Integrating sustainability in Engineering Education in Denmark

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How is sustainability incorporated into the engineering curriculum? The case of DTU and AAU

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Abstract

How to include sustainability in engineering education is currently the main concern among engineering educators. In one way or another, engineering educators are increasingly addressing sustainability issues in the courses they teach, the programs they design and run, the institutional activities they promote and the accreditation criteria they develop. But this is not the first time engineering educators have attempted to bring social and environmental issues into the engineering curriculum. In this paper we examine different approaches to incorporate environmental and energy issues into the education of engineers and use them as a background for a discussion of how sustainability may and should impact engineering.

In the first part of the article, we account for the ways in which environmental and energy issues were incorporated in the education of engineers of the Technical University of Denmark and at Aalborg University since the 1970s until today. Environment surfaced as broad social concerns already in the 1960s and together with energy issues its importance grew during the 1970s into a concern, which should be addressed, in all engineering educations. Environment and energy technology lead to new ass on courses and even established engineering educations on their own, but tending to focus only on partial and sector specific technical topics like e.g. water provision and waste and solid waste treatments or new energy technologies. Thus, rather than the environment as a broader social concern to be reflected in engineering at large, what has prevailed is dominated by a conception of the environment as nature (outside society) to be handled by technology. Energy on the other hand has been conceptualized as renewable energy and has remained in the physics and electrical related research groups and departments.

Now that engineering educators are focusing on sustainability as a societal concern we face the same challenge. Is sustainability going to become a narrow set of physical indicators and metrics (emissions, fossil fuel consumption, energy efficiency, temperature increase), or will it remain to be a broader social concern to be taken across programs or eventually in specialised new professional endeavours? To further this discussion, in the second part of this paper we examine how environmental, energy and sustainability we will present some details of the design of the Master Engineering programs on Sustainable Cities and Sustainable Design at Aalborg University in Denmark. These programs claim to have developed effective strategies for educating robust engineers capable of dealing with the complexities of the needed calculations and the modelling of physical processes and at the same time able to cope with the political and administrative dynamics of cities. With this exercise we anticipate that sustainability will not meet the same fate as environment and energy but that the integration of sustainability in university program may be participating in a transition on the character of engineering education as a whole.

1 Introduction

At Aalborg University – as at many other engineering universities – there is currently an internal debate: should sustainability be a fundamental value of all educational programs or is it something that needs to be addressed specifically? The promoters of the former view believe that it should be a fundamental value and thus not single programs should use the notion sustainability in its name. With time it should become obvious to anybody inside and outside the institution that sustainability is a core value in all educations just as quality, ethics and service are at the moment (interview with Henrik Brohus). However, severalprograms use the word sustainability in their titles. More concretely four masters and one bachelor in engineering do this. They are the master in Sustainable Energy Planning and Management (SEPM); the Master in Environmental Management and Sustainability Science; the master in Sustainable Cities (SusCi); and the bachelor and master in Sustainable Design (SD). All these programs are offered at the Department of Development and Planning at Aalborg University. How these programs came to be is a discussion that needs to be understood in the context of a broader historical development. Which social concerns (social, environmental, safety, energy, health) have been brought into engineering education? In which way do they cohere to a common sustainability perspective? Have they been translated into specific technologies that students should be familiar with, or specific solutions they should be capable of developing, or a set of criteria, methods and metrics that must be used to assess solutions, or a set of skills and competencies to do certain types of developments or is something else core?

To investigate these questions, we will first take a historical approach by accounting for the ways environmental and energy concerns were incorporated into the education of engineers in two institutions: at the Technical University of Denmark (DTU) and at Aalborg University (AAU) since the 1970s until the present. This research has been part of the Project on Opportunities and Challenges for Engineering Education in Denmark, which set out to assess engineering education initiatives, structures, traditions and indicators in Denmark (www.proceed.dk). From the outset, the project focused in three different challenges: the first related to environmental and climate challenges; the second to the increasing social complexity of technology (design); and the third to the blurring of boundaries between science and technology (high-tech: bio-nano).

