

D. Project Description

Opportunities and Challenges in Engineering Education in Denmark

1. Summary

The accelerating pressure on natural resources that has been brought to light in the debate over global warming, the increasing permeation of technology into society, and the rise of ‘technosciences’ that call for new forms of cross-cutting competence and design capabilities raise serious challenges for engineers. This research alliance will examine how engineering educational institutions are responding to these challenges and propose ways in which they might respond more effectively, so that engineers are better able to turn them into new opportunities, both commercial and societal.

By analysing the challenges and identifying examples of ‘best practice’ in regard to reforming engineering education at different levels in different countries, the Alliance aims to provide a solid basis for making improvements and taking new initiatives and thereby contribute with valuable input into reforming engineering education in Denmark. The research Alliance will connect three important strands of research that are seldom brought together in a meaningful way. One has its focus on engineering education itself, the second strand has focused on engineering epistemology, and the third strand of research has been developed both in the field of science, technology and society studies, as well as in social and cultural history, and focuses on historical transformations in science and engineering toward what has been termed a new mode of knowledge production or knowledge society. By bridging between these different strands, the research is meant to bring about synergies and interactions that will provide a highly relevant knowledge base for educational reform and institutional initiatives in engineering. Through the use of participatory methods these will be introduced into the curricula of engineering education in Denmark.

2. Objectives of the project

The overall objective of the project is to investigate how engineers and engineering educators are responding to the environmental, societal and technological challenges facing their profession and propose a range of educational reform measures by which they might meet those challenges more effectively.

The specific aims of the proposed research are to:

- improve the education of engineers, so that they might better be able to turn the challenges into new opportunities, in both commercial, societal and professional terms,
- bring together Danish and international researchers with expertise about these issues,
- compare systematically the different ways in which the challenges are addressed in engineering education in Denmark as well as internationally,
- identify examples of ‘best practice’ in regard to reforming engineering education, and
- reach out to engineering educators and other relevant stakeholders in a series of interactive workshops and seminars to bring the results of the research into direct contact with potential users.

The alliance aims to provide a solid basis for making improvements and taking new initiatives and thereby contribute valuable input into reforming engineering education in Denmark, with emphasis on the bachelor’s programs at University Colleges and Universities. It also aims to contribute to contemporary reform initiatives in engineering education internationally.

3. Main results of the project

The results of the project will be both practical and academic. The practical results will take the form of specific suggestions for curriculum design, including proposals for new courses, teaching methods, teacher training and other educational reform activities, as well as new analytical and evaluative instruments, or methods, for understanding how curriculum design affects learning outcomes and competence development.

A number of academic publications will be produced, in the form of

- articles that will be submitted to journals in the fields of engineering studies, engineering education, history of science, technology and education, philosophy of science and technology, and science and technology policy,
- books that will be produced at different stages in the research, one in the form of an anthology during the first two years, reviewing the relevant challenges and state of the art, and one in the form of a jointly-written synthesis, combining the results and conclusions emanating from the thematic projects, out-reach activities, workshops and international conference presented below.

It is expected that the results of the out-reach activities that are planned to be conducted during the second half of the project will be presented in more popular and less academic form, both as printed, or written material, as well as audio-visually. Various kinds of visions, foresights and/or scenarios drawing on the out-reach activities will be produced, together with the participating engineering educators and other relevant actors, and together with the participants, the project partners will disseminate the results in an active way to relevant users.

4. Background and hypothesis of the project

Three fundamental challenges facing engineering education are taken as the starting point for the strategic alliance:

- one related to the widely recognized need for societal responses to resource depletion and environmental deterioration, that has been brought to light in the debate over global warming and climate change,
- another related to the increasing complexity of technology and its permeation of all aspects of contemporary life, society and global collaboration, giving rise to a need for design skills for socio-technical integration and a sense of social responsibility on the part of engineers, and
- a third coming from advances in technology and science themselves, in such fields as information technology, biotechnology, media technology and nanotechnology, in which the traditional boundary between scientific and technical knowledge is increasingly blurred, creating new needs for engineers both in terms of design capabilities and modeling, or simulation skills.

