Chapter 12
Socio-technical Integration in Engineering Education: A Never-Ending Story

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Abstract The introduction of theory of science in Danish engineering education may be seen as an exemplary attempt to integrate socio-technical and contextual competencies into bachelor's engineering degree programmes. In this chapter, we set out to investigate in what way boundary definition and demarcation between technical text and social context have influenced the process of introducing and implementing theory of science into professional engineering bachelor's degree programmes. To set the stage, we first discuss how contextual issues and socio-technical competencies have been incorporated in accreditation criteria for first-cycle engineering degree programmes in the United States and Europe and some of the impediments for responding in engineering education. Second, we give a brief account of the rationale for implementing theory of science into Danish professional engineering bachelor's degree programmes. Third, we discuss our findings from an institutional example: a longitudinal case study carried out at Aarhus University, Institute of Business and Technology from spring 2007 to fall 2010.

Keywords Dialectics of boundary definition • Socio-technical competence • Contextual knowledge • Theory of science • Contested area • Translation process • Discursive strategies

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S.H. Christensen et al. (eds.), *Engineering, Development and Philosophy*,
Philosophy of Engineering and Technology 11, DOI 10.1007/978-94-007-5282-5_12,
© Springer Science+Business Media Dordrecht 2012

Introduction

The importance of incorporating contextual issues and developing socio-technical competencies in engineering education has been widely acknowledged in the engineering education community in Australia, Europe and the United States. High-quality engineering design requires understanding of how the engineered artefact interacts with individuals, society and the environment, both natural and manmade. In the US, the ABET EC 2000 criteria (www.abet.org) for accrediting engineering programmes incorporate context in two out of eleven programme outcomes (a–k) under criterion 3. The two context-related outcomes to be achieved by first-cycle engineering students are (c) 'an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability' and (h) 'the broad education necessary to understand the impact of engineering solutions in a global, economic, and societal context'. In the European EUR-ACE accreditation framework (Document A1-en Final 17 November 2005, Document C1-en Final 17 November 2005), context is incorporated as one outcome out of five under the heading 'Transferable Skills'. First-cycle engineering students are expected to 'demonstrate awareness of the health, safety and legal issues and responsibilities of engineering practice, the impact of engineering solutions in a societal and environmental context, and commit to professional ethics, responsibilities and norms of engineering practice'. In Denmark, Executive Order No. 527 of 21 June 2002, from the Danish Ministry of Education, ordains inclusion of contextual concerns as one outcome out of five. Students graduating from professional engineering degree programmes should thus be able to 'plan, realize and control technical plants, and in doing so, include societal, economic, environmental and work environmental consequences in the solution of technical problems'. As it appears both in the EUR-ACE transferable skills criterion and the Danish executive order, there is a clear resonance with the American EC 2000 programme outcomes mentioned above. A common feature in all three sets of outcome and goals is that emphasis should be put on increasing the *breadth of problem scoping* (Kilgore et al. 2007) to embrace both local and global contexts when engaging in a design task.

However, contextual concerns defined in the US EC 2000 outcome (c) as an injunction to engineers to increase the breadth of problem scoping are but one out of a broader range of socio-technical competencies to be acquired by first-cycle engineering graduates. In the EC 2000 criterion 3 (see below), no less than five (d, f, g, h, j) out of eleven outcomes are socio-technical competencies required of first-cycle engineering graduates. Outcome (i) and to some extent also outcome (j) cannot be said to be socio-technical competencies in a narrow sense. They should be interpreted as an injunction to engineers to currently update and develop their knowledge, skills and competencies. However, all six outcomes below relate directly to liberal education (Ollis et al. 2004):

(d) Ability to function on multidisciplinary teams
(f) Understanding professional and ethical responsibilities
(g) Ability to communicate effectively
(h) Understanding impact of engineering solutions in a global and societal context
(i) Ability to engage in lifelong learning
(j) Knowledge of contemporary issues

Acquiring these socio-technical competencies is aimed at enabling students to focus on the general perspective and thus to contemplate their actions and their future profession in the larger context.