In this article we focus on the challenge related to the widely recognized need for social responses to resource depletion, environmental deterioration and new energy technologies. We have conducted an ethnographic analysis based on semi-structured interviews with 25 engineering educators at DTU and AAU. We applied the general principles of situational analysis to guide our research choices (Clarke, Leigh Star 2008, Clarke 2005). During our interviews and discussions we found that environment issues are understood and translated in diverse ways at different times and in different institutional setting and in the main text we will show the specifics of those translations. Although our initial enquiry was as to how the environment was incorporated in the engineering curriculum, our interviewees soon started to talk also about energy provision,management issues, production processes and,when referred to the last two decades, sustainability issues.

The text is organized in foursections: first we present the general theoretical framework of our investigation; second, we account on how environmental and energy issues were taken up at DTU; third, we do the same with AAU; and fourthwe provide some detail into the contemporary process of bringing in sustainability issues in the design of the engineering masters programs of Sustainable Cities and the Sustainable Design at the AAUCopenhagen Campus.

2 Theoretical framework

The general theoretical problem we are addressing in this investigation is how educational programs in engineering are configured. Who and/or what define the content of the curriculum? We are especially interested in accounting for the ways in which broad matters of concern, like the environment, are included into the curriculum. The motivation for doing so stems for two strands of recent research. On one hand we observe the rise of sustainability as a matter of concern. Some researchers claim that as a general social objective, sustainability is the first one after almost three decades of free market hegemony, when social priorities and development was entirely delegated to market forces. There is no agreement as to what sustainability is, but the point is that it is the first matter of concern that remains high on policy, politicians and governments' agendas in one way or another. As such it stabilises sustainability as a fundamental discourse about what makes policy and management legitimate. On the other hand, engineering educators all over the world are discussing how education of future engineers should be.

These discussions point in many directions like globalization, social justice, international competivity, and also sustainability. There are many aspects to this interest in the future of engineering education including decreasing interest among young people in several countries, a resurgence of interest in design in others, international competivity (more fear in Europe and United States of being outperformed by engineers from big Asian countries) and among many scholars concerns as to how do we educate engineers capable of understanding and tackling the increasing complexities of our modern societies.

Following Andrew Jamison there have been historically three types of approaches to engineering education: science driven in which the development is guided by engineering educator's own disciplinary problems; market driven in which the contents of engineering education change according to pressures from the market for trained engineers outside the academia; and socially driven where engineering educators actively translate and incorporate in the education of engineers social concerns that need to be addressed, even if they do not have a commercial value to traditional big companies (Jamison 2013). These approaches are ideal types often found to be mixed in the specific histories of educational programs. For a more chronologically oriented presentation please refer to the research reports on PROCEED.

Gary Downey claims that when Nation's change their paths of development, engineering educators get worried about the contents on the engineering curriculum and how engineers are been educated (Downey ref.?). This claim is substantiated by extensive work on the history of national cultures of engineering education and practice (Jørgensen 2009). We relate to this body of work, and in this contribution we trace particularly how the environment, energy and sustainability have been translated from general preoccupations to specific teaching activities. To account for these translations we discuss the nature of influence. Downey and Lucena have proposed that engineering educators switch between different codes of meaning when they take decisions about curricular design. This implies that rather than passively reacting to external influences, engineering educators create narratives and discourses to make sense of the conflicting configuration of codes of meaning affecting them. Through curricular design they attemptto upscale this narratives from small teaching activities, to courses, to entire programs of education. We call these narratives and discourses object worlds inspired by Louis Bucciarelli because as they refer to a rather specific set of technologies, methods, metrics and disciplins that constitute what this professional (sub-)group is concerned with and trained in (Bucciarelli 1996). This object worlds constitutes not only the things to include in processes and solutions (like pipes, treatment processes, bacteria, measures of pollutants, etc.) but also frame how problems are conceived and transformed into solutions. The constitution and further development of these object worlds depend heavily on the configuration of actors that support them e.g. represented through the professional groups of engineering and specialised technical consultant who work with them and refer to them. In turn actor configurations also depend on institutional trajectories, which entails the rather important

role that existing ways of organising research into disciplines and departments and educations into curricula and pedagogical principles are core to understand the role of engineering education and a set of institutions with their own history and politics.