The responses to these challenges have been contradictory. On the one hand, engineers are expected to add commercial and entrepreneurial skills to their scientific and technological competence, and, on the other hand, they are expected to contribute to the development of more sustainable and socially useful technologies, which calls for an environmental consciousness and sense of social responsibility as part of their engineering identity. Experience throughout the world, as well as in Denmark, has shown, however, that it is difficult to meet these rather different expectations in one engineering education. Rather, a tension, or contradiction has emerged that has served to pull engineering in different directions – into a new kind of global engineering identity versus a reinforcement of more traditional professional roles (Williams 2002; Jamison 2009).

It has not been easy to change established routines and entrenched assumptions, as has been noted in several recent reports on engineering education (e.g. Sheppard 2009, Millennium project 2007).

The typical responses have been a renewed emphasis on basic scientific knowledge as the core of an engineering identity at the same time as new courses focusing on the 'human dimensions' of engineering have been added to educational programs in an attempt to meet the new challenges facing the profession (Christensen et al 2009). The resulting overcrowding of the engineering curriculum forms the basic point of departure for the proposed research program (Jørgensen 2007).

It is the contention of the proposed alliance that responding to environmental, societal and technological challenges in a comprehensive way requires a serious rethinking and reorganization of engineering education. While new courses in such topics as entrepreneurship, marketing, environmental ethics and sustainability can perhaps have a useful role to play in engineering education, such 'add-on' components to a fundamentally unchanged and already overcrowded curriculum are unable to foster the 'hybrid' competencies that are called upon for engineers in the contemporary world (Jamison & Mejlgaard 2009). The challenges facing engineering call for a more integrative form of education, combining social, environmental and economic understanding with scientific knowledge and practical training in technical skills in an integrated way.

It is the hypothesis of the proposed project that designing and developing such integrative education requires what might be called trans-paradigmatic understanding, and more specifically, connecting three important strands of research that are seldom brought together in a meaningful way.

One has its focus on engineering education itself, and has devoted most of its attention to pedagogical methods and curriculum design. In Denmark, this strand of research has been particularly strong in relation to the project- and problem based learning methods that have been applied both at Roskilde and Aalborg Universities. Research in this strand has an instrumental character, trying to make more effective the learning process (Graaff & Kolmos 2007). The second strand has focused on engineering epistemology, with an emphasis on 'what engineers know' in the influential formulation of Walter Vincenti (1990) and the philosophical aspects of engineering practice (Mitcham 1994, Bucciarelli 1996). In Denmark, this strand of research has been particularly strong in the teaching of the philosophy or theory of engineering knowledge at DTU and in research done at Roskilde and DTU (Jørgensen 2009; Olsen, Pedersen & Hendricks 2009). A third strand of research has been developed within the field of science, technology and society studies, focusing on issues of social responsibility in engineering (Beder 1998), as well as on broader historical and societal transformations toward what has been termed a new mode of knowledge production and new forms of computer-based engineering (Gibbons et al 1994; Akera 2006). In Denmark, this strand has primarily taken the form of historical and other cultural studies, in relation to science, technology, and their interaction with the broader society (Hård & Jamison 2005; Christensen et al 2009). By building an alliance among these different strands, the program is meant to bring about synergies and interactions that will provide a highly relevant knowledge base for educational reform and institutional initiatives in engineering.

By bringing researchers with diverse expertise together in a concerted and coordinated strategic alliance, and by establishing collaboration with leading international scholars, our intention is to provide a more comprehensive understanding of the challenges facing engineering education and of how those challenges might best be met.

5. Innovative value, impact and relevance of the project

The innovative value of the alliance lies in the cross-fertilization of expertise and experience among the participating researchers resulting in a possible strategic renewal of engineering education, not least at the bachelor's level which has often been seen as difficult to renew. Most research in engineering studies and engineering education is carried out according to one or another dominant paradigm, or approach, in which a certain set of methods and theories are applied to a particular topic. Such paradigmatic or disciplinary-based research is valuable in many problem areas, but in relation to the challenges facing engineering, it is insufficient. The need for a reform in engineering education and training has been recognised internationally in several reports (see e.g. NAE 2004;

Millennium project 2007; Crawley & Malmquist 2007) and several international networks working with engineering curriculum reform: CDIO (Conceive, Develop, Implement, and Operate), PBL Global Network (organised by UNESCO Chair in Problem Based Learning), IFEEES (International Federation of Engineering Education Societies) and ALE (Active Learning in Engineering).