The broad education requirement as formulated in the EC 2000 criteria 3 under outcome (h) above is thus focused more broadly on the consequences of technology. The meaning of context here is different from outcome (c). The aim of outcome (h) is to incorporate contextual knowledge as background knowledge related to the relationship between science, technology and society. One way to interpret outcome (h) would be to see it as an STS requirement. Considerations of the impact of engineering solutions in a global, economic, environmental and societal context therefore incorporate a broad variety of strategies and approaches. Since context is a dialectical concept, perceptions of boundaries between technical *text* and social *context* differ both among engineers and non-engineers. This observation is equally valid for the EC 2000's outcomes (c) and (h). Boundaries between *the technical* and *the social* are not stable entities, neither in engineering education nor in engineering practice, but are amenable to reflection, negotiation and change over time (Bucciarelli et al. 1997; Faulkner 2000, 2007). Contextualization thus unfolds its inherent dialectic in the realm between *is* and *ought* both in engineering practice and in education. In engineering education, the dialectic of boundary definition may be highlighted by the two fundamental questions: What is engineering for? What are engineering studies for? (Downey 2009)

The introduction of 'theory of science' in Danish engineering education may be seen as an exemplary attempt to integrate contextual issues and socio-technical competencies into engineering bachelor's degree programmes in much the same way as defined in EC 2000 outcome (h). However, since the 2000 decision to introduce theory of science, this curricular novelty has given rise to a good deal of hesitation, resistance and controversy resulting in a considerable delay in its implementation (Christensen and Ernø-Kjølhede 2008, 2009). A possible explanation for the hesitation and in some respects resistance lies at an epistemological level. The dominant identity of engineers as 'problem solvers' has been moulded upon an epistemological distinction in engineering curricula between technical core and the non-technical periphery. The technical core/non-technical periphery distinction has had the consequence that knowledge hierarchies have emerged, which in many ways act as barrier mechanisms for development of socio-technical competencies. Usually, attempts to develop such competencies are relegated to the non-technical periphery as add-on components to an already overcrowded curriculum (Downey et al. 2007).

Hybrid engineering degree programmes, however, are interesting exceptions with different epistemologies which to some degree should make it easier to overcome epistemological barrier mechanisms. We therefore examine both a purely technical and two hybrid engineering degree programmes in our longitudinal case study below.

In many ways, theory of science has been a challenge to engineering identity. Hence, outcome and approaches have been very different among the Danish engineering education institutions (Christensen and Ernø-Kjølhede 2008, 2009). Before we embark on an account of the translation process that theory of science went through to gain legitimacy at our institute, let us very briefly look into what initiated the discussion on introducing theory of science in engineering education in Denmark (for a more comprehensive account, see Fink 2001; Christensen 2003, 2005; Christensen and Ernø-Kjølhede 2008, 2009; Hussman and May 2009).

The Struggle for the Soul of Engineering: Four Discursive Strategies to Tackle the Implementation of Theory of Science into Professional Bachelor Engineering Education

In 2000, theory of science became a compulsory curricular element in all bachelor's degree programmes in Denmark. This curricular novelty was intended to replace a previous Danish university tradition of offering what was called *philosophicum* or *studium generale* courses intended to provide a general understanding of scientific work and specialization. Contrary to that, theory of science was meant to be a platform for specific reflections on professional identity related to the following: (1) the objects, theories and worldview of the professional field, (2) the relationship to other professional fields and disciplines and (3) the relationship between professional fields and society (Christensen 2005).

The new curricular ingredient was expected to be fully implemented by 2004. The aim of theory of science was laid down in a letter to higher education institutions from the Danish Government in 2000. The letter stipulated that for all degree programmes both academic and professional:

> Students should be offered an opportunity to qualify their professional specialty by seeing it in a broader and more general perspective, and that 'The content of this curricular component must correspond to its purpose, namely to ensure correspondence between professional concerns and relevant concerns of a more general nature'.
>
> (Ministry of Education 2000)

In 2006, The Danish Evaluation Institute (EVA) formulated the following accreditation criterion (criterion 15 out of a total of 40 accreditation criteria) only for professional engineering degree programmes: 'Research methodology and theory of science must be part of the professional degree program in order to enable students to follow and apply R&D results in their field of specialization' (Danmarks Evalueringsinstitut 2006, 2008). It is noteworthy here that both research methodology and theory of science are made a compulsory requirement in order to achieve accreditation of professional engineering bachelor's degree programmes. Three additional criteria (9, 12 and 16), which together with criterion 15 were defined as 'central criteria', stipulate requirements for R&D underpinning of professional engineering degree programmes and their knowledge base:

> Criterion 9: Easy access to and integration of knowledge about research and research results related to the specific field of the degree programme should be provided through collaboration with universities and/or sector research institutions.
>
> Criterion 12: The knowledge base of professional training must embrace results from both Danish and international R&D and experimental work.
>
> Criterion 16: Professional training must integrate results from national and international R&D and experimental work relevant for the profession and well suited to serve as exemplars for the development and application of new professional knowledge.

Today, theory of science has been fully implemented in all engineering bachelor's degree programmes, whether professional or academic, in Denmark. Approaches have been different but nevertheless, theory of science has now found a place in engineering curricula. An overall assessment of the outcome has, however, not yet been carried out.

What concerns us here is the chain of reaction between the general governmental stipulations put forwards in 2000, the specific accreditation criteria put forwards by the Danish Evaluation Institute (EVA) in 2006 and the process of institutional implementation taking place from 2001 onwards. An indication of doubt, hesitation and controversy regarding institutional response strategies on the part of engineering degree programmes is that the implementation process in general has been characterized by a considerable delay compared with the original goal that theory of science should be implemented by 2004. As the initiative did not originate in the engineering community but was imposed, both internal and external constituencies became entangled in a struggle over the soul of engineering. Theory of science thus became a *contested area* and went through a *translation process* where discursive strategies were mobilized by relevant constituencies to safeguard or redefine boundaries between the technical and the social in engineering education (Christensen and Ernø-Kjølhede 2008, 2009).

Based on previous research by the authors (2008, 2009) and based on a reading of a number of other sources (mentioned below), we argue that it is possible to construct a typology of responses or discursive strategies that stakeholders might adopt when faced with challenges that seek to alter the balance and the boundaries between the social and the technical. And clearly, engineering education is a sort of battleground where the contested area is fought out. We believe that four basic discursive strategies may be and have been mobilized by stakeholders in the Danish case:

1. *The discourse of Bildung* addressing the engineer as a human being (For the German origin of the notion of Bildung, see, e.g. Ringer 1969; Gispen 1989. For US connotations, see, e.g. Florman 1987, 1996. For the Danish discourse of Bildung, in which theory of science in engineering became embedded, see, e.g. Børsen Hansen et al. 2000; Johansen 2002; Sjöbjerg 2005; Christensen 2003, 2005; Christensen et al. 2006)
2. *The discourse of business and commerce* addressing the engineer as a businessman (See, e.g. Goldman 1991; Johnston et al. 1996; Holt 2001; Undervisningsministeriet 2005, 2006; The Danish Government 2006)

3. *The discourse of engineering science* addressing the engineer as an innovator and researcher (See, e.g. The Danish Evaluation Institute (EVA) in 2006, 2008; Millennium project 2008; The National Academies 2009)
4. *The discourse of engineering practice* addressing the engineer as a professional problem solver in different professional roles such as, e.g. the environmental consultant, the designer, the system builder, the staging director and the model developer (See, e.g. Bucciarelli et al. 1997; Beder 1997, 1999; Jørgensen 2003; Sheppard et al. 2009)

In the influential formulation of Bourdieu (see Nash 1999), what was at stake in the debate on how to implement theory of science in Danish engineering education was the formation of the *habitus* of engineers. In Bourdieu's definition, habitus implies a set of habits and dispositions that have been inculcated through a social acculturation process: 'The habitus as the word implies, is that which one has acquired, but which has become durably incorporated in the body in the form of permanent dispositions… the habitus is a capital, but one which, because it is embodied, appears innate' (Nash 1999). *Capital* as we use it here is thus related to the habitus of engineers and refers to the cultural and social capital broadly defined that engineers acquire through their education. Historically, especially, the discourse of Bildung which relates to Bourdieu's notion of cultural capital has created a climate of controversy across the liberal arts-engineering divide, as this discourse was and still is alien to many engineers and largely seen as a misguided effort to reform engineering education. Moreover, the discourse of Bildung was implicitly seen as a proxy for the cultural capital of an elitist Mandarin culture (Ringer 1969; Gispen 1989) which was aptly described by C. P. Snow in 1959 in his influential essay '*The two cultures and the scientific revolution*' (Snow 2001). As will appear from the analysis below, at our institute particularly, discourses 2 and 4 appear to have had formative influence on the positions taken by engineering faculty members in the process of implementing theory of science in professional bachelor engineering degree programmes.

