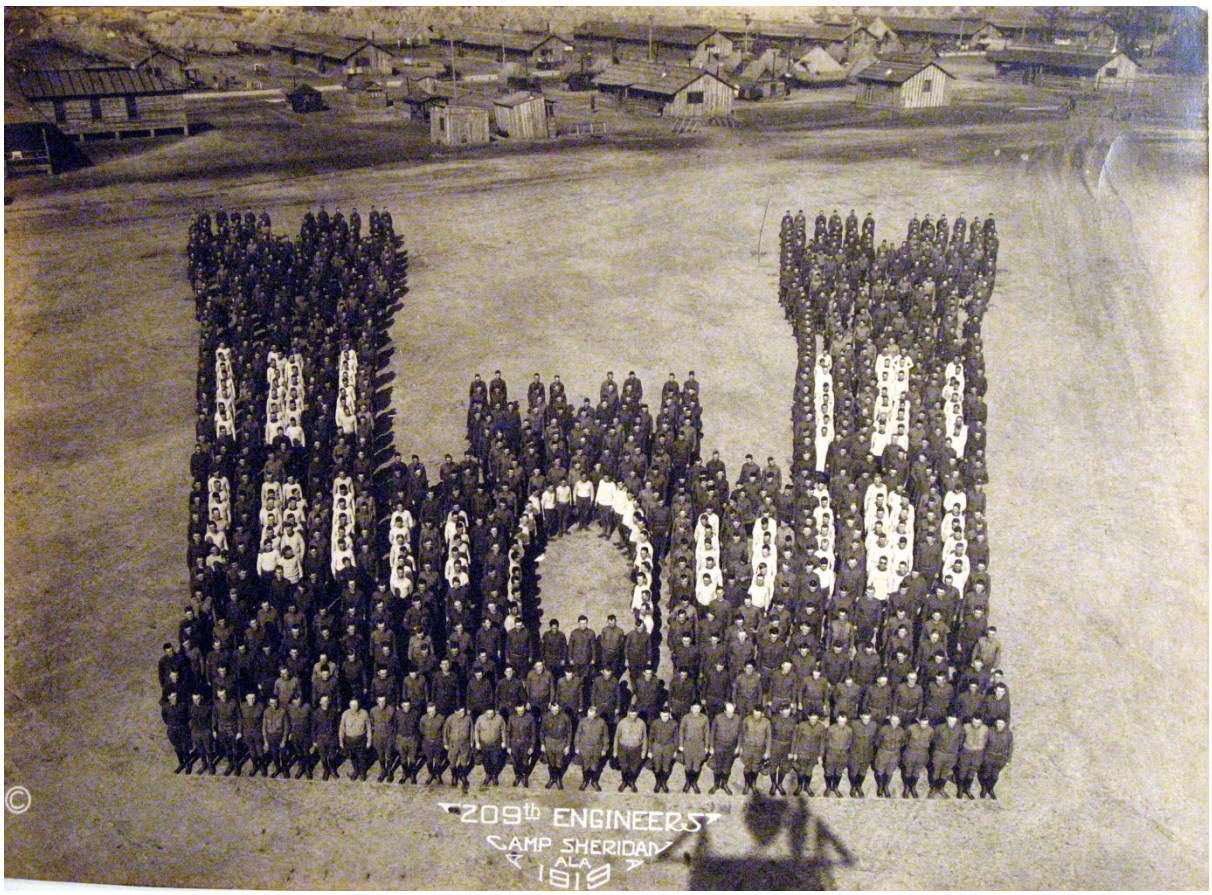
Engineering Education in Context:

Integrating cultural and social aspects of sustainability



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Abstract

As people who put ideas into action, engineers play an important role in the world and in our society. They maintain our present and design our future and are central to the process of moving towards what has come to be called sustainability. A crucial aspect in this regard is education, as Engineering Education for Sustainable Development (EESD) prepares today's students as the practitioners of tomorrow. Along with the growing complexity of what sustainability entails, so does the need to incorporate more of its aspects within the education of engineering students.

This paper takes a look at how different interpretations of sustainability influence the general trends within EESD and proposes an expansion towards incorporating more cultural aspects in EESD. This stems from the basic contention that Universities should teach engineering students the importance of social responsibility of their unique profession, a knowledge that expands from a traditional academic training.

This paper uses the concept of 'hybrid imagination' as a way of characterizing what a 'culturally aware' engineer can represent, and discusses a range of examples of how some Universities have tried to bring cultural and social aspects of sustainability into their curriculum. In doing so, it identifies the barriers which have kept such initiatives far from mainstream acceptance, but also growing interest in them.

It presents one such initiative that has been taken at Aalborg University in Denmark as part of the outreach phase of a research program on engineering education, Program of Research on Opportunities and Challenges in Engineering Education in Denmark (PROCEED)

Title page

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Preface

This thesis, written as part of the 4th semester at Aalborg University in Denmark, is the result of my studies within the Joint Erasmus Mundus in Environmental Science master program and participation in the Program of Research on Opportunities and Challenges in Engineering Education in Denmark as a 3rd semester intern.

Within JEMES, but also going back to my undergraduate study in Ecology at the University of Bucharest in Romania, I have been interested in people's relationship to the environment. Looking life and the environment from the molecular to the biosphere level, Ecology was, to me, a way of explaining how Nature works and how everything is connected. Environmental Management and Sustainability Science at AAU taught me more about how companies and industry are taking steps to becoming more sustainable, and what that means on a policy and institutional level. A semester in Environmental Engineering at the Technical University Hamburg-Harburg meant focusing on the scientific, technical aspect of environmental issues: it was not only about understanding the water cycle, for example, but modeling it into specialized programs and looking at its complex chemistry.

This paper is an attempt to reflect upon these experiences.

Acknowledgements

I would like to thank all the teachers and fellow students that have inspired me in my studies.

The supervision process has meant not only academic guidance, but meaningful insights and friendship, and so I would like to express my sincere gratitude to Prof. Andrew Jamison for his time, patience and stories.

Contents

Chapter I: Introduction

I.1. Defining sustainability

Sustainable development is a term that has gained mainstream circulation in society as a way to address the many ways in which our industrial development over the last century has brought about an unprecedented level of economic and population growth, but also environmental degradation on a global scale. This fundamental relationship between environment, economy and society, the so-called 'triple bottom line', is common to most definitions of sustainability, but from there on interpretations vary as to what exactly it constitutes:

"*At the very least, the definition varies by scale and context of application; at the most, it varies by ideological constraints in its application. The fuzziness of the concept can be frustrating, especially for engineers accustomed to working with great precision*" (Vos 2007, 1)

Along with the new concept of sustainability, so has the engineering profession gained new meanings. Rosalind Williams, in her book "Retooling. A historian confronts technological change" (quoted from a collection of articles titled "Engineering in Context", which also inspired the title of this thesis), observes that:

"*What engineers are being asked to learn keeps expanding along with the scope and complexity of the hybrid world. Engineering has evoloved towards an open-ended Profession of Everything in a world where technology shades into society, into art, and into management, without any strong institution to define an overarching mission. All the forces that are pulling engineering in different directions – toward science, toward the market, toward design, toward systems, toward socialization – adds logs to the curricular jam*"(Williams, as quoted in Christensen et al, 2009, p. 15)

This gives an indication of the many ways in which sustainable development (SD) is interpreted, not only within society at large, but also within the University environment. It has an influence on what is interpreted to be the appropriate 'scale and context of application', as mentioned earlier, of knowledge about SD within engineering education (EE).

Charters such as COPERNICUS, which Aalborg University, among other 328 universities, has signed, indicate "*developing a multidisciplinary and ethically-oriented form of education in order to devise solutions for the problems linked to sustainable development*" (COPERNICUS 1994, 1)

However, studies (Segalas, Ferrer-Balas and Mulder 2012) (Carew and Mitchell 2008) show that there are variations in engineering academics conception of sustainability, as well as in their pedagogical approach towards it. This poses a

challenge, as a 2010 Report on International Progress in Engineering Education for Sustainable Development, suggests that there is

"*an 'ad hoc' and highly variable approach to such curriculum renewal and it is concluded that there has not been a large-scale transition to producing engineering graduates with the knowledge and skills to meet the changing needs of the profession*"(Byrne et al, 2010, p. 5)

This is not to say that is it not happening, but according to another report, educational outcomes show that:

"Students initially perceived sustainability as mainly related to technology, which they consider should be able to resolve the environmental problems of the planet. They saw little relevance in the social and attitudinal aspects of sustainability [...] Courses that apply a more community-oriented and constructive, active learning pedagogical approach, increase students' knowledge of SD" (Segalas, Ferrer-Balas and Mulder 2012, 1)

It is this kind of approach to education that will be explored in this paper, and more specifically, with an understanding that "*if we are able to make use of our scientific and technological developments in socially appropriate and ecologically sustainable ways, we must wander outside the confines of any one discipline and any one mode of interpretation in the wider worlds of culture and history*" (Jamison 2001, 36)

I.2. The role of the engineer in sustainability

This is not the classic perception of the engineering profession: socially-involved, culturally-aware and change-driven. That is reserved for politicians, artists and activists. Engineers are supposed to be the ones who build and make things work, fix what is broken and create new solutions in order to resolve problems. But it is their place in society that grants engineers a unique leverage point from which to make real change in the world: they have the opportunity to influence the way things actually become a reality. Engineering is not pure science, it is a profession that serves the needs of humanity, which also gives it the ability, if fostered through a boundary-breaking education, to be able to inspire change in what those needs represent and how they are satisfied.