By examining - and, not least evaluating in a comparative manner - how engineering and engineering education are addressing both technological and societal challenges the Alliance will provide the basis for better education that can attract students and prepare them for employment more effectively. Particularly crucial will be a mapping of the engineering educations at the Engineering University Colleges, or CVUs – and an identification of possible areas of cooperation, interaction, and improvement.

By actively reaching out with the research results to engineering educators and to the decision-makers in both the public and private sectors, the Alliance will attempt to have a significant impact on the future planning and reforming of engineering education. The project will also add important value to the existing accreditation criteria to be developed and used by the Danish accreditation body ACE inspired by criteria developed in accreditation institutions for engineering education like ABET, EURACE and OECD's AHELO project on assessment of learning outcomes globally.

6. Project's methodology and results

While focusing on the same challenges facing engineering education, the partners will explore different ways in which these challenges are being responded to, using different methods of investigation, ranging from surveys, individual and group interviews, participatory observation, historical and philosophical analysis, and various forms of action-oriented research, or situated interventions. The work will be organized in the form of thematic projects that will first be conducted in parallel and then brought together in an active process of cross-fertilization. The results of the projects will be produced as separate reports and then presented in a more integrated fashion both at the series of out-reach activities discussed below in the project plan, as well as in a final jointly-written volume.

A. Social, economic, and environmental challenges in historical perspective

As a frame of reference for the research as a whole, this project will, at the outset, provide an overview, or background report, on the historical emergence of the three challenges that we have identified as being central to our alliance, what might be termed the environmental, social and technological, drawing on previous works of cultural history written by Andrew Jamison (e.g. Jamison 2001; Hård & Jamison 2005). The challenges facing engineering education in the contemporary world are not altogether new, and the further aim of this project is to investigate other periods in which engineering education was significantly reformed in order to meet social, economic and environmental challenges. In particular, the experiences of the early 20th century, with the rise of new science-based industry and, with it, the need for new competencies on the part of engineers, will be examined, as will the reform processes of the 1970s and 1980s, when engineering education took on the challenges of the post-world war II era concerning environmental, social, and technological changes.

The specific focus of this project will be the ways in which 'contextual knowledge' about the social and economic contexts of engineering have been brought into engineering education, first in the early 20th century, and then in the 1970s and 1980s, and, as such, it is closely connected to project E. The project will apply historical methods, examining archival material and other forms of relevant documentation, as well as, for the more recent period, a limited number of interviews with key actors in the major reform activities, in particular the establishment of Aalborg University and the promulgation of problem-based learning in engineering education. This project will be managed by Andrew Jamison, professor of technology, environment and society at Aalborg University, in cooperation with Matthias Heymann, a historian of technology at Aarhus University

and Ulrik Jørgensen at DTU, who has written on the history of technology and engineering education.

B. Curriculum design and learning outcomes

One of the most constraining elements to reforming engineering education is on the one side to align the curriculum to new societal demands and on the other side to avoid an overloaded curriculum. Sheppard et al (2009) (in *Educating Engineers: Designing for the Future of the Field* produced for the Carnegie Foundation for the Advancement of Teaching) have shown, that a number of strategies have emerged in the educational response to these new requirements. The dominant model for developing undergraduate programmes is based on traditional academic disciplines with a deductive approach to teaching, learning and practice and involves a linear building block model that is focused on primarily technical knowledge. However, this model is not aligned with the new requirements from society (Williams 2002; Jørgensen 2007; Graff & Kolmos 2007).

The project will compare curriculum reform and educational initiatives at Danish engineering programs (both at AAU, DTU and selected engineering colleges) by focusing on how the challenges facing engineering are being met in the construction of the curriculum and, in turn, how differences in curriculum models are reflected in students' learning outcomes. The intention is to examine different strategies and choices in the mixing of pedagogical form and the construction of specific projects and problems that are included in the curriculum and the rationale behind these choices. How effective are the different approaches in preparing engineering students for dealing with the challenges that they will be facing as they enter into professional careers? Methodologically, curriculum design and educational initiatives will be investigated based on documentary content analyses combined with qualitative interviewing of faculty, as well as key actors such as external evaluators. A mix of surveys among large samples of students and tests, assignments and other experimental designs will provide data on student learning outcomes with the intent of comparing the effectiveness of different curricula and pedagogical approaches. The project will draw on the experience and methods of major studies that have recently been carried out in the United States, and some of those involved in those studies have agreed to take part in the project as international advisers (see section 8, below). An important outcome will be the development of new instruments for understanding how curricular models affect learning outcomes. This project is to be managed by Professor Anette Kolmos and involve Associate Professor Xiangyun Du and Associate Professor Jette Holgaard at the Chair for Problem-Based Learning in Engineering Education at Aalborg University, in cooperation with Niels Mejlgaard, a political scientist specialized in survey methodology, at Aarhus University.