Balancing the Social and the Technical: An Institutional Example of the Implementation of Theory of Science into Professional Engineering Degree Programmes

The contention is that our institute provides a site that is well suited for a study of the process of implementation of theory of science as a proxy for the discussion of text and context in engineering education. The reason being that our institute at the professional bachelor's level offers both two hybrid engineering programmes mixing technical and social science (Global Management and Manufacturing and Business Development) and one purely technical engineering degree programme (Electronics).

We have investigated the *translation process* of the theory of science requirement into specific course programmes as a longitudinal study. We have studied teaching plans, required readings and lists of literature in the 3 professional engineering bachelor's degree programmes at our institute, and we have gathered empirical data from engineering faculty members. Our research design consists of both *ex ante* and *ex post* data collection. The *ex ante* data were collected in 2007 and 2008, while theory of science was in the preparatory phases and not yet fully implemented in the degree programmes. For the collection of the *ex ante* data, we used two methods, an anonymous questionnaire survey carried out in 2007 and semi-structured focus-group interviews carried out in 2008 in three focus groups with three faculty members of each degree programme[1] (this *ex ante* research was partly published in Christensen and Ernø-Kjølhede 2008, 2009). By 2010, theory of science was fully implemented in the bachelor's engineering degree programmes making it possible to carry out an *ex post* study. The method applied for this *ex post* study was semi-structured interviews with the two teachers responsible for theory of science in the bachelor's engineering programmes plus content analysis of course descriptions, teaching plans, required readings and lists of literature. In the following, we give a brief summary of our findings starting with the *ex ante* study drawing on data collected in 2007 and 2008 and published (in part) in 2008 and 2009.

Pre-implementation Expectations of and Attitudes Towards Theory of Science Among Teaching Staff

As theory of science is a new subject in the Danish engineering curriculum, it was, at the beginning of its implementation, not yet well established in the minds of engineering faculty members at our institute. A comment written on the back of a questionnaire filled in by a respondent may serve as an illustration: 'The issue (theory of science in engineering) and the way in which it is presented is some galaxies away from my world for which reason I haven't answered a number of questions. A more extensive oral presentation might have been able to compensate for my engineer's handicap'.

Below, question 11 out of a total of 16 questions is meant to highlight issues of relevance for theory of science for engineers and to measure attitudes among engineering faculty members towards these issues. Question 12 is intended to measure perceptions among engineering faculty members regarding the relative importance of theory of science and research methodology.

As responses to question 11 are not binding in the sense that they would have formative influence on the implementation of theory of science, they are more likely to measure perceptions of what engineering faculty members would think would be

[1] The questionnaire was distributed to 35 potential respondents comprising the entire full-time teaching staff of our institute's three professional bachelor's engineering degree programs in electronics, business development and global management and manufacturing (part-time teachers not included). 26 respondents filled in the questionnaire – one respondent however only partly. 16 respondents are engineers, 4 hold degrees in business studies, 5 in science and 1 in psychology.

Question 11 Please indicate on a scale from 1 to 5 the relevance of the below-mentioned issues for theory of science courses in engineering education

Dimension	A	B	C	D	E	F	G
Scale	Engineering roles and identity	Engineering culture and norms	The design process as a technical and social process	Knowledge generation and forms of knowledge in engineering work	The importance of technology and its impact on society	Ethical problems in engineering	Requirements of interdisciplinary and intercultural collaboration
1. Irrelevant	2	2	0	0	0	2	0
2. Minor relevance	4	7	2	2	0	1	1
Subtotal X 1+2 opponents	***6***	***9***	***2***	***2***	***0***	***3***	***1***
3. Some relevance	9	7	8	9	4	6	9
4. Relevant	7	8	10	8	12	12	6
5. Very relevant	3	1	5	6	9	4	9
Subtotal Y 3+4+5 proponents	***19***	***16***	***23***	***23***	***25***	***22***	***24***
Total	25	25	25	25	25	25	25

Question 12 How would you evaluate the relative importance of research methodology and theory of science respectively?