3 Environment and energy at the Technical University of Denmark (DTU)

The first wake-up call to focus attention on environmental issues was a series of discussions taken up at the Danish Engineers Union (Dansk Ingeniørforening, DIF) in 1964. In four transactions of those discussions, the environment was divided into issues related to air, soil, water and chemicals. This approach projected into nature an elementary view of natural aspects to deal with, though the origin of these new challenges originated from the growth and intensity of production especially after WWII. In 1972 at the United Nations Conference on the Environment in Stockholm, this view was further strengthened and engineers felt the need to take actions in order to "clean up the mess" produced by industrial societies. At the same time, researchers joining in the Club of Rome and at MIT concluded that in terms of resources, we were reaching levels of usage that will deplete the planet in a few years (Limits to Growth), by way of deploying some mathematical models to analyse population growth, consumption and resource use (Meadows et al. 2004).

3.1 The first initiatives and responses at DTU

To attend these concerns, during the late 1960s and the 1970s students, faculty members and administrators at the DTU (then named Danmarks Tekniske Højskole, DTH) began developing the first activities directed to meet the increasing environmental challenges the country was facing. We have identified four of these activities as becoming the most important. The Laboratory of Technological Hygiene established in the 19th century framed the environment in terms of controlling wastewater. The focus in this Laboratory thus was on technical solutions for controlling pollution. The second set of activities was developed at ISVA, which was an institute concerned with how flows of ground water could supply clean water and also prevent contamination of clean water wells. The third activity was focused on specific projects and course development in very diverse fields as food processing and the pollution from burning coal and from chemical processes. As an example professor Østergaard started developing a notable research in burning efficiency for the production of energy and professor Mosbæk developed a whole set of courses in Chemical Processes and environmental analysis for the education of engineers interested in environmental issues.The fourth set of activities was lead by professor Niels I. Meyer who initially was trained in physics with focus in semiconductors. He turned his interest to renewable energy production after meeting Donella and Dennis Meadows in a congress in 1972. Niels I Meyer was participating in the congress due to his central position at DTH as vice president and president for the Academy for Technical Science.

Unlike American universities and colleges, DTH was not organized in academic units that administrated specific educational programs. DTH was a collection of many different departments that existed around specific research agendas defined by fields of technologies and natural science disciplines. The different departments and laboratories were structured around professorial positions and depended highly on the leading professor. There existed four education programs (the classic: Civil, Mechanical, Chemical and Electrical Engineering), which were administrated centrally by the university and where faculty members from different institutes taught their subjects according to their particular competences. After 1972 this began to change as the whole educational curriculum was reformed with the introduction of a modular structure of courses with an increased degree of freedom for the students to choose courses to follow. This opened for a large number of experiments and new courses offered including electives on matters such as 'Science, Technology and Society' and similar social and environment topics but also left the experimentation to an

'open market' of courses with only limited baking in the structured study plans now typically organised through 'recommended curricula'.

The initial steps towards creating a new (recommended) masters program in Environmental Engineering were taken in the mid 1980s. This program was launched with the first students starting in 1987 and headed by Arne Villumsen, who was hired as professor at Institute of Geology in 1983. His research focused on the contamination of soil and water sources. The program was especially targeting foreign students who wanted to study in Denmark due to the countries reputation in environmental policy. However prior to this, difficult negotiations had taken place about what should be included in the curriculum. The main aim by creating the education was to structure some of the activities already dealt with at DTH into an education program. Due to an emphasis on operating with already existing courses framed by a science-based understanding of engineering the focus in the new program became on the physical environment (nature out there), and issues such as ground water pollution, chemistry, geology and waste management were given the priority. The aim was to educate engineers, who were better in exploring soil, surface and ground water, cleaning highly polluted areas and developing new techniques for doing so.