C. Models and simulations in engineering

The instrumental character of large parts of engineering knowledge builds on idealised models of complex situations in the form of constructions, engines, control systems, etc. Engineering science is not just applied natural science, but is a distinct and intentional approach to model and simulate socio-technical systems. Simulation models have been growing in importance in many fields of engineering, not least in relation to climate change, due to the growing sophistication and proliferation of information and communication technologies.

The way in which engineers handle complexity has changed dramatically during the last part of the 20th century, primarily due to the development of computers. Today computer simulation is an essential part of engineering work. It is important both as tool in engineering research and as tool for solving concrete practical problems in industry and other areas of the modern society. An important part of the project will be a detailed study of the development of simulation models and how they are used both in engineering research as well as in selected application areas. In this regard, there will be a close interaction with the ethnographic studies in project D. The central outcome will be the development of a classification of the kinds of simulation models in engineering science and practice and to study the conceptual and epistemological changes in concept formation and problem solving. These studies will provide an important basis for the

alliance's discussion of didactics in engineering education. This project is to be managed by Stig Andur Pedersen, professor of philosophy at Roskilde University Center, in cooperation with Vincent Hendricks, formerly at Roskilde and now at the University of Copenhagen, Ulrik Jørgensen, professor at the department of management engineering at DTU, and Matthias Heymann.

D. Design capabilities and engineering practices in industry

Project D will focus on specific domains of practice/knowing in engineering in industrial and other occupational contexts. This will enable us to understand how specific labour market demands in relation to engineering competencies are constituted and translated into engineering practices. The term 'practice' is an in-between concept which relates on the one hand to the semantic domain of habit and habitual action, and on the other, to the domain of deliberate action. By applying a practice 'lens' it will be possible to obtain a clearer picture of labour market demands for engineering competencies than can be obtained by means of statistics and quantitative surveys.

The project will use methods of ethnographic fieldwork, qualitative interviews and discourse analyses of significant texts. We will focus our research on the specific domains of engineering that are most closely connected to the challenges that form our point of departure, and investigate differences of perspective among co-participants in material-discursive practices, how opportunities for learning are developed within relevant communities of practice, and how individuals are included, excluded and positioned according to the predominant forms of habituation, or habitus. We will finalize the research sites for our investigation when we have received funding, but attach letters from three of the types of companies that will be studied: one large company, VESTAS, one small company, INVISIO, and a consulting company, COWI. In relation to the project as a whole, this project will provide a grounded knowledge as to how the challenges appear, or are made real, in actual engineering life-worlds. This project will be managed by Ulrik Jørgensen, in cooperation with Anders Buch, who has carried out research on engineering identities at the Danish Association of Engineers (IDA), and Lars Bo Henriksen, Aalborg University.

E. Integrating contextual knowledge into engineering education

Even though contextual knowledge and socio-technical competencies that are essential for meeting the challenges facing engineering have in principle been given high priority in Denmark, both in legal documents and in terms of accreditation procedures the problems of integrating these ingredients into engineering education and to align them with the dominant agendas of engineering disciplines has been quite difficult (Ollis et al 2004; Christensen et al 2009). At the regulatory level a lack of consistency of formulation in orders from the Danish Government and Danish accreditation criteria may be observed, and it will be an important part of the project to investigate how criteria for this accreditation is constituted and the various motives, or rationales that guide how accreditation guidelines are translated into curriculum requirements. This project will further compare the ways in which contextual knowledge is brought into engineering degree programs in Denmark by means of a content analysis of course and program descriptions and by qualitative focus group interviews of faculty and engineering students at the bachelor's level at Aalborg University, DTU, and selected university engineering colleges, to identify strengths and weaknesses of different approaches.