Scale	Frequency
1. To learn research methodology is more important than theory of science.	17
2. To learn theory of science is more important than research methodology.	0
3. Research methodology and theory of science are equally important.	7
4. Neither research methodology nor theory of science is important.	1
Total	25

'nice to know' for engineers (chiefly, 'The importance of technology and its impact on society' and 'Requirements of interdisciplinary and intercultural collaboration'). However, responses cannot be said to measure perceptions of what engineers would think they would 'need to know'. By contrast, responses to question 12 to a greater extent measure perceptions of what engineers think they would 'need to know' (research methodology is clearly rated as more important than theory of science).

In our analysis of the data from the three focus-group interviews carried out with teaching staff, we were furthermore able to identify a number of recurring arguments of an ideal typical nature. We have termed these arguments regarding the need, rationale and scope of theory of science as follows:

1. The 'no need' argument. Illustrative quote: 'The type of engineer that we educate is supposed to work in a company. He should be able to put things together and make them work. He is not supposed to question philosophically what he is doing and why he is doing it'.
2. The 'instrumentalize it' argument. Illustrative quote: 'Taking professional engineering degree programmes which are not wildly academic as a point of reference, I think some of these abstract concepts, especially the methodological part of theory of science, simply may help the students to become better at solving problems'.
3. The 'split it up' argument. Illustrative quote: 'In my view it is not wise to make theory of science an independent module. Ideally it should be taught when needed in specific engineering disciplines or problem areas. In so doing, it would not have the negative side effect of increasing the pressure to remove vital engineering topics'.
4. The 'trade-off' argument. Illustrative quote: 'Which new topics should be incorporated and which ones should be removed? At the moment the curriculum is tightly packed… with courses which we have selected very carefully and which have proved their value in a company context. If additional courses are to be incorporated into the engineering curriculum they must relate to the engineering mode of thinking. They should not be constrained to merely philosophical reflections'.

These arguments taken together clearly serve to demarcate a boundary between 'nice to know' and 'need to know'. As shown above, our findings demonstrate a clear demarcation between the relevance of theory of science as 'nice to know' and research methodology as 'need to know'. However, this boundary cannot simultaneously be interpreted as demarcating a boundary between 'the technical' and 'the social'. As an illustration, a respondent argues, 'A broader vision is needed. I firmly believe that to be able to cooperate with people with different educational backgrounds and participate in interdisciplinary and international collaboration we will have to learn to understand their norms and ways of framing and defining problems'. And another respondent comments that 'we are not used to thinking along these lines. It has something to do with the engineering way of thinking. We do not seek knowledge merely for the sake of knowledge to be able to discuss it in the lunch room'. Moreover, to demarcate the Bildung and engineering science discourses, the discourse of business and commerce and the discourse of engineering practice are in large measure mobilized by teacher respondents; some examples are the following:

> Example 1. They [the companies] say that the project managers they need must have business talent. They should be able to negotiate the right price and be capable of establishing networks both internally and externally.

> Example 2. They [the students] simply live and breathe for the companies, in which they are hired and in which they work. I personally feel likewise.

> Example 3. Our students have a very good reputation indeed in the local companies: quite often we receive mail from companies that wish to hire our students or ask whether we have students who will complete their study within a short time in order to offer them employment. This quality stamp on our education therefore allows us to conclude that we currently teach our students the qualifications which are requested by companies.

The overall impression of our *ex ante* study was thus that respondents gave more weight to concrete research methodology as compared to the more general concept of theory of science. Further, the respondents attached more importance to theory of science supporting the engineer as a businessman and problem solver rather than as a cultivated scientist. As also reported in our 2008 and 2009 articles, respondents on the whole held positive expectations and attitudes towards the inclusion of theory of science in the curricula. It was widely believed that theory of science had a potential to help improve the study programmes. However, it should also be noted that the implementation phase had been remarkably long (6–7 years by the time of the survey) and that interviews reflected a good deal of hesitation and doubt as to *how* theory of science might be implemented in order to improve the studies and as to exactly which parts of the study programmes it might be able to improve.