Not all activities related to the environment were included into the program. Niels Meyer's developments in renewable energy remained outside. They were located mainly in Physics department andat first included in the education of Electrical Engineers only but as elective courses also taken by others. The explanation of these priorities are due to the main affiliation of some of the core figures like Meyer and Villumsen, who were engaged in departments with a strong and traditional disciplinary background that also defined the core of the environmental and energy courses and programs all were dominated by an interpretation of the environment as a condition defined by "nature out there" and to be handled primarily within a natural science conceptualisation. The management and societal perspectives on the environment stayed at the margins in the Environmental Education, since they were perceived as not belonging to the core of engineering competences though these perspectives and topics were represented in a few courses.

3.2 Involving industry through cleaner technology and management activities

During the early 1990s a different approach to the environment began taking shape at DTU (DTH became DTU in 1994). Due to frustration over the effects of the enforcement of the environmental laws of the 1970s a number of professional engineers, consultants, regulators and engineering researchers in Denmark and elsewhere began in the mid 1980s to shift focus from pollution and emissionsas a result from production activities in companies, to the origins of these pollutants in the whole production process and how these processes and practices could be improved. A whole academic and social movement was developed around the concept of Cleaner Technology. These activities were translated at DTU into specific research activities such as Life Cycle Assessment and Environmental Impacts Assessment funded by among others the Ministry of Environment programs on Cleaner Technologies and developed at the Department of Production.

This resulted in new research based courses at first developed for the educational programs in Mechanical Engineering and Chemical Engineering that also included the teaching of topics within the fields of production processes. These courses combined technical subjects on specific cleaner technologies with management courses focused on procedures and practices improving the ways companies should handle environmental concerns. There was scientific support from the disciplines of management and organisation to these new and often more interdisciplinary course activities combining a technical and social science perspective. A specific educational activity bloomed in the professional, part time Master of Environmental Management (Teknisk Miljøledelse, TML), which was initiated by research groups organised in the Interdisciplinary Centre and the Unit of Technology Assessment in 1994/95 (later merged with the Social Science Department into the Department of Technology and Society). The TML program was initiated due to conclusions from a research project funded by the Danish Engineering Union and the Ministry of

Environment. The aim of the TML program is to provide an education in Environmental and Health issues for employees with more than five years of experience in the industry and governmental institutions.

3.3 Controversies over the role of disciplines, new departments and experiments

An important outcome of the student movements at DTH in the 1970s was the influence they achieved on the general planning of the university. Around 1976, students and young researchers proposed a change in the ways the budget of the university was negotiated. In this manner they broke a tradition of incremental growth completely aligned with existing academic traditions at the university. Instead, a substantial proportion of the new budgets could be negotiated to support the creation of units to attend social concerns at large. Due to this developmentand the influence of students was created the Department of Ecology and Environmental Education (Miljølære in Danish) with professor Finn Bro-Rasmussen as the leading person. Another department, which was established in 1978 was the department called Social Science (Samfundsfag in Danish) that later became one of the components in the Department for Technology and Society. The role of these new departments was at first to present additional courses to the general modular structure of the educational programs, but not to organise special new programs. Their research bases were disciplinary; the one combining ecological perspectives with assessing chemical pollutants and climate change issues, the other bringing sociological and economic perspectives on technology into engineering.