Project E also has the aim to identify 'best practices' internationally that might be instituted in Denmark as part of our recommendations for reforming engineering education. Thus participant observation and focus group interviews will be carried out at Delft University of Technology, Stanford, and Colorado School of Mines, working with members of our international advisory board, where a range of efforts have been made to integrate contextual knowledge into engineering education, in response to the challenges that are central to our project. This project will be managed by Steen Hyldgaard Christensen, who has been responsible for international comparative research on humanities and engineering (Christensen 2007, 2009), and teaches at Aarhus University Institute of Business and Technology, in cooperation with Andrew Jamison and Ulrik Jørgensen, who have been active in teaching contextual knowledge at AAU and DTU respectively.

7. Project plan

The project is planned to be carried out in four phases:

- A first phase of some six months will be used to initiate the research alliance among the partners and to specify, for each thematic project the exact nature of the international collaboration, in terms of timing when research visits by our international advisers will be arranged, as well as in terms of organizing in detail the work process among the partners. Although the general structure of the research has already been formulated, it will be especially important in an initial, first phase to plan the precise ways in which interactions between the separate projects will be maintained. This will be done by planning the scope and schedule of the workshops that will be held in the second phase, including the invitation and scheduling of international commentators/collaborators, as well as by organizing the ‘division of labour’ in relation to the production of the research reports and more formal publications to follow. The partners will meet in an initial planning conference, which will also include presentations by international colleagues and intended collaborators that will lead to a volume of proceedings. This volume will serve as a shared point of departure for the characterization of the challenges facing engineering and engineering education that are to serve as the basis for the research to come. By reviewing the ways in which the various paradigms or research approaches that are to be combined in the program have investigated these challenges, the conference and proceedings volume will serve an important learning function and help the partners better ‘get to know’ each other and their different methods, concepts, and theories.
- A second, longer phase of some 24 months will consist primarily of empirically-based research investigation in the five projects described above. While each project will have its own methodology and internal organization, there will be ongoing interaction between the projects by means of regular discussions and active ‘hands-on’ involvement on the part of Andrew Jamison, the alliance coordinator, who will regularly visit and interact with each of the project teams. There will also be a series of workshops for the entire Alliance, approximately every four months, where participants in the different projects, with their international collaborators, where relevant, will present and discuss the work in progress. Especially important in this second phase will be the exchange of experience with our international collaborators, by means of extended visits in which our international collaborators visit Denmark and in which the alliance members visit other countries to learn more about the good examples as to how educational institutions are responding to the challenges facing engineering and engineering education.
- A third phase of some 18 months, overlapping with the second, will involve a range of out-reach activities with relevant users, engineers and engineering educators, both at the alliance members’ institutions, as well as with the specialized societies within the Danish Association of Engineers, the accreditation board ACE, and with DACIN (Danish Centre for Engineering Education Development) responsible for pedagogical training of staff at Engineering University Colleges. These out-reach activities will make use of various action, or intervention methods, that have been developed and used by alliance members in their research and teaching. Thematically, such topics as the role of science in engineering education, the hidden assumptions behind the knowledge hierarchies that exist, the construction of engineering identities, and, not least, the perceptions of the challenges facing engineering will be taken up with the help of such techniques as role play, dialogue workshops and interactive seminars. The kinds of ‘change-oriented’ research that Andrew Jamison has carried out in relation to environmental politics (e.g. Jamison 2001), and the experiences of Anette Kolmos and Ulrik Jørgensen in relation to evaluating and designing new approaches to engineering education will be valuable points of reference. These activities will include both experiments that are based on some of the creative design and laboratory techniques that are used by DACIN involved in the

training of engineering education staff at university colleges as well as more traditional forms of seminars and workshops. These interactive experiments will be carried out at engineering university colleges (e.g. in Copenhagen, Hørsens, Odense, as well as Herning) and in bachelor programs at AAU and DTU. The experiences and audiovisual documentation of these out-reach exercises will then be analyzed and discussed in a process of reflection at 'internal' workshops and provide an important input in our collective understanding of processes of change, as well as the barriers to changing engineering education. A key aspect will be to identify, and characterize the activity of potential change agents, that is, those people in the organizations that will be involved in these activities, who are interested in facilitating reform processes.