Post-implementation Expectations of and Attitudes Towards Theory of Science Among the Teachers of the Subject

In this section, we examine how theory of science has been implemented in the three professional engineering bachelor's degree programmes at our institute. Before embarking on this, it is necessary to briefly describe the epistemologies of the three programmes. Business development engineering (BDE) and global management and manufacturing (GMM) can be characterized as hybrid engineering degree programmes (combining social and technical science), and they differ from the third programme, electronic engineering, as the epistemological core/periphery distinction cannot be said to uniformly follow the technical core/non-technical periphery distinction. In GMM, it may even be argued that the epistemological distinction is one between the business core and the technical periphery. A GMM respondent in the focus-group interviews reported above thus observed that 'GMM could equally well have been positioned as a business degree program… focused on management and supply chain management'. In BDE, marketing, business creation and business knowledge are defined as the epistemological core. However, here the epistemological core also embraces technical issues which are seen as the basis for business creation. Among teacher respondents from electronic engineering, the epistemology is clearly moulded upon the technical core/non-technical periphery distinction for which reason a technical orientation clearly prevails. When therefore speaking of theory of science in these three engineering programmes, the crucial questions are the following: Theory of science and methodology for what? Business or technology? How much business and how much technology? And, can these concepts at all be separated?

We have carried out semi-structured interviews of one-hour duration with each of the two teachers responsible for theory of science at our institute, and we have made a content analysis of course descriptions, teaching plans, required readings and literature lists. In the spring semester 2009, 5 years after the year of implementation stipulated by the Danish government (2004), a new compulsory add-on course module was developed to be implemented in spring 2010. The workload of the course is equivalent to five ECTS (European Credit Transfer System) credit points, and in spring 2010, it was delivered (1) as a common course for students in electronic engineering and business development engineering at the sixth semester and (2) as a separate course for students in global management and manufacturing at the fifth or seventh semester.[2] The objectives of the course are defined as follows:

> The main purpose of the course is to give to the students a basic understanding of different approaches to problem-solving. Besides, the students are introduced to the relationship between scientific approaches and methods used to collect empirical information and data. The course also introduces students to professional cultures related to problem-solving and the conflicts and misunderstandings that may arise between the different perspectives. The students will also learn to assess alternative scientific approaches when defining solutions for specific issues.
>
> (Course description 20 November 2009)

Problem-solving in both engineering and business and inter-professional and intercultural collaboration are thus the central concerns in all three degree programmes. This is very much in line with the *ex ante* attitudes expressed by respondents above,

[2] As formulations of objectives and main areas of content in the two course descriptions differ in length but not in substance, we have chosen to quote only from the course description for electronic engineering and business development engineering as this course description is more elaborate than the one for GMM.

and it would thus seem that faculty attitudes and discourses 2 and 4 above have been very influential in shaping the theory of science course module. The course content is focused on the following main areas (Course description 20 November 2009):

- Knowledge of various scientific approaches such as positivism, post-positivism, systems theory, hermeneutics and social constructivism
- Understanding of the consequences of scientific positions at ontological, epistemological and methodological levels
- Understanding of the consequences of scientific theory for the concrete use of methods in connection with the resolution of a concrete problem
- Understanding of the link between theory of science and the way a scientific article is organized and written
- Understanding of the link between different professions and their methodological approaches to problem-solving.

For electronic engineering students and BDE students, the subject is taught by a teacher with a PhD in sociology and with an assistant teacher trained as an engineer. In the course for GMM students, the subject is taught by a teacher with a master's degree in business. The courses are based on lectures, student presentations and case study-based exercises. The literature in the courses mainly draws on business and social research methodology.[3]

In the interpretation of data from the semi-structured interviews with the two teachers of theory of science, we follow a fourfold structure: (1) attitudes among engineering faculty members and students at the beginning when theory of science was introduced, (2) the proportion of theory of science/research methodology related to technical science, social science and the humanities or other fields in the course, (3) the competencies that theory of science courses are meant to create and (4) attitudes among engineering faculty members and students today.