From thesenew research and educational activities came a number of new disciplinary courses but also questions concerned with the lack of integration and impact on engineering competences and approaches. This led to the creation of temporary units that took specific topics under scrutiny in attempt to build new, interdisciplinary approaches. The two most important initiatives during the early 1990s were the already mentioned Interdisciplinary Center (TværfagligtCenter) and the Unit of Technology Assessment (Initiativet for Teknologivurdering) The Interdisciplinary Center was mainly concerned with the contamination of food in the production process, new strategies for organic food production and pollution from industry. Its members promoted a comprehensive view of the environment and thus advocated for the education of engineers in the principles of ecology, organic food and provided courses based on this perspective. These scholars, during the 1990s, also developed courses, research projects and activities in environmental management, cleaner technology and life cycle assessment. But most of these initiatives remained contributions to the large provision of elective courses, with the exception of some years experimentation based on offering the students study packages (fagpakker in Danish) for their first years of education where especially the two programs on environment and on energy offered space also for some of the inter-disciplinary elective courses and included an early engineering project activity (fagpakke-projektet in Danish). In parallel the Unit of Technology Assessment was especially instrumental in introducing Science and Technology Studies (STS) at DTU including new approaches to understanding technology, nature and the foundation of engineering knowledge and practices.

The contributions of these new approaches to the environment as a social concern was given a place in the Environmental Engineering curricula as well as in the education of Production Engineering, but at the same time remained in a rather marginal position in relation to the strong disciplinary character of engineering educations at DTU. A specific requirement of just half a semester's coursework load was for a period of ten years added to the modular structure, called the AMS-points motivated engineering students to take a number of courses in the field of environmental and social science topics, which at a general level sustained these in the general curriculum, but also kept them in the role as add-on activities. Also the period with the study start curriculum packages offered some stable space for another approx. ten years. Courses like Environmental Management, Environment and Society, Environmental Engineering in the Tropics, and many others were available for students. However, these courses were electives and only two of those became part of the core of the Environmental Engineering program at DTU.

4 Environment and energy activitiesat Aalborg University (AAU)

There are several differences in the history of AAU and DTU, which make their development follow different paths and at the same time show some complementarity. While DTU has been a successful engineering and science school and research environment with a long tradition (it was founded in 1829), AAU is a young university (founded in 1974) combining the spirit of the social and environmental movements of the 1960s and beginning of the 1970s and the disciplinary traditions of two professional institutions: the Engineering Academy and the Polytechnic School of Aalborg that were integrated in the university. The founding idea behind the planning of the new university was to provide the country with a different pedagogical approach to higher education in general including a stronger focus on the outreach to society and professions. Three characteristics of AAU are salient to this analysis: the first one, is that interdisciplinarity was encouraged from the beginning; second, all educational programs are structured based on a problem- and project-based learning concept; and third, the structure of departments was from the beginning organised to support interdisciplinary aspects of engineering education and research as well as educations in other fields. In terms of engineering education all these aspects provided Aalborg with a competitive advantage to produce business and practice oriented professionals to feed into the dynamic, larger industries of Jutland specifically and to the growing demands for environmental professionals in government and consultancy more generally.

Like many other young universities in the world, the practical educational choice at AAU in the 1970s was to award degrees in Engineering, with some small specializations in different topics according to students' choices of project work. That is how some of our interviewees who were trained at AAU hold an Engineering degree with specializations in things as different as: Indoor Environment; Energy Planning; or Environmental Technology.

In the 1970s the new Department of Development and Planning housed mostly surveyors and engineers working on issues of physical planning but with time it became more interdisciplinary and inclusive especially with emphasis on planning in the fields of environment and energy focusing both on industry and government needs. Teachers and researchers in this department were closely related to and working on issues affecting the local society and the municipalities in North Jutland. Problems such as: agriculture processes; the use of fertilizers and pesticides; contamination of local lakes, rivers and fjords; warming of houses, offices and shop floors and indoors climate in general; infrastructure for water provision, waste-water treatment and solid-waste treatment; and many others. Because the teachers and researchers worked on several problems, and the students developed their educations based on problems every semester, it was practical and economical to have the students engaged in research on practical problems. In this way the barriers coming from the history of disciplinary ideas was overcome by institutional design and alignment between societal priorities and engineering education was achieved.