- A fourth phase, or the final year, will consist both in the production of an anthology with edited versions of papers that will first be presented at a final international conference, with invited contributions by our international collaborators and others, as well as a jointly-written book by the alliance members on the results and recommendations of the research program. This conference will be organized together with an invited panel, or organizing committee, with high-level representatives from the companies, organizations, and the engineering associations that have taken part in the research, as well as deans and other administrators of engineering education. Andrew Jamison, who has long experience in both editing anthologies and in collaborative book projects, will be responsible for, and serve as the lead editor for both of these publications. The final jointly-written book will attempt to combine the separate areas of expertise, and the separate results of the projects that will also be published in journals, into a more coherent synthesis. It will be important to blend the abstract, philosophical and epistemological interests of some of the partners with the practical, empirical and pedagogical interests of others into a common language and a shared product.

8. Project's international dimension

The project will involve the active collaboration of leading international researchers in engineering education, philosophy of technology, and in science, technology and engineering studies, with whom the members have long-standing relations. In the proposed research program international scholars who are active in reforming engineering and engineering education will take active part in the various workshops and conferences specified above, and funds are budgeted for some of them to make extended visits of one to two month duration, to take part in research and out-reach activities in Denmark. Our international advisers will also serve as hosts for Danish research visits by alliance members, in relation to the thematic projects. The international colleagues will serve on an international advisory board that will be a part of the overall management of the program. Among those who have agreed to participate are:

- Atsushi Akera, professor at Rensselaer Polytechnic Institute working with the role of computers in engineering science and the historic changes in engineering education.
- Cinthia Atman, professor in industrial engineering and engineering education research at the University of Washington, director for two centres working with curriculum development and contextual knowledge.
- Caroline Baillie, Professor at University of Western Australia and leading author of several books on engineering education and ethics.
- Sharon Beder, an engineer by training and currently professor in Media and Communication at the University of Wollongong, author of many books on global challenges to engineering.
- Peter Kroes, professor of philosophy of technology, Delft University of Technology, where contextual knowledge and other forms of non-technical instruction have been integrated into engineering education.
- Carl Mitcham, professor of philosophy, Colorado School of Mines, and initiator of the educational program in Humanitarian Engineering, and a leading figure in the philosophy of technology.

- Sheri Sheppard, professor of mechanical engineering at Stanford University and associate vice provost for graduate education, lead author of *Educating Engineers* (2009), the report of the Carnegie Foundation of the Advancement of Teaching.
- Bach Tan Sinh, department head, National Institute for Science and Technology Policy and Strategy Studies in Vietnam, who has known Danish engineering as a student (PhD from Aalborg) and research collaborator, and now works with human resources development and in a number of projects on adaptation to climate change in Asia.

9. Legal and ethical aspects

The ethical aspects of qualitative research are well known to the alliance partners, and every effort will be taken to respect the privacy and integrity of those who are subject to our research investigations. Since we are humanists and social scientists, the legal issues around the rights to our intellectual results are not considered commercial property by any of us, but obviously the publishers with whom we negotiate will be treated with due professional respect for their legal procedures in relation to copyright and other legal matters.

10. Publication and promotional strategy

Since we are an alliance of many different researchers at different stages in our research careers there will be a variety of publishing and promotional strategies that will be pursued. The logic of the proposal is that the project is divided into two main parts, one of which will consist of somewhat independent research projects, and one of which will be more actively coordinated and collective in nature. This means that, in the one part, the publishing and promotional strategies can be expected to be more diverse, with the partners attempting to follow their own agendas and connect the findings and publication of those findings to their overall research strategy, while in the other, second part of the project, the collective strategy will be two-fold:

- On the one hand, by actively disseminating the results through out-reach activities in explicitly non-academic form, we will seek to reach as many potential users of our results as possible, among engineering educators, administrators and active engineers,
- On the other hand, we will aim with our anthology and jointly-written final volume, to make a contribution to the ongoing international discussion about reforming engineering education, by publishing with respected international publishers and by actively promoting the works in the international societies and networks that are concerned with engineering studies and engineering education

11. Exploitation of results

The importance of bringing new inputs into engineering education to deal more effectively with the challenges of climate change, technologically-influenced societal change and techno-scientific change requires that our results do not merely enter into the scholarly, or academic literature, however valuable that also is, but that they also are exploited and utilized by relevant stakeholders, especially engineering educators and working engineers.

By actively reaching out with our research results to engineering educators and to decision-makers in both the public and private sectors, the alliance will attempt to generate a meaningful exploitation of the results into the life-worlds of engineering and engineering education. This will require both dissemination and popularization, and not least the active participation of those involved in engineering education in our out-reach activities. It is also to be hoped that the project's results will be exploited by the Danish accreditation body ACE in the future development of accreditation criteria.