This idea is not new, and history has much to teach us, as a 1921 illustrative article titled *'Engineering as a Profession and the Value of an Engineering Education'* says:

"[...] *Whether or not the wasteful methods of the past have been always justifiable, there can be no question that the time has come when everything possible must be done to conserve what remains of our originally tremendous natural resources. It is only necessary*

to mention timber, coal and petroleum to emphasize this point. The trained engineer is better qualified than anyone to take the lead in this important work.

What has been said previously regarding the great future for the profession of engineering shows also the value of a proper engineering education. Such an education is not only of value to those expecting to engage in engineering occupations but also to those intending to take part in general productive or operating activities. The underlying idea in the best engineering schools is to teach the habit of concentration and to encourage clear and logical thinking, the actual knowledge gained during the years of study being considered a valuable incidental but not the main object of the work. It is hardly believable that this mental training will not prove to be a fine preparation for many of the difficult tasks that are daily to be met with in the industrial world of today, whether these tasks are of an engineering nature or more directly concerned with problems of direction or of management" (Crane 1921)

This observation from the beginning of the 20th century shows that, even before concerns for environmental protection and afterwards, SD, became widely acknowledged by society, this article in an automotive engineering journal discussed how the "*great pressure of haste has caused the doing of many things in inefficient and uneconomical ways*". The 'industrial world of today' it mentions has since then grown significantly, leading to even greater importance of the profession of engineering and the value of an engineering education, as he calls it.

Some years later, A. Kucher of Ford Motors Co., in a talk titled '*Engineering 100 years from now*' given in 1956, notes:

"*For one thing, the future demands of each of us an increasing respect and regard and recognition of the abilities of others...and thereby the full utilization of convergent knowledge through collaboration and cooperation.*

Each of us can possess but a minute fraction of accumulated knowledge. So, we are increasingly dependent upon intimate association with others who possess related knowledge and ability. We are making progress, but much remains to be done to remove artificial barriers mainly generated by intolerance toward new concepts and a lingering resistance to change.

Many people resist change and innovation, not so much because they fear a new approach, but because to accept the new they must first give up the old" (Kucher 1956)

While reflecting on change, it also suggests the importance of "hubris" (Hard and Jamison 2005), a term inspired from ancient Greek mythology, which can be described as the 'if only' syndrome:

"*if only we could develop an even better instrument of production or destruction, if only we could tame another force of nature to provide us with unlimited energy, then our wealth and our capacities- the values by which we measure progress- would be so much*

greater. More than two millennia after the sun melted the wings of Icarus for coming too close, we are still under the spell of hubris, trying to fly higher and higher" (Hard and Jamison 2005, 5)

It suggests that, in focusing mainly on the technical fix as the solution to society's problems, we have somehow left our culture and our human face on the sidelines, in the contention that it is through an even greater push of science and technology that everything will be set right for humanity, and that well-being and balance will follow. It is not to say that science and progress have not brought about a great improvement in the quality of our lives, but as Martin Luther King put it, "*modern man suffers from a kind of poverty of the spirit which stands in glaring contrast to his scientific and technological abundance. We've learned to fly the air like birds, we've learned to swim the seas like fish, and yet we haven't learned to walk the earth like brothers and sisters*" (Hard and Jamison 2005, 1)

I.3. Engineering Education for Sustainable Development

"*What if education systems prepared learners to enter the workforce as well as handle a crisis, be resilient, become responsible citizens, adapt to change, recognize and solve local problems with global roots, meet other cultures with respect, and create a peaceful and sustainable society?*" (UNESCO 2011)

This is how the declaration of the 2005-2014 United Nation's 'Decade of Education for Sustainable Development', led by the United Nations Educational, Scientific and Cultural Organization (UNESCO) frames the approach to address global challenges in the 21st century. 'Education for sustainable development' (ESD) and 'Engineering Education for Sustainable development' (EESD) have become recognized terms (Byrne et al, 2010, p. 2). An example is the Chalmers University of Technology in Sweden where this is a central part of the policy of the university (Svanström 2012) But implementation has not been easy, as Jenstrom, quoted by Wright, declared in 2000 about the situation at Göteborg University in Sweden:

"*Some university staff members still say that it cannot be a main goal for the University to work actively with Sustainable Development, the Society has to go first. At all universities you have to accept that some staff members will hold a different view. At Göteborg University we try to bypass these staff members and instead activate those that see sustainability as a natural step. We often talk about a bottom-up-perspective where we activate the people at the departments and encourage them to do environmental work that will influence other staff members. This process takes time, but we have to accept that changes in lifestyle are not made overnight*" (Wright 2002, 6)

As an intern within the Program of Research on Opportunities and Challenges in Engineering Education in Denmark (PROCEED) I have done a survey and a series of interviews exploring the motivations and values that have led some of the first semester master students to enroll in the Environmental Management and Sustainability Science program at AAU. The most common reason they were there is because they recognized "*the need to better integrate socio-economical aspects of sustainability*", and one student even mentioned wanting to "*fight greedy corporations that want to destroy the planet for money*". From simply "*seeking better job prospects*" up to "*doing something meaningful in life*", their answers indicated their open-mindedness, creativity and passion.

It is the responsibility of the University to respond with the same energy and acknowledge that "*only a hybrid educational environment will…prepare students for handling…life in a hybrid world*" (Williams, 2002, quoted in Christensenet al, 2009, p. 16)

I.4. Problem formulation

The point of departure of this paper is my experience within PROCEED as a 3rd semester intern at AAU.

As a logical next step, this present study is aimed at gaining a better understanding of Engineering Education for Sustainable Development (EESD), the variability of how EESD is interpreted and put into practice at Universities and why there has not been a fundamental shift towards a 'hybrid' educational strategy.

The main research question, or problem, can be formulated as follows:

"What are the opportunities and barriers for integrating cultural and social aspects of sustainability within Engineering Education for Sustainable Development?"

Cultural and social aspects of sustainability, as a way of gaining broader understanding of the challenges facing the engineering profession and its role in SD, face a number of constraints, but there are a number of initiatives that try to integrate these aspects into educational reform.

More specifically, the objectives of this thesis are to:

- describe different responses to the challenges facing engineering and engineering education from the perspective of PROCEED

- discuss theories and concepts in relation to EESD

- present particular examples of educational reform initiatives, including the one in Aalborg I have participated in

- reflect on the opportunities and barriers

Chapter II: Methodology

To answer the research question, this paper uses empirical research that has been carried out within PROCEED. It is supported by the opportunity to participate in an academic initiative regarding curriculum change at AAU which goes under the acronym of MUSLI - "Meeting place for University Sustainability Learning Initiatives", representing a part of the outreach phase of PROCEED. It involves teaching staff at AAU linked to EESD discussing the opportunities and barriers of designing educational reform. Valuable theoretical and conceptual inputs were also obtained from attending the 3rd Nordic Network in Engineering Education Research seminar held in Aalborg from 23rd-25th May 2012 (http://www.ucpbl.net/NNEER). There, a number of experts and academics interested in broadening their knowledge discussed change within engineering education and EESD in particular. This was an opportunity to learn more about the ideas concerning this thesis research, and also to receive insights on the topic from multiple viewpoints.

The paper focuses on finding relevant connections between the concepts it presents, identifying examples that showcase possible ways of including contextual knowledge within EESD, and using the particular example of MUSLI to relate to curriculum change. In this way, the research may prove useful outside its particular context.

The study uses mixed methods by combining literature review with a form of action research or participatory observation. Action research has been defined by McKernan as "*research done by practitioners to solve their own problems and to improve practice*" (1991, p. ix). I have made use of observational methods to describe and interpret "*from the inside rather than strict measurement and prediction of variables using a quantitative approach*"(1992, p. 59). Also, "*It is unstructured in the sense that strict controls are not placed on the context, action or the type of data collected, as well as there not being any a-priori research hypotheses to test in the field setting*" (1991, p. 60)

I have explored the territory of EESD through direct participation, driven by interest to find out more about what sustainability means in the different contexts I encountered and to the people I talked to, whether they were teachers or other students. It has been an ongoing personal interest that started as an undergraduate in Ecology and Environmental Protection at the University of Bucharest and continues to this day. It is a form of experimental research and an ongoing attempt to find a 'method in the madness' of such a complex issue, to paraphrase Hamlet.

As empirical research within PROCEED, I have surveyed and interviewed students about what they considered to be important aspects of sustainability in EESD. Participation in the MUSLI meetings has given me a chance to interact with some of the teachers of those students, which provided a unique perspective on the issue in the

particular context of AAU at the Department of Development and Planning at the Faculty of Science and Engineering.

A big part of the knowledge I have gained can thus be called 'informal knowledge', gained through situated and experiential learning within communities of practice, as described by Lave and Wenger (Lave and Wenger 1991). This relates both to my experience with the people involved in PROCEED, MUSLI, and also the Nordic Network in Engineering Education Research seminar.

Further on, the organizational framework of my own master program at AAU, JEMES, which will be explored in more detail later, has made it so that I have been able to re-attend the same classes as I have taken in the first semester in the company of the very students that were my research subjects. Because my internship took place at the University, I took that as an opportunity to essentially experience the same curriculum twice, while the other students experienced it for the first time.

My personal learning experience in itself, from the viewpoint of a student in JEMES, has provided numerous chances for reflection, such as experiencing different educational settings (a water chemistry laboratory in Hamburg or a seminar with an environmental manager from a large Danish company etc.) and the particular aspects of sustainability that they approach, along with their different pedagogical methods. It can be said that this was participatory observation as well.