This meant, in turn, that Aalborg graduates have been traditionally appreciated for their capacity to find knowledge and to solve problems, instead of being particularly well versed and established within academic disciplines. This has also fostered their entrepreneurial capacity and their tendency to innovate in engineering education. Still some educational programs that grew out of the engineering school pre-existing the university also had an influence in maintaining a focus on wastewater treatment in the perspective of the classical technical hygiene perspective as well as energy educations focusing on specific types of energy machines and their optimisation. But also in these engineering programs the pedagogical reform putting students project learning at the centre favoured a focus on societal challenges.

Consequently during the 1980s two different strands of engineering educations developed. On one hand were the research groups concerned with the technical aspects related to energy and the environment with focus on indoors climate; sanitary systems, energy technologies and environmental technology. It could be said that

all these programs had focus on technical issues and on the provision of services or end of pipe solutions. On the other hand, the scholars at the Department of Development and Planning were concerned with urban, energy and transportation planning, that eventually also began to incorporate issues of environmental assessment and strategic planning during the 1980s. In both cases, students of engineering were trained in the same basic core competencies of mathematics, physics and design; and thereafter, during their senior years and what today is equivalent to the masters, they developed special competencies within the fields that the teachers and research groups could support.

During the 1990s collaboration among the two strands of engineering outlined above continued, but due to the growth of AAU both in number of researchers and number of students, more specializations became possible. Up until around 2002 there were several specializations within this master program including Energy, Transport, Urban and Environmental Planning. Further growth in the number of students, the adoption of the Bologna regulations and the internationalization of master's education in Denmark encouraged engineering educators to attract more students. Thus separate masters in Environmental Management, Urban Planning, Sustainable Energy Planning and Management (2004) and Sustainable Cities (2012) were developed.

5 The sustainability challenge and agenda

Sustainability issues have been increasingly taken up in both research and teaching activities since the publication of the Brundtland report (World Commission on Environment and Development 1987). The research and planning in energy systems has always been an interactive activity in Denmark, especially with authorities at the municipal and regional level, but also with the ministries and the regulatory bodies. Therefore when the possibility of making separate masters appeared, the educators sought a translation that captured this interactive character, and therefore they chose "sustainable energy planning and management". In this sense, they differentiated the more participatory Danish type of planning from the more strategic top-down meaning accepted internationally. Additionally, the Department of Development and Planning has a tradition of substantial integration among levels, knowledges and project work, which in many ways captures the spirit of the journey towards sustainability is all about.

Nevertheless this reflects the basic interpretative flexibility of the notion of sustainability not per se including the integration of social, political and long term issues into the perspective of specific ideas of improved environmental protection, energy systems not based on fossil fuels or a more interactive process of planning. While at AAU in some departments it may be obvious to include the social and economic aspects there are other departments and educations here as well as at DTU that may shift the balance more or less to focus on environmental and energy issues in what is considered the core professional knowledge areas and metrics of sustainability. As in the demonstrated historical cases the content assigned to environment might entail quite different interpretations concerning the competences and knowledge needed by engineers to become environmental professionals, the same is the case for the use of sustainability as a prefix. It may just cover a specific set of metrics, methods or technically preferred solutions, it may include a broader perspective on how planning is performed in a more interactive and integrative fashion, or it may raise demands for engineers to be able to analyse societal challenges including all facets of sustainable change to be able to navigate, design and give advice on the choice of technologies and how they are to be implemented.

In the case of DTU as for AAU the strategic management level has been keen on inscribing sustainability in the core of their vision and strategy for research and education, but what this implies for the specific demands to educational programs in general, to specific educations and for research priorities stays rather open. In some educational programs at DTU as well as at least one at AAU sustainable is simply added to almost traditional engineering topics to improve their market credentials. In other cases the perspective is

transformed into a basic orientation and interest more linked to student preferences at large and extra curricula competitions at which students can present results from their project work. But what can be identified when the sustainability challenge enters into both the core of technological knowledge and the priorities concerning futures societal change?