According to both teacher respondents, they were facing three challenges at the beginning when theory of science was first introduced: (1) to be able to interact constructively with engineering faculty members to get their support for the internal marketing of the course to students, (2) to be able to convince engineering faculty members that theory of science could help engineering students improve both their problem-solving skills and their ability to reflect critically and (3) to position theory of science and research methodology as part of the epistemological core in engineering problem-solving in the three degree programmes. Below, the teacher of the common course for students in electronic engineering and BDE gives the following characteristic of the initial situation:

[3] Examples of typical references are the following: Arbnor, Ingemar and Bjerke, Björn (1997). *Methodology for creating business knowledge*. Sage Publications. Bryman, Alan and Bell, Emma (2007). *Business research methods*. Oxford University Press, Oxford. Bryman, Alan (2004). *Social research methods*. Oxford University Press, Oxford, Guba, Egon and Lincoln, Yvonna S. (1994). Competing paradigms in Qualitative research. In: Denzin, Norman K. and Lincoln, Yvonna S. (Eds.). *Handbook of qualitative research*. Sage Publications, Neuman, Lawrence (2003). *Social research methods*. Allyn and Beacon Publishers.

> When I started I didn't see theory of science as the most fascinating subject to teach because of what I had heard… I really had to work hard to show that theory of science was not a threat to engineering students and faculty members… At the beginning faculty members were sceptical about me as I was seen as an academic (as opposed to a more practically oriented engineer. (inserted by the authors))… The engineering faculty members saw theory of science as something really academic… The students were told by engineering faculty members that theory of science is a boring subject… Engineering faculty members didn't try to make sense of it and adapt to this new curricular requirement.

The GMM teacher respondent characterizes both the initial and the present situations this way:

> As I see it theory of science is the glue that binds all the subjects in the engineering curriculum together… On the GMM program I have the feeling that the attitude of engineering faculty members towards theory of science is that they are not interested and that they really don't care about it.

The electronic engineering and BDE teacher respondent also notices that there is a difference in the readiness to accept different worldviews and approaches between electronic engineering students and BDE students:

> The readiness to accept that life can be different is higher in BDE than in electronic engineering… In electronic engineering the method is more rigid… In electronic engineering it is generally held that there is one right way and one right answer… Courses are not challenging students in the sense that they are confronted with different research paradigms and approaches… When they come to the course the BDE students are receptive to different approaches because they have seen the differences working in their courses.

Regarding the relative proportion between the more general theory of science component and the more specific research methodology component, the GMM teacher respondent comments:

> As the course is oriented towards practical application the main focus of the course is on methods and techniques… I would say 80% lies here which also makes it easier to sell the course to students… I would however not go so far as to suggest that Bildung should have no place in the course. In my course Bildung would amount to 20%.

The other teacher respondent comments that emphasis should be put on what is readily applicable in the engineer's toolbox and warns against too much emphasis on Bildung: 'If you design the course as a merely theoretical course with a focus on critical reflection and discussion after a while there would only be very few students left in the class'. Moreover, according to the electronic engineering and BDE teacher respondent, the proportion of research methodology related to technical science is 40%, social science 40% and the humanities or other fields in the course 20%. In GMM, the proportion is that 10% research methodology is related to technical science, 70% to social science and 20% to the humanities or other fields. Finally, regarding the various purposes that theory of science and research methodology are meant to support, the two teacher respondents unanimously carried out the following ranking (ranked by relative importance in the course):

1. The student's ability to solve concrete practical problems, be they commercial or technical in nature
2. The student's ability to collaborate with people who demarcate and define problems differently in a corporate setting

3. The student's ability to work in a scientific way both methodologically, theoretically and critically
4. The student's acquisition of a broad background of contextual knowledge – Bildung – related to the relationship between science, technology and society (STS)

As it appears, the ranking of the four purposes is in accordance with discourses 2 and 4 mentioned previously.