In this sense, a comparison could be made to the epistemology of Henry David Thoreau which stated that "*we do not learn by inference and deduction and the application of mathematics to philosophy, but by direct intercourse and sympathy*" (Jamison et al., 2011, p. 51). Thoreau's example as an engaged environmentalist has been one of the sources of inspiration throughout the two years within the master's program.

MUSLI, as a group of academic staff reflecting on the engineering curriculum and their professional practice, is linked to action research, as "*the curriculum can be improved through action research and that teachers and other practitioners are best placed to conduct such inquiry*" (McKernan, 1991, p. 1)

My position and research approach within MUSLI was that of participatory observation, described by McKernan as "*the practice of doing research by joining in the life of the social group or institution that is being researched […], bears the highest fidelity with the methodological purpose of action research*"(1991, p. 63) The main challenge of this position is to be able to "*render interpretable the process of events and behaviour as it occurs naturally*" (1991, p.60) This does not come without disadvantages, as it is difficult to quantify the data, as it is based mainly on description rather than measurement and counting.

A mention must be made to the possibility of "*going native*", as a tendency to become emotionally involved with the research to a point where the participatory observant becomes a participant (McKernan, 1991, p. 65), risking developing a 'biased' perspective. For me, personal engagement is an important source of knowledge and I would claim that research can never be truly neutral and 'objective'.

In documenting MUSLI, the main body of data is in the form of an audio recording of the first meeting of the group held on the 18th of April, and field notes from the first and second meeting on the 30th of May 2012. The meeting was taped and notes were taken after asking for consent from all participants, who are quoted using their initials.

Chapter III: Theories and Concepts

III.1. Context in EESD

Context is a key concept in this paper. Like 'sustainability' itself, context is a complex term which is difficult to define: "*contextualizing in itself is dependent on definitions on what is perceived to be the relevant boundaries regarding both the education and the practice of engineering*" (Christensen et al, p. 13), and is concerned both with what engineering "*is*" and what it "*ought to*" be.

By using the theoretical framework developed by PROCEED, we will take a look at how such different contexts are defined by identifying the challenges of engineering and EESD and educational response strategies, which are based on different modes of knowledge production and interpretations of sustainability. Finally, the concept of 'hybrid imagination' is defined as a way of integrating knowledge as reflections on the culture and implications of engineering practice in society.

III.2. Challenges for engineering: the PROCEED research program

Is a strategic alliance between Aalborg University, Aarhus University, Roskilde University and Danish Technical University, funded by the Danish Strategic Research Council, spanning the years 2010-2013. A fully detailed description of the program can be found at Andrew Jamison's website, the coordinator of the program, at http://people.plan.aau.dk/~andy/.

PROCEED has identified three main challenges for engineering, on different levels:

- Environmental challenge: dealing with well-known problems of environmental degradation, resource use, energy and climate change which are increasingly acknowledged by society

- Societal challenge: relates to the permeation of society by technology on all levels and aspects of life, which mandates a sense of social responsibility from engineers

- Technological challenge: focuses on technological aspects of science and engineering itself, as knowledge production and research within designing, simulation and modeling changes: emerging fields such as information technology, biotechnology and nanotechnology are blurring the traditional boundaries of science

(Jamison, Christensen and Botin 2011, 7)

All in all, it can be said that the global issue of sustainable development, with its multifaceted dimensions, is the overarching challenge, as the goal is to instill within EESD an understanding of this concept to a degree which is as inclusive as this complex problem itself.

III.3. Contending response strategies

PROCEED has identified two ideal-typical response strategies for meeting these challenges. These will be presented through the perspective of my own study experience.

JEMES

The European Union-funded Joint Erasmus Mundus in Environmental Science (JEMES) program (homepage at www.jemes.eu) is a good example in the sense that it is based around the concept of two 'streams' of education: management and engineering. As a JEMES student you are expected to spend at least one semester studying within each stream. In other words, a training environmental engineer must spend one semester learning about environmental management, and the other way around. The aim is to provide students with competences stemming from these two different perspectives, each with their own characteristics.

I have personally spent three semesters at AAU within the Environmental Management and Sustainability Science (EMSS) program from the Department of Development and Planning from the Faculty of Science and Engineering, and one within the Environmental Engineering program at Technical University of Hamburg-Harburg (TUHH), which has given me an opportunity to experience these two different response strategies directly.

AAU: the 'market' response strategy

With its focus on environmental management, policy making, innovation and corporate social responsibility, it gives students the ability to "*define and solve environmentally related problems in the business world as well as in public organizations and the broader society*" (Aalborg University 2012). As Jamison puts it, this strategy attempts to "*convert global challenges into commercial opportunities in accordance with the new precepts of academic capitalism*" (Jamison,2012, p. 4, n.d) and is called the 'market-driven strategy', an "*incorporation of environmental concern into the world of business*"(Jamison, 2012, p. 21, n.d). There is a strong connection to the business world, as commercial networks of innovation and partnerships link the University to industry, an example being the historical link to wind energy companies such as Vestas and Siemens, students often performing internships within such companies.

In this program, sustainability is approached from the following perspectives:

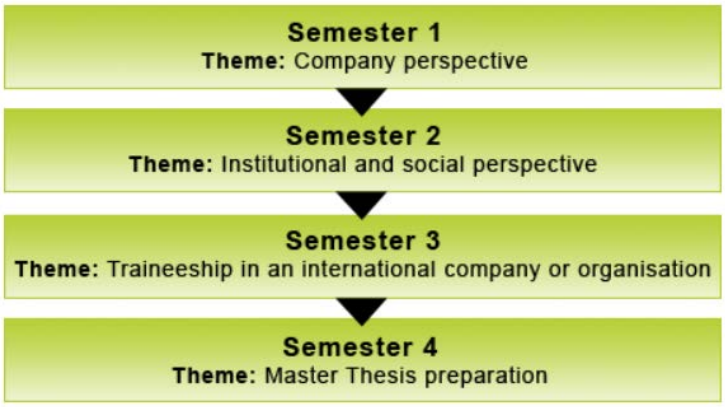

Figure 1: Structure of the Environmental Management and Sustainability Science master program (Aalborg University 2012)

One example of students working together with Danish industry is Access2innovation. This is an "*open innovative partnership between NGOs, universities and commercial companies that develops sustainable and commercially viable solutions based on actual needs and demands in developing countries*" (Access2innovation 2012). So far, three independent companies formed as a result of the organization's activity, having developed such solutions and commercialized them. The fundamental idea is that NGOs in Denmark and in developing countries, mostly Tanzania, Uganda and Vietnam, identify concrete problems which fit the focus areas of water and sanitation, food and renewable energies. Access2innovation functions as a network agent for researchers from Danish universities and possible co-operators from the target country which develop innovative methods and technologies, supported by the Confederation of Danish Industry with hands-on business development and international networking. Thus, "*concrete end-user needs are tackled by the knowledge and research of the academic world alongside the world of commerce*" (Access2innovation 2012).

Themed seminars offer a common possibility for students to interact with guest lecturers directly involved in the topics discussed within the curriculum. Examples are government officials dealing with environmental issues at a local, regional or national level, environmental managers working with Danish companies or specialists from other Universities. Such guest have been head employees from the Danish companies Novozymes, world leader in enzymes and biotechnology, or Grundfos, a company producing energy-efficient water pumps. Other instances have featured government officials responsible with environmental strategies of the city of Aalborg or Aarhus, with the aim of "*understanding of the relationships between companies and stakeholders, the environmental challenges facing businesses operating on international markets*" (Aalborg University 2012). One course that is of a quite different nature is called Theories of

Science, which discusses the different philosophies of science and how they influence scientific research and thought. The second semester focuses on politics, organizations and institutions and their relationship to environmental management in different countries and cultures.

A particularity of AAU is the Problem-based learning (PBL) model which is centered on semester projects conducted in groups of students with mixed competences and cultural backgrounds, which is acknowledged to be an effective pedagogical approach, in particular in relation to sustainability.

TUHH

In Hamburg, a more traditional scientific approach is present. With its main activity spanning the field of water studies and waste treatment, the Environmental Engineering master program is an example of how sustainability is 'translated' into specialized fields of study taking life within a hardcore engineering approach. PROCEED identifies this as the 'academic response strategy' (Jamison, 2012, n.d). A Royal Academy of Engineering (2007) report, quoted by Christensen et al, describes it as such: "*Universities must continue to teach core engineering and not dilute course content with peripheral subject matters*" (Christense et al, 2009, p. 13)

It delves into technical aspects in search of producing quantifiable, usable, scientific results and professionally trained students as experts in their field. Examples of courses I have taken are Applied Surface Hydrology, Thermal waste treatment, Air pollution abatement etc. While sustainability was acknowledged to be the main 'umbrella' for education, a holistic approach was difficult because of the need for each course to provide students with its own specialized content, as TUHH aims to provide engineers with strong technical capabilities. Such training is invaluable for a student seeking specific job employment within the engineering field.

There are also courses at both universities which 'meet in the middle' in terms of these two ideal-typical educational response strategies, as neither are only about sustainability from a company perspective or hardcore environmental engineering, although these are the dominant approaches.