The exploitation of our results by the international scientific community will be fostered via publications and meetings of the international networks within which we are actively involved - in

engineering education research, engineering studies, science and technology studies, and philosophy and history of technology. Since we are members of editorial boards and governing bodies of several relevant journals, scholarly societies and networks, we will also be able to see to it that our results enter into the ongoing and more informal conversations within these societies and networks. As such, we seek a maximum exploitation of our results by relevant academic communities, as well as among engineering educators.

12. Participating parties' scientific competencies and contributions to the alliance

Andrew Jamison, the overall coordinator of the program, has carried out research on science and technology policy and theory of science and engineering for over 30 years. He has an undergraduate degree in history and science from Harvard University and a PhD from University of Gothenburg in theory of science. He has been professor of technology and society at Aalborg University since 1996 (changed to technology, environment and society in 2004). He has been involved in science and engineering education since the early 1970s when he organized and directed a course on science and society for natural science students at the University of Copenhagen, and he later taught at Lund University, Roskilde University, University of Gothenburg and the University of California, Los Angeles in courses in the history and theory of science and science, technology and society. He has published widely on environmental politics, social movements, and intellectual history, most recently *The Making of Green Knowledge* (2001) and, with Mikael Hård, *Hubris and Hybrids - A Cultural History of Technology and Science* (2005). He has worked with all of the other members of the alliance in teaching and research activities.

His current position at Aalborg involves teaching contextual knowledge in undergraduate science and engineering programs, together with associate professors Jette Holgaard, Xiangyun Du, Lars Bo Henriksen, who are also involved with the newly-established UNESCO Chair in Problem-Based Learning in Engineering Education (UCPBL) at Aalborg University, headed by Professor Anette Kolmos, the incoming president of the European Society for Engineering Education (SEFI), who has been carrying out research in engineering education for over 15 years. The Chair has been established as part of a global network to foster research and international exchange in doctoral education on problem-based learning in engineering. Several international research projects have been established with, e.g. Victoria University, Australia and Beijing Normal University, China. The UCPBL works in close collaboration with the SEFI Working group on European Engineering Education Research and as part of this organization is involved in a NNEER (Nordic Network for Engineering Education Research). Furthermore, there is a close collaboration with the Danish Centre for Engineering Education Development and Research located at the Engineering University College at Ballerup, Denmark, which is to be actively involved in the out-reach activities.

The Department of Management Engineering at the Technical University of Denmark (DTU) has been studying engineering practices and educations since the 1980s. The emphasis has been on engineering practice studied with the use of qualitative and quantitative methods (Jakobsen & Jørgensen 1984), ethnographies of engineering projects (Jørgensen 2002), as well as quantitative analysis of the labour market for engineering in Denmark. Since 2001 the department has been involved in the program for Design and Innovation at DTU which has become one of the major new and successful educational reforms. Ulrik Jørgensen headed the planning of this education and is responsible for the teaching of Philosophy of Engineering to all students at DTU (Jørgensen 2009). Anders Buch is working part time at DTU and part time in The Danish Society of Engineers. He has been working with ethnographic studies in engineering and has published on Social Learning (Buch 2002) and conducted studies of engineering identities which is being published in the forthcoming book on knowledge work (2009).

Three units at the University of Aarhus will participate in the alliance, participating in different themes: the Institute of Business and Technology in Herning (HIH), the Danish Centre for Studies in Research and Research Policy (CFA), and the Department of Science Studies. Steen Hyldgaard Christensen (HIH) has recently been engaged in several major international, EU-funded projects on

contemporary challenges to engineering (Christensen et al 2007, 2009) and will manage thematic project E. Niels Mejlgaard (CFA), has taught contextual knowledge at Aalborg, where he received his PhD and is now an associate professor at CFA, which monitors developments in science, technology and innovation policy in Denmark and internationally. Mejlgaard has participated in several international research projects related to human resources and capacities in science and engineering, measures and statistical indicators of R&D, and public communication of science and technology. Mejlgaard has a particular expertise in survey methodology, which will be utilized primarily in thematic project B. Matthias Heymann at the Department of Science Studies has done extensive work on the history of engineering design and on methodological discussions in engineering design education (Heymann 2005, 2009) and will provide historical expertise to thematic projects A and C.