Most recently, the new generation of engineering educators took a window of opportunity to further develop an engineering master in Sustainable Cities (SusCi) at AAU. The window was linked to expanding the programs at a campus that AAU is developing in Copenhagen. The program builds on the traditions of integrating knowledge from different disciplines bridging between social sciences and technology at the Department of Development and Planning. One of the arguments for the new program has been that independent planning activities in isolated sectors is no longer feasible; instead a cross sector perspective is employed. Additionally, cities and urban settings as locus for research and integration have become more and more important, in general economic terms, and also in the literature on transitions to sustainability (Bulkeley, Betsill 2005).

During the process of designing and obtaining accreditation for the master in Sustainable Cities (www.sustainable-cities.aau.dk), engineering educators underwent two critical moments. One was the very positive response from the panel of external partners that reviewed the proposal, of which especially the potential employers of graduates from the program were very encouraging to the prospect of having engineers capable of integrating and working across sectors as well as capable of navigating municipal administrative bodies, national regulations and innovating institutionally and technically. The other critical moment was an inquiry from the accreditation bodies as to what made this program an engineering program and not a social science program. The argumentation finally relied on the argument that students would get a training both in broader management issues such as resource measurements, climate change processes, urban development and at the same time would become competent in the development and use of modelling tools such as life cycle assessment, carbon and environmental footprints, eco-design and energy systems.

The Sustainable Cities program is based on a combination of courses presenting existing methods and metrics including some of their disciplinary background in combination with the pedagogic of project and problem-based learning giving the students opportunities to work with projects that include contemporary societal challenges. Its take on sustainability lies in the combination of topics and project assignments defined by their usefulness within the professional perspective of engineers working in cross sector planning while the integration of interdisciplinary knowledge specifically focusing on new challenges to perform jobs in planning departments and to develop the sustainability agenda through a broader involvement of actors is touched upon but not supported in the coursework.

A further step is taken in a new engineering program beginning this fall of 2013 with its focus on Sustainable Design (SD) (www.sustainable-design.aau.dk). In this program the inclusion of different societal actors in setting the stage for sustainable change and broader transitions that challenge existing technological products, models and systems is at the core providing the students with analytical tools to handle the uncertainties, the interdisciplinary and socio-material integration inspired by STS and the need for new models and solutions as part of their engineering design work. Sustainability is within this educational approach as much a part of the design challenge as are the technical products and systems that are to be designed. This program has taken as the outset that opening up engineering design through more focus on problem analysis and definition by including a larger set of societal actors in creating change agendas and navigating the profound changes of not only technical solution, but also values and institutions is what is core to sustainable transformations.

6 Conclusions

What is going to happen to sustainability in the engineering education curricula in the coming years? Is sustainability going to become a core value integrated in all curricula, which is not necessary to mention in any name as many educators want at AAU? Or is sustainability going to become a discipline or maybe better a challenge and an approach to socio-material analysis and design on its own? If it does, will it be a new discipline as narrow in scope as any other engineering specialization – including most notably Environmental Engineering? Or will this be an opportunity to reform engineering education at large from the inside?

There are no easy answers to these questions, but from an intellectual point of view, it appears that a substantial reform of engineering education towards sustainability requires changes in research priorities, educational structures, accreditation criteria and institutional design. It seem obvious that different incorporations of the sustainability agenda may be relevant to cater for both the specialised knowledge within engineering disciplines and specific technological domains as well as the broader challenge confront traditional engineering solutions and curricula and demands broader reform initiatives. In the meantime, and from the material gathered for this paper, we can conclude that there are windows of opportunity in the existing institutional and cognitive settings. Particularly in Denmark, at AAU, in front of the official accreditation authorities, there has been space to innovate with programs like SusCi and SD at Aalborg University, at least at the educational level. However, the success of these educations is still to be seen and a strategy to scaling up its possible successes to other engineering programs is still to be conceived.

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