Some clarifying examples: learning about Life Cycle Assessment methods at EMSS can be applied in other contexts, not only in a company. Also, the Theories of Science class explores philosophies of science and how epistemological considerations affect practice and research. On one occasion, a theater group from the city of Aasen (http://www.aasen.dk/index_uk.html) conducted a seminar about sustainability. The participants, both students and teachers, myself included, reflected on different aspects

of the topic by improvising short acts depicting human rights violation, deforestation, cultural barriers etc.

At TUHH, the Water and Wastewater in a Global Context course touches upon social and humanitarian aspects of water resource distribution and use, with implications on standards of life and health. The Methods of Technology Assessment course critically reflects on the implications of engineering with its impacts on society, and is a space for open debate.

Semester 1 (Winter Semester)

Modul	*Prüfung*	*Nachweis*	*Prüfungsart*	*ECTS*
Environmental Protection in different Climates				[4]
Environmental Protection and Sustainability		1	TN	2
Rural Development in different Climates		1	TN	2
Environmental Protection and Environmental Analysis	1		MP	4
Integrated Pollution Control				
Environmental Analysis				
Wastewater Systems - Collection, Treatment and Reuse	1		MP	4
Wastewater Systems - Collection, Treatment and Reuse				
Fundamentals of Fluid Dynamics	1		MP	4
Fundamentals of Fluid Dynamics				
Health, Safety and Environmental Management	1		MP	4
Health, Safety and Environmental Management				
Waste Resources Management	1		MP	4
Waste Resources Management				

Figure 2: First semester course selection at Environmental Engineering at TUHH (Technical University of Hamburg-Harburg 2011)

Perspectives from other Universities

The UK Royal Academy of Engineering recently coordinated the "*biggest collection of industry views on graduate engineers ever collected in the UK*" (Royal Academy of Engineering 2006, 7)This stemmed from the nation's funding framework, wanting to "*ensure that the UK can strengthen its position as a centre for world-class high value added engineering to respond to the changing global market*", referring to the fact that "*the balance of economic power is changing - the economies in the BRIC nations (Brazil, Russia, India, China) are set to overtake the G6 (US, UK, Japan, Germany, Italy, France) by 2040*" (2006, 5) Thus, sustainability is framed primarily from an economic

perspective, with engineering education as having to contribute to the shifting face of industry and commerce towards more sustainable practices.

A short conclusion can be drawn after looking at these two opposing strategies. Among different universities, as well as within many of the same ones, there is an ongoing tension or competition between the practical, market-oriented approaches and the scientific, academic-oriented approaches "*whichmakes it difficult for students to receive a well-rounded and comprehensive education*" (Jamison, 2012, n.d, p. 4)

III.4. Contending cultures of science and technology

An explanation of the difference between response strategies is based on what Jamison et al call 'contending cultures of science and technology' as described by the theory of 'contending cultural formations' put forth by cultural theorist and literary historian Raymond Williams (Jamison 2010) These are built on 'structures of feeling' and specific ideas and practices, something that Williams calls 'social experiences in solution'. Basically, an emerging culture faces a struggle between the incorporation of its structures of feelings from the dominant formation and a reactive stance from the residual formation.

During the environmental movements of the late 70s, a new 'paradigm' of science and research concerning environmental issues, different from established sciences, was starting to take shape, what Jamison calls 'green knowledge': "*a multifaceted process of cultural transformation, by which environmental ideas and practices had been appropriated by the surrounding culture, first by providing new words, things and activities, and gradually by transforming institutional, laws and routines, and, not least, forms of knowledge-making*" (Jamison 2010, 15)

This is the emerging ecological cultural formation, and describes what is understood by 'cultural and social aspects of sustainability' in this paper.

The environmental movements of the 70s served to bring the topic to an unprecedented level of public debate and awareness, sparked mainly by Rachel Carson's "*Silent Spring*" and other works such as "*The Limits to Growth"* and Barry Commoner's "*The Closing Circle"*. This was furthered in the late 80s along with the "*articulation of a new discursive framework*", that of sustainable development, but which did not serve as a completely unifying concept, as there grew a divergent view on what that means in terms of practice between what can be called "*green business and critical ecology, one articulating discourses of ecological modernization and natural capitalism, and the other linking sustainable development to other discourses of global justice and sustainable community*" (Jamison 2010, 15)

The emerging culture has faced tensions in two directions: "*against the dominant commercial culture which attempts to incorporate what Raymond Williams (1977) termed its "structure of feeling" into established business, on the one hand, and against*

residual cultures of traditional ideologies and scientific disciplines, which attempt to capture sustainable development in outmoded discursive frameworks, organizational forms and personal identities" (Jamison 2010, 15), and in relationship to education engineering for sustainable development, consistent with the two response strategies described previously.

Contending Cultures of Science and Engineering			
	Residual	*Dominant*	*Emergent*
core values	academic professional	commercial entrepreneurial	cooperative flexible
discursive tradition	rational analytical	utilitarian pragamatic	systemic holistic
type of knowledge	abstract mathematical	empirical experimental	synthetic contextual
organizational form	discipline-based research groups	market-driven networks	change-oriented aliances
form of education	scientific philosophical	managerial technical	integrative cross-cultural
type of learning	"by the book"	"by doing"	"hybrid imagining"

Figure 3: Contending Cultures of Science and Engineering
(Jamison, Christensen and Botin 2011, 25)

III.5. Residual cultural formation: the academic response strategy

The basic mechanism is 'turning the new into the old', and it can be compared to the 'mode 1' type of knowledge production put forth by Gibbons et al in 1994, and influenced by 'the forces of habitus', as described by Pierre Bourdieu, both terms borrowed by Jamison et al. Bourdieu used this term to explain how, in our case, engineers, face objectivity with a set of acquired 'dispositions' which limit their ability to be completely open towards accepting other valid points of view, or to continually re-assess them, seen as a lack of 'reflexivity' as a conscious act of reflecting on one's habitus:

"A discipline is defined by possessions of collective capital of specialized methods and concepts, mastery of which is the tacit or implicit price of entry to the field. It produces a 'historical transcendental', the disciplinary habitus, a system of schemes of perception and appreciation (where the incorporated discipline acts as a censorship)" (Bourdieu, cited by Jamison 2012, 11)

III.6. Dominant cultural formation: the commercial response strategy

This is defined by transdisciplinarity, as knowledge adapts to 'what is needed' outside of the University, as shown in the Royal Academy of Engineering reports (Royal Academy of Engineering 2006). It means shaping research that serves a particular context, which in Gibbons et al's terminology corresponds to a 'mode 2' type of knowledge production.

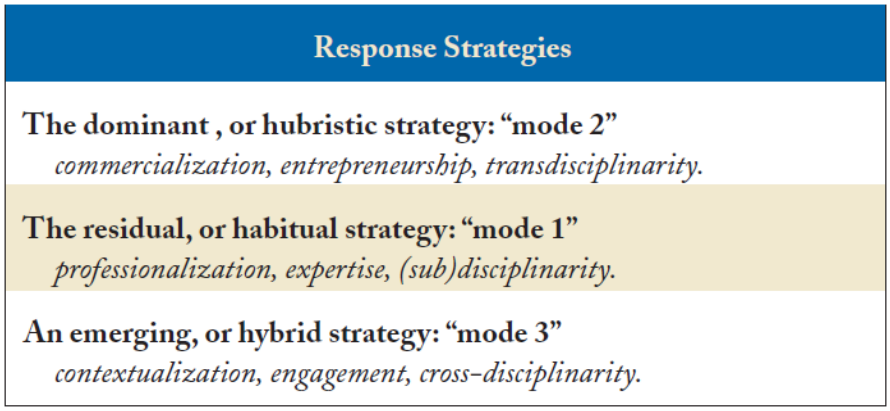

Figure 5: Overview of response strategies, along with the cultural formations that underlie them (Jamison, Christensen and Botin 2011, 7)

Next, we will take a look at what is understood in this paper by 'integrating contextual knowledge as cultural and social aspects of sustainability' into EESD:

III.7. Emerging cultural formation: A Hybrid Imagination strategy

The name of this strategy comes from the idea of 'hybridizing' the academic and the commercial response strategies in an attempt to bring out 'the best of both worlds' along the lines of what Alfred North Whitehead wrote in 1929 in *The Aims of Education*:

"*Imagination is not to be divorced from the facts: it is a way of illuminating the facts [...] It enables men to construct an intellectual vision of a new world, and it preserves the zest of life by suggestion of satisfying purposes. The tragedy of the world is that those who are imaginative have but slight experience, and those who are experienced have feeble imaginations. Fools act on imagination without knowledge; pedants act on knowledge without imagination. The task of a university is to weld together imagination and experience*" (Whitehead, as quoted in Jamison, Christensen and Botin 2011, 1)

The aim is "*neither to reject nor accept new contextual conditions of science and engineering, but rather to creatively interact with them"* in an attitude of *"critical engagement*" (Jamison, Christensen and Botin 2011, 7).

It can be considered as a proposed third response strategy.

It is not fundamentally opposing commercial initiatives, as business is a normal activity in society, but it is the "*over-emphasis on commercialization*" (Jamison, Christensen and Botin 2011, 8) within the University environment which hybrid imagination addresses. Focusing on science, technology and education mainly as able to provide more profitable innovations for the commercial world runs contrary to the image of the University as a space for producing and designing new knowledge and solutions for a common good. As Derek Bok, former president of Harvard, states:

"*Commercialization threatens to change the character of the university in ways that limit its freedom, sap its effectiveness, and lower its standing in society…The problems come so gradually and silently that their link to commercialization may not even be perceived. Like individuals who experiment with drugs, therefore, campus officials may believe that they can proceed without serious risk*" (Bok, as quoted in Jamison, Christensen and Botin 2011, 8)

This trend does not leave much space for discussing other meanings of science and technology which are important to society, and which include considerations of culture, for example. While difficult to define, as they are intrinsically diverse and highly dependent on context, they are present, to varying degrees, in each of us as people.