The Science Studies research group at Roskilde University has, since the 1970s, been involved in studies of medical and engineering practises and the role of mathematics and natural sciences in such practises. A main focus has been to characterise the structure of theories and knowledge in the scientific disciplines that are part of and play an active role in medical and engineering problem solving. The main approach has been historical and epistemological. A recent contribution has been a reader in the philosophy of technology (Olsen & Pedersen 2008). Since 2007 the group has been involved in the development of a new technological-humanistic basic education and bachelor program at Roskilde University, which started in 2008.

13. Project management

The program is to be organized and managed as a cooperative alliance between four universities – Aalborg, Århus, Roskilde and DTU – with the coordination based at Aalborg University. Each university will be represented in the alliance by 2-4 senior researchers and there will be three Phd students, who will have supervision from senior researchers at at least two of the partner institutions.

Each member university will be represented in a steering committee, or management board, led by the overall coordinator, Andrew Jamison. The management board will meet every three months and decide on administrative and budgetary matters, and once a year all of the researchers in the alliance will meet at a conference, where the overall management and research agenda will be discussed.

Each phase that is presented in section 6 will have a particular form of organization and management. Phase 1, including the initial workshop and conference will be organized jointly by the management board. Phase 2 will be organized in a more decentralized manner, with Andrew Jamison managing project A, Anette Kolmos managing project B, Stig Andur Pedersen managing project C, Ulrik Jørgensen managing project D, and Steen Hyldgaard Christensen managing project E. The results of the research will be presented at workshops and out-reach activities, and collected in an anthology, edited by Andrew Jamison, and provide the basis for the collectively-written final volume

The empirical research in the projects will be refined and planned in detail during the first phase of the program. Since the aim of the research alliance is to connect in an active and explicit way the different research approaches of the members, there will be at least one other institution represented in each project, and on site visits to the other members will be part of the empirical research. Exactly how this is to be carried out will be formalized once the program begins.

In the third phase, each out-reach activity will be organized by the management board in cooperation with engineering educators, administrators and other users, who are already rooted and experienced in dissemination activities. Several engineering colleges have expressed interest in taking part, and an advisory user group will be established to help manage the out-reach activities. The editing of the final book and the management of the final conference will be the responsibility of the entire board, but Andrew Jamison will play a leading role, due to his long experience in editing and writing books.

The external contribution to this project is in this application coming from the Association of Danish Engineers and the institutions providing engineering training at CVU and as bachelor's programs, as well as by the various companies, providing access to studying engineering practice and participating in the implementation of the results of the project. We have taken contact with COWI, VESTAS and received a positive interest, and will obviously contact several more companies when we receive financing. Indirectly there will be contributions from the Federation of Danish Industry and other companies, who will be involved in the empirical studies.

14. Network function

One of the main reasons for applying for this project is the fragmented nature of expertise in Denmark in relation to engineering and engineering education. In terms of networks, this means that history of engineering and engineering education, engineering education itself, engineering philosophy, engineering studies, and the broader humanistic study of engineering are all organized in separate networks, both within Denmark, as well as internationally.

Since the alliance partners have all been active in these different networks, one of the ambitions of the proposed project is to contribute to a much more active conversation and interconnection between the different areas of interest, and the proposal can be seen as an attempt to create a new kind of 'meta-network' among scholars interested in reforming engineering education. This also has an important international dimension, in that our research can enrich the different international networks within which we are involved by facilitating increased interactions across networks. A similar kind of enrichment can be anticipated with our own separate PhD and master programs, where the alliance can contribute to a broadening of expertise and an increased interaction and 'collective learning' process.

It is extremely difficult to foresee how successful the effort will be, since the forces of separation or fragmentation are quite strong, and it is hard to imagine that possibilities for pursuing interdisciplinary or cross-disciplinary careers will become significantly better in the four years to come. However, the alliance will actively try to connect people, both within Denmark and internationally, and, as such, carry out a network function that can hopefully improve the situation.

If we are to meet successfully the challenges that we are addressing in the proposed research alliance it will be necessary to break through established and entrenched routines and ways of working. The search for more effective and meaningful ways to combine pedagogical form and substantive content, and, for that matter, theory and practice, that will be the topic for our research is not limited to engineering education, and so the ultimate 'network function' of our alliance is to spread the results of our search to other areas of education and education research, and to society as a whole.

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