After completing the first common course for electronic engineering students and BDE students, the teacher comments that attitudes among engineering faculty members and students in BDE have changed positively, whereas attitudes among engineering faculty members and students in electronic engineering have remained sceptical as they were initially. This is a clear indication that the boundary between the technical and the social is drawn differently in hybrid engineering degree programmes and purely technical degree programmes illuminating a difference between heterogeneous and more 'mono-technical' engineering cultures. The teacher says it this way:

> The BDE students value the course because they can see that it makes them stronger… Presently both engineering faculty members and students see theory of science as a natural part of their study program… Among electronic engineering students and faculty members there is a more sceptical attitude as it is not so obvious for them that theory of science is relevant for them… Electronic engineering students didn't really take part in the course and they were not really able to see the use of it… because they so to speak work at the screwdriver level.

In GMM, attitudes among engineering faculty members have remained uninterested as they were at the beginning when the theory of science course was taught for the first time, 'they really don't care about it' as the teacher puts it. Students however are not negative towards the course but

> compared with the openness that I have experienced in introductory methodology courses at the first semester [in other degree programs] students are gradually socialized into a professional engineering culture which makes them less open in the final part of their study [where the course is taught]…However I have not experienced that engineering students are dissatisfied with my theory of science course.

We might therefore conclude that students from hybrid engineering degree programmes at our institute have attitudes towards theory of science and research methodology (as perceived by the teacher respondents) that are located along a continuum ranging from satisfied to not unsatisfied, whereas students from the technical degree programme are more sceptical as they cannot see the use of it and therefore find it hard to believe that it can help them in any way.

Conclusion

To be able to respond to the grand challenges of our time (The National Academies 2009) and to avoid engineering work declining into purely technical support vis-à-vis the threat from low-wage countries (Millennium Project 2008; Downey et al. 2007), it has been argued that there is a need for hybridization in engineering education

(Williams 2002; Jamison et al. 2011). 'Hybridization reflects the need for different communities to speak in more than one language in order to communicate at the boundaries and in the spaces between systems and subsystems' (Gibbons et al. 2005, p. 37). Moreover, Jamison et al. (2011) have argued that theory of science could be interpreted as an exemplary attempt to help develop a hybrid imagination in Danish engineering students:

> A hybrid imagination can be defined as the combination of a scientific-technical problem solving competence with an understanding of the problems that needs to be solved. It is a mixing of scientific knowledge and technical skills with what might be termed cultural empathy, that is, an interest in reflecting on the cultural implications of science and technology in general and one's own contribution as a scientist or engineer, in particular. It can be thought of as an attitude of humility or modesty, as opposed to arrogance and hubris, in regard to scientific and technological development, and for that matter, to any kind of human activity. A hybrid imagination involves recognizing the limits to what we as species and individuals can do, both the physical limits and constraints imposed by "reality" as well as those stemming from our own individual limits of capabilities and knowledge. As such, a hybrid imagination is often manifested collectively, involving collaboration between two or more people when it is not explicitly a part of a social or cultural movement.
>
> (Jamison et al. 2011, p. 4)

It would seem that such an endeavour is not an easy task. What has become evident from our longitudinal case study of the implementation of theory of science at our institute is that the degree of openness and readiness to acknowledge this new curricular component is varying in the three degree programmes both among engineering faculty members and students. Attitudes range from positive acknowledgement and indifference in the two hybrid degree programmes to scepticism and lack of acknowledgement in the more technical degree programme. It has also become evident that what engineering faculty members may say in an *ex ante* survey may differ from how they act when it concerns core aspects of their professional identity (the *ex ante* survey showed positive attitudes among faculty towards the implementation of theory of science, whereas the *ex post* interviews with the two theory of science teachers demonstrated that they experienced a good deal of scepticism or indifference among the very same faculty especially at the outset of the course).

The combined theory of science/research methodology approach that has been implemented at our institute is but one out of a broad variety of approaches that have been implemented in Danish engineering education. It seems that a viable approach has been found in the two hybrid degree programmes, whereas the approach in the electronics programme might be characterized as only a temporary *modus vivendi*. There appears to be no optimal and final solutions in implementing theory of science in engineering education but only temporary solutions reached by negotiation and compromise. The integration of socio-technical competencies therefore seems to be a never-ending story.

Acknowledgements The writing of this chapter was made possible by a grant from the Danish Council for Strategic Research (DSF) to the Program of Research on Opportunities and Challenges in Engineering Education in Denmark (PROCEED). This chapter also draws on previous research carried out by the authors in 2008 and 2009.

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