The hybrid strategy acknowledges the value of a strong professional education and scientific rigor, but moves away from the normal science approach which "*separates knowledge from policies, is mechanic and deterministic, excludes feeling and intuition*" (Ferrer-Balas 2012) and recognizes that sustainability entails "*complexity, interdependencies and contextualisation*", which is characteristic to post-normal science (Ferrer-Balas 2012).

The idea is that an 'ivory-tower' approach to science and research is not fully compatible with the fact that sustainability involves mechanisms which go beyond a reductionist approach, and that engineering education should, as Rosalind Williams suggested, be "*lowering the threshold of entry, mixing itself with the larger world rather than to keep trying to expand its own world*" (Williams, as quoted in Christensen, et al. 2009, 16)

The type of research that defines hybrid imagination is carried out not only within established contexts, but also with "*activists and other concerned members of the public who are trying to change things; It is change-oriented research*", and has similar understandings in research and society as "*action research, advocacy, participatory planning, public education, technology assessment etc.*" (Jamison 2010, 8)

According to Jamison et al, Hybrid imagination works on three levels:

- Macro (discursive) level: integrates science, technology and cultural understanding as 'contextual knowledge'

- Meso (institutional) level: creates sites of cross-fertilization, or collective learning, to provide a 'space' for interdisciplinarity for an emerging 'mode 3' which is not yet clearly defined

- Micro (personal) level: combines identities into 'hybrids' and forms of practical competence

It is not the contention that the hybrid imagination become 'dominant', but rather for it to have an equal standing, a better chance to "*activate those that see sustainability as a natural step*", as Jenstrom declared in the introduction.

Chapter IV: Hybrid response strategy in action

In the following, we will take a look at some initiatives that were sparked by a similar approach to EESD. They showcase different ways in which students can learn about sustainability by doing projects in the community, by looking at EPICS at Purdue University and the Alley Flat Initiative in Texas, and also how the university itself re-evaluates its position in society through the example of the Vasile Alecsandri University in Romania.

Engineering Projects in Community Service

What is recently gaining ground under name of Engineering Projects in Community Service (EPICS), originally from Purdue University in the US, shows an example of how a different approach to EESD can result in 'real-world' experiences. The basic idea is that "*undergraduates earn academic credit for their contributions to long-term, team-based design projects that deliver innovative, technology-based solutions to problems identified by not-for-profit organizations in the community*" (Coyle, Jamieson and Oakes 2005, 2)

The design of these programs must offer students "*a compelling context for engineering design, a multidisciplinary team experience, sufficient time to learn and practice professional skills, personalized mentoring and exciting technical challenges*" (Coyle, Jamieson and Oakes 2006, 3)

Context and time are central to EPICS. Because projects are driven by needs identified in the community, students know that if the project is done well it will be in fact used, adding to their sense of responsibility, accountability, and commitment, Coyle et al argue. EPICS is a continual process: a student can participate in the team for more semesters or even years. Like this, "*artificial barriers are bridged*" and "*teams therefore have the time to deliver well-designed, well-tested projects to their partner*" and to also "*gain a sense of the role of engineering in society, self- and team-awareness, and professional skills*" (Coyle, Jamieson and Oakes 2006, 3)

Beyond addressing a general decline in numbers of students enrolling in engineering programs, EPICS seeks to popularize the notion that "*no longer is engineering just a bunch of equations, now I see it as a means to help mankind*" (Coyle, Jamieson and Oakes 2006, 4) as an EPICS student declared. In 2006 at Purdue, the program had 30 teams and a yearly total enrollment of more than 300 students. Their projects include working with local museums, zoos, associations, and people with disabilities. While community-oriented, some EPICS projects are also sponsored by companies like Shell, Alcoa or Boeing.

Figure 6: EPICS students demonstrating their self-designed learning software for children called Merlin's Magic Castle (Purdue University 2012)

A full description of the program can be found at https://engineering.purdue.edu/EPICS/About (Purdue University 2012)

The Alley Flat Initiative

The "Alley Flat Initiative" in Austin, Texas grew out of a sustainable design course at the University of Texas for master students in architecture and planning. By spending time in East Austin, the Latin American part of the city, and making 'postcards' of what they saw, the students were able to come up with the idea of creating "*sustainable housing solutions that can support growing communities by being affordable and adaptable*" (Alley Flat Initiative 2012) by taking into consideration the cultural heritage of the local community and delivering state-of-the art climate solutions for housing.

The Alley Flat Initiative has led to prototypes being built and has since developed into a Public Interest Design Institute where students from other universities can take place in summer programs connecting design education to community renewal. The alley flats are now to be complemented by an alley regeneration project together with the city government by which community sustainable development projects will be carried out as part of the educational process.

Figure 7: Students working on alley flats in Austin (Alley Flat Initiative 2012)

The home page: http://www.thealleyflatinitiative.org/

Bistrita Valley – "Matter that gives birth to energy: Environment, Engineering, History"

This summer school project in Romania, currently at its second edition, is an initiative from the "Vasile Alecsandri" University of Bacau which focuses on revitalizing the Bistrita Valley area and promoting its sustainable development. It was started by two staff members, mechanical engineer Gabriel Puiu and university assistant Alin Popa. While an official home page is under construction, a blog has been made at http://sivub.blogspot.dk/. It is currently seeking international collaboration, also with AAU, through a former alumni of both the University of Bacau and AAU, currently employed as a mechanical engineer in Aalborg.

The project engages all the departments of the university into creative dialogue, working with local authorities and businesses to reinforce the University's status as a hub for local knowledge and innovation producer for the community.

An important aspect is linking sustainable development with the cultural values of the area, which are threatened to disappear slowly under the influence of globalization. Its point of departure and inspiration is local farmers, craftsmen, artists

and civic societies in an attempt to bring back the cultural identity of the area into the collective memory, serving as a guideline for development.

While modernization is essential for Bistrita Valley, the University engages a wide range of academics, from historians to anthropologists, tourism experts, ecologists and renewable energy teachers for designing modern solutions, but by 'appropriating' them to the local culture, similar to the Alley Flat Initiative. The first edition brought these specialists together to discuss possibilities for inter and trans-disciplinary collaboration.

The second edition, taking place in July 2012, focuses on rural sustainable development within a European context. The local history is investigated to rediscover traditional practices which have proven to be sustainable, such as clay-based houses. Clay is a natural, cheap material that is also energy efficient, cooling the house in the summer and retaining warmth in the winter, and does not leave significant marks on the landscape. This compares traditional to modern energy efficient 'passive houses'.

The main goal of the second edition is ambitious: to start work on a pilot project for a 'historical village' in which traditional architecture and practices are combined with new, cutting-edge sustainable technology to showcase possibilities for future development. As a longer-term vision, international collaboration will transform the science park into incorporating similar examples from all over Europe, to facilitate cultural and technological transfer and ecological tourism.

Chapter V: Systemic educational change in engineering

So far, we have looked at why it is important to consider cultural and social aspects of sustainability in engineering education. The initiatives that were presented showcased some examples of what has been done to bring them into the university curriculum.

Through the MUSLI initiative we will look at how such an initiative is born and its chances for becoming embedded in the core of the educational strategy at AAU. This is what a recent study funded by Massachusetts Institute of Technology and the Royal Academy of Engineering terms 'systemic educational change in engineering' (Graham 2012). It examines a number of similar initiatives at Universities from all over the world in order to identify what was their 'recipe for success'. Its author, Ruth Graham, along with Didac Ferrer-Balas from the Polytechnic University of Catalonia in Spain, Andrew Jamison from AAU and Magdalena Svanström from Chalmers University in Sweden, were all present at the Nordic Network for Engineering Education Seminar in May 2012, Aalborg, where they presented their research findings and experience about the topic. Below is Chalmers University's strategy:

