managers. The seminar did not generate any results of significance for the research question guiding this paper, thus no results from the seminar are included here.

### **2.2 Results from Document Analysis**

The document analysis revealed that 59% of the 111 curricula analysed contained no aspects of sustainability. This overall result does not, however, reveal the great variations between the three schools, where in the School of Architecture, Design and Planning 64% of the 14 curricula analysed contained aspects within all three spheres of sustainability, while, for example, in the School of Engineering and Science, the largest school for more classical engineering education with 68 programmes, only 13% of curricula contained aspects from all three spheres and 59% contained no aspects of sustainability. In terms of no aspects of sustainability the School of Information and Communication with 29 programmes had a full 83% of curricula without any sustainability.

### **2.3 Results from Interviews**

The interviews revealed a situation that differed slightly from the results found in the document analysis. A number of interviewees mentioned during the interview examples of courses and projects containing aspects of sustainability, examples that were not mentioned in the written curricula and therefore not revealed through the document analysis. To a question about the role of problem based learning and project work in integrating sustainability into engineering education, 15 out of the 16 interviewees agreed that PBL and project work is the best way to integrate sustainability. One of the respondents said:

*“With PBL you are no longer just dealing with sustainability in theory, but also in practice – you learn how to use sustainability when you design houses – within architecture, plan cities within urban planning etc.” [11]*

Another result that is important to the research question guiding this paper is that all respondents found that sustainability is relevant to engineering education, although not all aspects of sustainability is necessarily relevant to all engineering programmes. Even so, almost all respondents answered ‘No’ to a question about whether there were plans for integration of sustainability into curricula in the near future.

### **2.4 Summing up**

Based on the document analysis it can be concluded that in general the results for FoES are not very impressive as far as integration of sustainability into curricula is concerned, although the interviews documented that there are ‘invisible’ aspects of sustainability in both courses and projects across the Faculty. And it should not be forgotten that there are good examples of educational programmes which are performing very well in terms of integration of a holistic understanding of sustainability in both courses and projects. From the interviews it was obvious, that even if respondents agreed about the problem based projects as being the way to

integrate sustainability this does not happen automatically and respondents felt that there is still work to be done in this regard.

In the third and final section the results will be discussed and a conclusion in the form of an answer to the research question guiding this paper will be proposed.

### **3 DISCUSSION AND CONCLUSION**

#### **3.1 Introduction**

In this final section the results reported in section 2 will be discussed in the light of the research question guiding this paper and an answer to the question in the title as well as to the research question will be proposed in the conclusion.

#### **3.2 Discussion**

As mentioned in the Introduction to this paper Aalborg University is well known within the field of research on engineering education for its innovative problem based learning approach to teaching and learning and in 2007 the university was granted the UNESCO Chair in Problem Based Learning in Engineering Education in recognition of this situation. The so-called Aalborg PBL model is characterized by key words very similar to the key words that are characteristic for education for sustainability.

Furthermore, the Faculty of Engineering and Science has a vision for the faculty as becoming "...a driving force in the creation of sustainable development, locally, nationally and internationally" [12].

Seen in this light it is disappointing to find that in more than half of the educational programmes at the Faculty the engineering students do not get any exposure to sustainability whatsoever. Furthermore, it is disappointing that a good part of the sustainability that students meet, whether in courses or in projects, is 'invisible'. i.e. it is not integrated as part of the programme profile and therefore graduates with this particular profile cannot document that they have knowledge and awareness about sustainability.

Looking for explanations for this situation at least three issues appear: 1) Lack of awareness about sustainability; 2) Curriculum overload in engineering curricula; 3) Resistance to change. Concerning lack of awareness the interviews during Phase 1 of the PBL-SUS project revealed that a number of respondents were uncertain about the meaning of the word 'sustainability' and when shown the illustration in figure 1 which was used as representation of sustainability, some of them identified elements of teaching containing sustainability aspects by being prompted by words in the illustration. Thus, sustainability may be implicit and thus 'invisible' because neither teachers nor students are aware that in fact they are working with aspects of sustainability either in courses or in projects.

Furthermore, a common comment about the lack of sustainability in curricula was that this was not due to animosity towards sustainability but simply because nobody in the Study Board had ever thought of it as being relevant for their study programmes and thus the concept of sustainability had never been discussed.

The curriculum overload problem is generally known throughout engineering education – new technology, tools and methods are continuously being invented and

included in curricula while old technology and methods are not being discarded and deleted from the same curricula at the same rate. This problem was brought up by a number of respondents with the question: "What has to go if sustainability is brought in?" In the Aalborg PBL model the curriculum overload problem has already to a large extent been tackled by introducing 50% project work in all curricula – but there seems to be scope for improvement in this area.

Resistance to change is a common human attitude and in all fairness it has to be said that study programmes at FoES have undergone a number of significant changes over the last 4 years, changes that have necessitated rewriting of curricula a couple of times. Thus, members of Study Boards do not feel very tempted to have to rewrite curricula yet another time in order to integrate sustainability into the curricula.

Furthermore, the concept of sustainability is a complex, interdisciplinary concept and therefore difficult to work with and often not seen as 'real engineering', especially within the more classical fields of engineering where a certain degree of technical narrow-mindedness may still be found.

To the above three explanations may be added that the Faculty vision for sustainability has not been shared widely across the Faculty and does therefore not at present represent a shared value amongst staff members.

### **3.3 Conclusion**

Based on the findings from the PBL-SUS project it can be concluded that the answer to the question in the title of this paper: "Is PBL the answer to the integration of sustainability into engineering education?" is a "No". This 'No' is a conditional answer, however, since there is no doubt that the approach to teaching and learning represented by the Aalborg PBL model is very suited to deal with sustainability, characterised as it is by the same key words that are characteristic of education for sustainability and mentioned in the introduction. Problem based learning does, however, deal with the form of teaching and learning, not with the contents of this teaching and learning. Therefore, the form is not in and by itself enough to secure integration of sustainability – sustainability needs to be brought into the projects through the type of problems used as the point of departure for the learning process.

The answer to the research question that has guided this paper, repeated here for convenience:

*To which extent is problem based learning a suitable approach to achieve integration of sustainability in engineering education?*

is therefore that as far as the form of education is concerned problem based learning is ideally suited to achieve integration of sustainability but the appearance of sustainability in the studies does not come automatically, but needs to be secured through the selection of problems that form the point of departure for the learning processes of students when working with their projects. Furthermore, sustainability needs to be visible, which is best achieved by integrating into the programme qualification profiles one or more learning outcomes, specifying what competences the engineering graduates need to acquire in relation to sustainability.

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<sup>i</sup> In this paper we will consistently use the formulation 'education for sustainability' rather than the more common terminology 'education for sustainable development (ESD)', thus leaving aside the important discussion raised by Selby [1] about whether we should educate for sustainable development or sustainable contraction.

Furthermore, by using the word 'for' rather than 'about' or 'as', we do not mean to underrate another important discussion about the level of engagement raised by Sterling [2] and followed up by Holgaard et.al. [3] but we do not intend to take up this discussion in this paper.