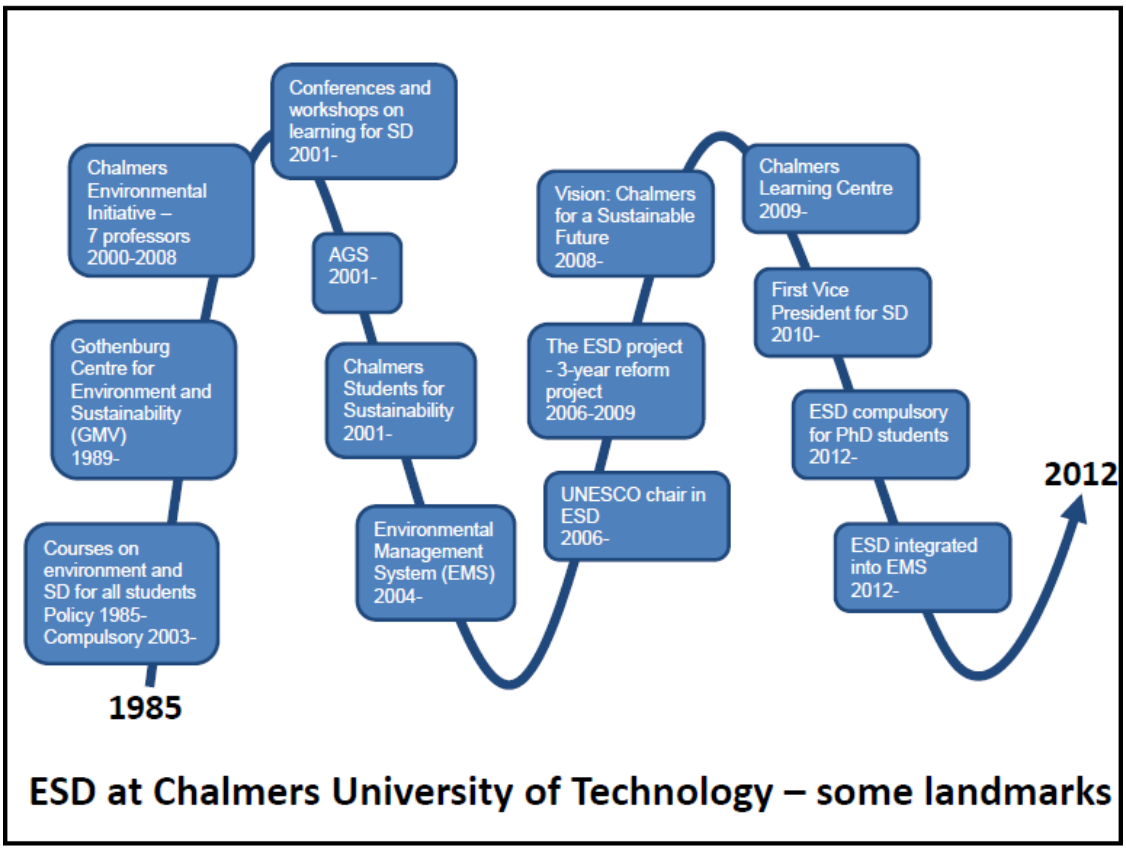

Figure 8: Achieving systemic educational change for incorporating sustainable development in engineering education at Chalmers University (Svanström 2012)

A growing number of educational programs, mostly from the US, show some common features of 'Engineering Leadership Education' (Graham 2010)

According to Graham, most of these programs are not a core element of the engineering studies, and are offered as elective programs operating outside the formal curriculum. Also, they are not designed conceptually, but rather comprise of 'off the shelf' courses put together in a newly themed program. Another important aspect is that they rely heavily on a 'project champion' which is the main responsible the success and continuation of the change initiative.

A distinction was made between "'*explicit' programs, where engineering leadership development is the primary and explicit objective, and 'non -explicit' progr engineering leadership development is embedded within a broader remit*"
(Graham 2010, 3)

One such highly regarded program is EPICS at Purdue University which, along with the Alley Flat Initiative and the Bistrita Valley summer school program, are examples of 'non-explicit' programs, while explicit ones are "*Gordon-MIT Engineering Leadership Program*", MIT or "*Leadership in a Technological Environment*", Monash University.

What defines *systemic* educational change, however, according to Graham, is the fact that programs are:

- *Planned*
- *Affecting the mainstream education of a high proportion of the student cohort (i.e. not optional or extra-curricular activities)*
- *Large scale (not one or two courses)*
- *Applied within engineering department or school*

(Graham 2012, 17)

V.1. MUSLI (Meeting point for University Sustainability Learning Initiatives)

The starting point was at a Pedagogical Day Meeting for teachers on the 14th of March 2012 at AAU where, amongst other topics, the research of PROCEED was being discussed. I attended as an intern with PROCEED. One working group discussed "How can a hybrid strategy be put into practice in our educational programs?" and "What does educating a green engineer mean for your particular program?"A core of three people, including the initiator of the discussion, Prof Andrew Jamison, encouraged by prospects of interdisciplinary collaboration, agreed to continue the debate at a later date. By word of mouth and e-mail, people considered to be potentially interested were also invited.

A. The first meeting

Was an informal round table discussion which took place on April 18th 2012. The first half hour was a round of self-presentations: the 9 attendants are listed in order, with a link to the AAU staff profile containing a description of staff position and publications. Quotes are from the audio recording and notes taken during the meeting.

Presentation rounds

a. **Eva Ritter** http://personprofil.aau.dk/100825 (ER)

Attended the initial Pedagogical Day meeting. Has a Ph.D. in Forest Ecology and M.Sc. Geo-Ecology. Teaches Architecture students at the Department of Civil Engineering and is interested in engineering education. Along with another colleague, she has attempted a similar initiative for educational change within that Department, trying to link Sustainable Forestry to Sustainable Architecture in a more holistic approach, but so far, "*a question of culture*" amongst the more conservative teachers there has posed difficulties. Present at MUSLI meeting to achieve more insight and is "*open to see what happens*".

b. **Kirsten Krogh Hansen** http://personprofil.aau.dk/116626 (KKH)

"*Trained geographer*" as former AAU student. Working on "*transition from PBL centre to UNESCO centre at AAU*" together with JEH and MLD, doing research on mapping sustainability in the curriculum at AAU and interviewing heads of study boards.

c. **Jette Egelund Holgaard** http://vbn.aau.dk/da/persons/jette-egelund-holgaard(200f904d-a5dc-4958-9463-af2b285acb40).html (JEH)

Background in thermodynamics and environmental management, is a lector working within the UNESCO chair on developing a center for PBL and Sustainability. Also a part of the PROCEED project.

d. **Mona Lisa Dahms** http://personprofil.aau.dk/103272 (MLD)

Also attended the Pedagogical Day meeting. "*Electronics engineer by profession*". "*Very much into interdisciplinarity; that is the reason I was at the Electronics Department for many many years trying to defend the soft values within that institute and I finally gave up and moved away, and now they are introducing it. So, yes, that is the irony of fate…*" Currently part-time lecturer working with the PBL for Sustainability project with JEH and KKH and also part of PROCEED.

e. **Vladimir Ion Proca** (myself)

f. **Aida Guera** (AG)

PhD Fellow at AAU looking at how "*PBL can facilitate the integration of Sustainable Development in Engineering Education"* by *"analyzing the potentials of the curriculums at master's level",* namely *"civil engineering and urban planning*". This is to "*better integrate what is already there, to see what is missing and come up with a theoretical framework and model that link education for sustainable development and engineering education*". A preliminary finding is that some "*competencies are copy-pasted*" from one program to another in their curriculum templates in an 'off-the-shelf' manner.

g. **Lars Bo Henriksen** http://personprofil.aau.dk/107362 (LBH)

Affiliated professor, part of the UNESCO chair, teaching Engineering Education and Engineering Practice. States "*I know absolutely nothing about sustainability but I've come to the conclusion that I've got to learn, because it seems unavoidable*". In reply to AG, remarks that "*curriculum templates fully confirm*" one of his previously written articles about the "*taylorization of the University: bureaucracy taking over, so we have to squeeze everything in little squares and boxes*". Currently "*very much into the engineering practice part of PROCEED*" and there "*to see what I can contribute*".

h. **Lars Botin** http://personprofil.aau.dk/105775 (LB)

Assistant professor teaching Theories of Science at AAU. Is "*here to listen as well*" as he "*doesn't know much about sustainability, at least not from this technical, environmental aspect*". Makes a reference to attending a recent conference in Philosophy of Technology where "*the sustainability word was banned from any sort of discussion because people were fed up with it because it was overused*", stating that "*responsibility*" was preferred by the philosophers. Also a part of PROCEED.

i. **Andrew Jamison** http://people.plan.aau.dk/~andy/ (AJ)

Is the coordinator of PROCEED and initiator of the meeting. Outlines PROCEED by mentioning the background and challenges that it deals with. Hopes to "*leave discussion with a next step, to be a little practical in our discussions*". Starts the session by introducing an idea from ER at the Pedagogical Day workshop, namely the possibility of making "*a proposal for something that could be done at the 9th semester*" [1]

The main ideas touched upon are noted with bullets, with highlighting quotes. The first meeting focused on assessing existing possibilities and envisioning opportunities for integrating sustainability, and discussions on what 'sustainability' actually means. It did not formulate concrete propositions for curriculum change but served, more than anything, towards 'familiarization' of its members with each other. This means assessing where each member 'is coming from' in terms of expectations from the group and what they can contribute, and the possibility of the group as a whole to establish itself in AAU.

- There is agreement that the 9th semester is a good starting point for discussion

LBH: "*9thsemester is very open; just yesterday the (Danish) Minister of Education announced that every student at Danish University should spend a semester outside the University in a practical environment; my point is that even from the highest political level there is support for this*"

LBH: going outside of the University for practical applications is easy "*especially for Universities based on the PBL model*". "*No matter how disastrous the internships are, they are always successful in terms of learning*" as "*the students discovered they could actually DO something and all their doubts they had about their own learning disappeared*"

- The notion of 'externship'

AJ mentions the Alley Flat Initiative at University of Texas which uses the word 'externship' to describe their particular approach as an alternative to a traditional internship within a company. "*Internships have a lot to do with internalizing those values of the place you go and work at rather than in some sense finding your own values as part of the learning process*"

[1] The 9th represents the 3rd semester of the master's program (with a total duration of 2 years, spanning the semesters 7th to 10th)

- Qualification framework is a good thing

JEH: "*the 9th semester and the internship give you some different competences*" and "*I like the notion of externship because you can learn to work interdisciplinary and to do some service learning as an act of being responsible, or whatever it should be called*"

- Interdisciplinary student project

Another proposed idea is to have students from different disciplines work together within the PBL system on a common sustainability themed project in order to get a sense of the very different backgrounds of their colleagues.

- Summer school in sustainability

The first meeting ended with an extended talk about the opportunities for making a summer school which would come before the 9th semester internship (which the group concluded is a valuable educational tool for AAU students and should not be changed, as it provides an individual experience). This point of this summer school would be to introduce students of different backgrounds to the topic of sustainability and what it means to be an engineer from different perspectives, essentially, what hybrid imagination means.

- Teacher training session

AJ proposes a "*sustainability integration*"-themed session which would serve as "*preparation for the teaching*", as MLD observes, introducing interested teachers to what MUSLI is about and how they can collaborate towards a better understanding of sustainability and how each teacher can bring it into their activity.

The meeting ends with agreement on the name: MUSLI stands for 'Multidimensional University-wide Sustainability Learning Initiative", and prepares the agenda of the next meeting: presentations of preliminary results of the UNESCO PBL for Sustainability centre as a starting point for taking the next steps.

B. The second meeting

"Almost without exception, successful and sustainable change starts with a fundamental assessment of curriculum-wide goals and involves a re-alignment of the entire curriculum in which a cross-section of faculty is involved. This successful approach to educational design appears to be independent of the scale of change undertaken" (Graham 2012, 3)

The second meeting took place on the 31st of May 2012. It had the same attendants as the first meeting. Currently, the focus within MUSLI is on what the hybrid imagination strategy calls the institutional level:

Creating sites of cross-fertilization, or collective learning, to provide a 'space' for interdisciplinarity for an emerging 'mode 3'

The importance is that the members keep motivated and share their knowledge. LB that "*the first challenge for sustainability is the social one*", referring to the fact that, first and foremost, people must work together.

MUSLI is fortunate to benefit from the fact that the majority of its members are a part of the UNESCO Chair for PBL in Sustainability where educational research is the main focus. The presentation of the chair, along with its activity, can be found at the following link: http://vbn.aau.dk/en/organisations/unesco-chair--problem-based-learning(a77a51e4-88b6-46bd-944e-54d639be4432).html

The second MUSLI meeting was centered on one such research looking at how much is sustainability being dealt with in the curriculum at the Faculty of Science and Engineering at AAU:

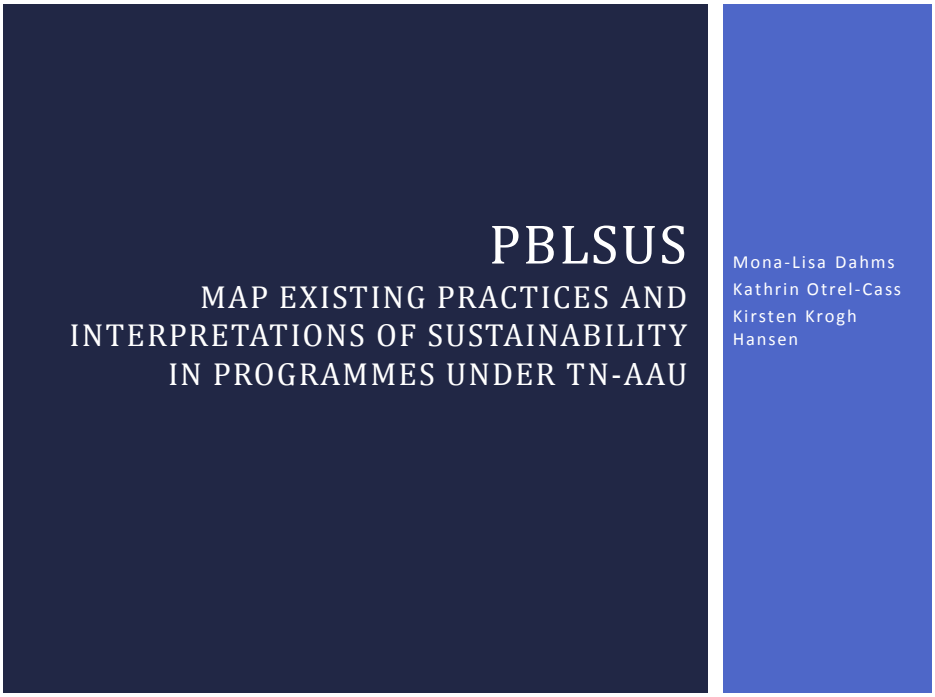

Figure 9: Research done within PBL for Sustainability at AAU looking at sustainability in study programs (Dahms, Othrel-Cass and Hansen n.d)

This research is assigned by the Dean, the background being that AAU is among 328 other universities that have signed the "University Charter for Sustainable development" (also called the COPERNICUS Charter).

All the study programs in the faculty were scanned to see to what extent they match keywords from the Global Report Initiative (www.globalreporting.org) concerning sustainable development. The second phase of the research comprised of interviews with key staff members. The following visual diagram of sustainability was used as the basis of discussion as to what extent they considered sustainability to be present in their particular curriculum:

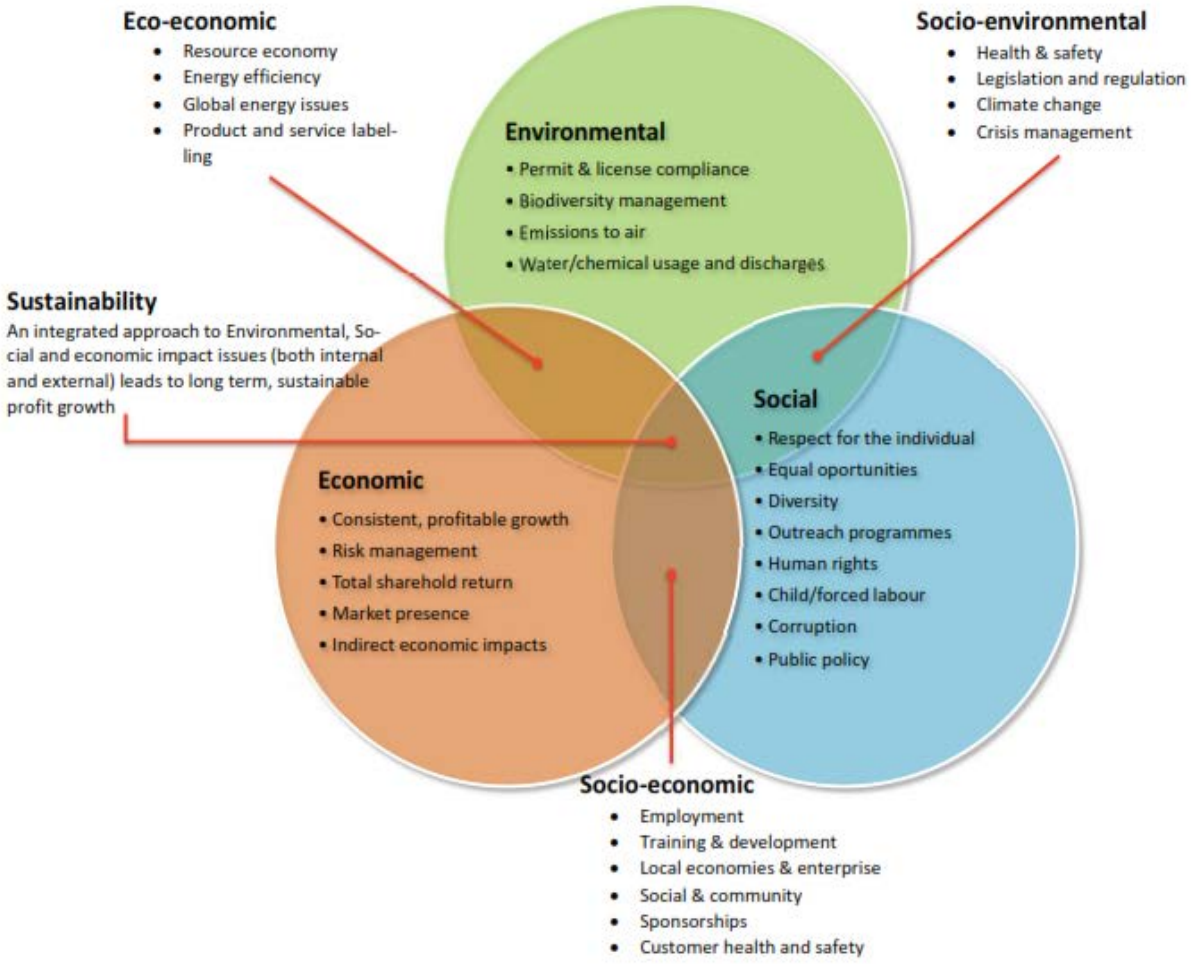

Figure 10: Diagram of sustainability adapted from the Global Reporting Initiative used for interviews with key staff members at the Faculty of Engineering at AAU in order to identify elements of sustainability within study programs (Dahms, Othrel-Cass and Hansen n.d)

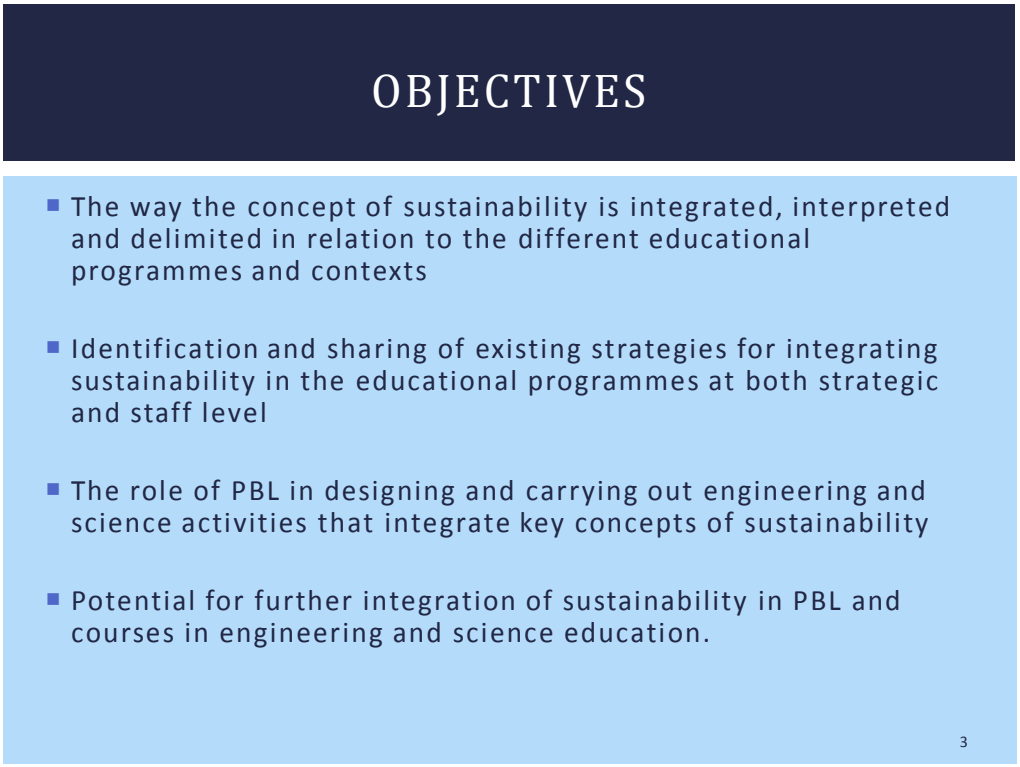

Figure 11: The objectives of the PBLSUS research (Dahms, Othrel-Cass and Hansen n.d)

The findings show positive prospects for change:

- Sustainability is present in the classroom more than is apparent in the written curriculum. The visual diagram of sustainability that was used in the interviews with teachers helped them identify elements of their study that they did not consider classified under sustainability, understood firstly as environmental sustainability, and helped give them a better image on what their role within it can be;

- PBL is acknowledged to be a efficient teaching system that can work as a great platform for integrating sustainability within engineering education, especially due to its inherent focus on interdisciplinarity;

- Preliminary impacts of the research: programs that currently do not include sustainability explicitly will focus more on identifying these aspects and making the connection to the particular program more clearly;

- Interview respondents all agree on the relevance of selected aspects of sustainability;

- "*Not all aspects of sustainability are relevant for all programmes, but some aspects can be included in all programmes*" and "*University as a whole should cover all aspects of sustainability*", answers say;

- There is support from the leadership of the Faculty, as the Heads of Study boards support initiatives from staff. Few are "*willing to tell people what to do*" and some Heads of Study boards "*welcome top-down initiatives, including financial resources, in order to work bottom-up with sustainability*", research has found;

- "*Not all graduates from TN-AAU should be generalists, there is also a need for specialists*". This statement from an interview with the Dean starts a debate at the meeting. While MLD states that "every graduate at AAU is a *specialist*, in one way or another". One of the basic ideas for MUSLI is to "*find a way for those (students and teachers alike) who do want to be generalists*" in the field of engineering, AJ observes, supported by ER, saying "*specialists that should be open to becoming generalists*"

In this discussion, a 'generalist' refers to 'hybrid imagination', as ER said, a specialist, someone with a strong academic background, that is *open* to knowing more about sustainability, if it is not present in the curriculum they are linked to, or to consider *other* aspects of it as well, in the case that is already dealt with.

Currently, MUSLI's vision is becoming "*a base for discussion for teachers to talk, see, show what is going on in other places of the University*", as JEH says, and to foster "*a sustainability frame of mind*", AJ adds.

As such, the group has a new name:

M*eeting place for* **U***niversity* **S***ustainability* **L***earning* **I***nitiatives*.

This is perhaps similar to the 'Learning Center' at Chalmers University. There, engineering education research and the UNESCO Chair in ESD work together with language and communication, teacher training and pedagogical development projects (Svanström 2012)

Perhaps it will become a working group of the PBL Centre for Sustainability at AAU. The aim for the next meeting is to write a description of the group and agree on "*what the group is and why it exists*", as MLD states. The next step is to make itself known to the Faculty and attract the interest of more members, as its ambition is to achieve systemic change in the university. A forthcoming key date is a teacher seminar on the 24th of August 2012 which will present the research of PBLSUS and the Copernicus Charter, with an introduction from the Dean, who called the meeting. Supporting topics are the history of sustainability initiatives at AAU, presentation of the Environmental Committee at AAU, considerations on designing new programs etc. The goal is to leave teachers with "*an awareness of what sustainability is and what other people in the University are doing about it*" and "*to give teachers something to work with*",

MLD states, an idea of how they can begin to implement it within their specialization and open up to new interpretations. Considering the PBL system at AAU, an approach could be to have teachers with an awareness of sustainability to work as 'sustainability supervisors' for interdisciplinary student projects, MLD adds.

Chapter VI: Conclusions

Summary

This paper has taken a look at the relationship between engineering education and cultural and social aspects of sustainability. While Engineering Education for Sustainable Development (EESD) has become an established term, there is still significant diversity of opinion, and as a result, educational strategies, on how sustainability is to be brought within engineering curriculum. Achieving real EESD entails a systemic change in education. This does not mean radical measures must be taken, but rather placing sustainability at the core of education, and identifying how particular programs and their underlying disciplines can adapt the concept to their particular teaching context.

While there is at least a wide recognition that the need for such a change is needed, a number of constraints have impeded wide-scale transformations. Those touched upon in this paper are discussed from the perspective of the Program of Research for Opportunities and Challenges in Engineering Education in Denmark. It has identified two different educational response strategies developed to respond to the challenges that engineering today faces, which go in the direction of academic over-specialization and market-driven approaches. This is illustrated by using the author's personal experience within the Joint Erasmus Mundus in Environmental Studies master program (JEMES), and explained in relationship to contending interpretations of sustainability and their relationship to the academic world. A third approach was proposed, which integrates cultural and social aspects of sustainability, under the term of 'hybrid imagination'.

Some engineering programs that have attempted such an approach were described: EPICS at Purdue University and Alley Flat Initiative at Texas University, and also the example of Bistrita Valley Summer School in Romania, which focuses on community outreach from the university as an institution of local importance.

The "Meeting place for University Sustainability Learning Initiative" (MUSLI) initiative at Aalborg University, Denmark served as the base of discussion for how systemic educational change can be implemented. Regarding pathways for future development, we have seen examples of how increasing interest in engineering

education supports a growing number of reform initiatives at Universities around the world. MUSLI benefits from a context that provides good chances for development: engaged members with varied backgrounds, specialized research in engineering education, top-down support, both from the university and the national level, and the institutionalized PBL model.

Concluding reflections

Regarding change in general, we as people are not always open to it, even in the face of evidence. The issue of sustainability is complex, difficult to understand and manage, and requires continuous efforts and commitment. The way we have built up society and industry makes it structurally challenging to implement changes, but more often than not, it is not matters of practicality, but barriers of ideologies that keep people stuck in rigid ways of thinking, slowing down change.

The two response strategies identified in this paper give an indication of two separate directions which address this situation. On one hand, the 'complexity of the hybrid world' is solved by breaking it down into ever-narrower specializations within which engineers can sustain their traditional approach. What is under discussion is not the value of the technical knowledge and innovation which results, but the fragmentation of knowledge, communication and understanding amongst scientists which goes contrary to the intrinsic holistic characteristics of sustainability.

On the other hand, the close relationship of engineering to industry and the dominant discourse of ecological modernization has made it so that the opposite direction of a narrow specialization presents itself mainly as a proposal of commercial entrepreneurship, supported by education, under national guidance, as a strategic step towards ensuring global competitiveness for engineering in the future. If restructuring of engineering education for including sustainability is done, it is mainly in terms of enhancing the networking, entrepreneurship and business capabilities of engineers, to become 'global leaders'. What is under discussion in this case is not the fundamental practice of business or the need for a 'greener' economy. Having open-minded and change-oriented engineers within industry is a considerable positive step forward. What this paper explores, through the concept of hybrid imagination, is finding a way to combine engineering and humanities.

In times of crisis, systems restructure and individuals re-assess their position and values. What the 'hybrid imagination' strategy proposes is to give those engineers and engineering students a real opportunity and educational experience that will allow them to develop multilaterally towards being a professionally trained expert, capable of

upholding a traditional engineering practice, but open to learning about other, un-established ways of applying their skills.

This means avoiding being caught up in the 'habitus' of the traditional academic identity, and on the other hand, envisioning opportunities for turning their 'Profession of Everything' towards making a difference in the world in ways that are not fundamentally designed to satisfy economical ends.

Because of this middle ground, this approach is difficult to define, as it is driven mainly by personal engagement on the behalf of the individual. Terms such as *humanitarian engineering* can be fitting, but on a more general level, the simple disposition towards experiencing other perspectives, and even assuming different identities in order to examine a topic (in the case of this paper, sustainability and its relationship to engineering education), means 'cross-fertilizing' knowledge and skills and becoming a 'hybrid'. By taking the best of two worlds, a more open, creative state of mind will hopefully result in greater tolerance and co-operation in the real world, beyond any one single discourse or scientific discipline.

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