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Published in:
Conference Proceedings

Publication date:
2014

Document Version
Early version, also known as pre-print

Link to publication from Aalborg University

Citation for published version (APA):
Buch, A., & Andersen, V. (2014). Engineering Teamwork. In *Conference Proceedings*

Stream12. Teams once again – Wellbeing in teams and temporality of work in teams

Engineering Team Work[i]

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ABSTRACT

The tensions between the individual and the collective in engineering work practices are profound. Engineers' self-perception as well as the consensus of the research community point to the fact that engineering work practices are essentially collective work practices – predominantly performed as coordinated activities within collective work units such as teams, projects, etc. But the picture tends to be more complicated. Historically, scientific and technological work has been perceived as individual achievements – focused on the production of knowledge, the search for truth and the creation of technological successful operations and artifacts. Turning, more specifically, to engineering, scholarly work on the engineering profession has pointed to the tensions between the corporate / practical ideal and the professional / scientific ideal of engineering practice within the profession.

In our contribution we investigate this fundamental tension within engineering through two ethnographic studies of engineering work practices. The tension manifests itself through discrepancies in the practices of in engineering work as performed on a daily basis. Our account is based on material from an ongoing research project on the ramifications of team based work-organizations in contemporary work life in Denmark. The parts presented here focus on two ethnographies conducted within two engineering consultancy companies that provide services and products to clients. Our contribution will give priority to present our ethnographic material – thus the aim is to give 'thick' descriptions of the work practices within the two arenas. Having provided these empirical accounts we will reflect on our material in order to discuss how the tensions within engineering work practices manifest themselves in modern work life and how visions about teamwork, collaboration, 'pro-activeness' and innovation is in fact enacted in engineering work practices.

Our discussion thus illustrate an issue and demonstrate a methodological approach central to work life studies – drawing the attention to how science and technology are interwoven with work organization, expert cultures and professionalism, and how notions of "team work" is transformed in specific domains.

Introduction

Among engineers there seems to be an overwhelming consensus concerning the way engineering work is performed: engineering work is performed in teams. A resent survey conducted by the Danish Society of Engineers among Danish engineers (Epinion 2012) concludes that 76% of the engineering population in Denmark is working within teams. It also concludes that more younger than older engineers are involved in team work and it indicates that the training of engineers within engineering education nowadays are predominantly centered around collective units such as teams. Thus, it seems, engineers perceive their education, training and work to be predominantly a collective activity. It is beyond doubt that engineering practices – like scientific practices – are social practices. Research within Science and Technology Studies (STS) over the last forty years indicates that scientific and technological practices are best understood as collective (social – material – discursive) achievements (e.g. Bucciarelli 1994, Biagioli 1999, Kaiser 2005, Shrum et al. 2007, Gorman 2010). Likewise, many researchers have pointed to the benefit of understanding scientific and technological practices as organized work practices (e.g. Barley & Kunda 2001) – immersed in and moulded by organizational, economical and societal transformations and transactions, just like any other collective work practices. Thus it seems, at first sight, that the engineers' self-perception and the consensus of the research community are aligned: engineering work practices are essentially collective work practices – predominantly performed as coordinated activities within collective work units such as teams.

But the picture tends to be more complicated. Historically, scientific and technological work has been perceived as individual achievements – focused on the production of knowledge, the search for truth and the creation of technological successful operations and artifacts. In *The Scientific Life* Steven Shapin identifies the virtues that have shaped the ethos of science and technology:

"Knowledge is the product of genius; genius is irredeemably individual; attempts to organize the production of knowledge worthy of the name is a recipe for disaster; a camel is a horse designed by a committee; and mediocrity is the necessary consequence of collectivity." (Shapin 2008, 170)

The tensions between the individual and the collective in engineering work practices are at the center of our research interests in this paper. We wish to investigate this fundamental tension within engineering through two ethnographic studies of engineering work practices. Our account is based on material from an ongoing research project on the ramifications of team based work organizations in contemporary work life in Denmark. The project pays attention to and study diverse domains of professional work – spanning from teaching in vocational schools, psychiatric diagnostic work to engineering work practices in engineering consultancy companies. In this chapter we will only focus on the engineering work practices. Our study is based on two ethnographies of engineering work practices. The ethnographies were conducted in two engineering consultancy companies in Denmark 2011-12[ii]. One company, Gitcela, has an explicit ambition to organize work in team structures – the other company, SARIN, previously had this ambition, but had just given it up, when our study began. Now work in SARIN is organized around projects and individual accountability.[iii]

In what follows we will give priority to present and discuss our ethnographic material – intending to give 'thick' descriptions of the work practices within the two arenas. Finally, we will reflect on our material in order to discuss how the tensions within engineering work practices manifest themselves in modern work life. Before we do so, we will, however, briefly present the methodological considerations behind our study.

Methodology

The point of departure for our research was the 'theory/method-package' (Star 1989) of Situational Analysis (SA) (Clarke 2005) and our studies was directed towards arenas of interactions that focused on issues of environmental engineering work in engineering consultancy companies. According to Strauss (1993, 226) an arena is characterized by involving social worlds that revolve and interact around issues – in our two ethnographic studies the issue were respectively the design and promotion of climate accounts and a project about the development of a public website for janitors engaged with cellar maintenance.

Our choice of SA as a research approach has to do with the complexity of the issues being researched in our project – namely the role of teamwork in professional work practices. The formation of competencies and the learning of the engineers must be understood and investigated in relation to the complex discursive-material situations of engineering work and education (Buch 2002). The engineering profession and engineering culture is being (re)produced within situations that can only be understood properly by reflecting on discursive, historical and material preconditions. SA's ambition to analyze situations by using diverse categories, perspectives and methods thus honors the complexity and heterogeneity of the engineering practices under study.

One of the two ethnographies gravitates around a small team (4 members) in SARIN that worked with the development and promotion of a new product: Carbon emission accounts. We have had the opportunity to follow the team for almost a year. During this period we studied their publications and work notes, conducted participatory observations, formal and informal interviews and worked with generative methods of investigation. In addition we have had the opportunity to identify and interview a number of actors adjacent to the team and individuals with opinions on engineering and engineering competencies in relation to environmental work. During our research we have made field notes and recorded most of our interviews and the team meetings we attended. The interviews have focused on diverse issues and themes. Some introductory interviews focused on the team members' life stories (Linde 1993) while others addressed the day to day assignments and the work of developing climate accounts. The other ethnography follows a small project that aimed to develop a public website for janitors and in particular the project manager (Morten) in the different phases of the project over one year. We were introduced to the project in its early stages and witnessed how Morten was assigned the role of project manager. By following Morten around – during meetings with colleagues, negotiating with a communication bureau, workshops with user groups etc. – we were able to observe how the work practices unfolded, and in subsequent interviews we had Morten reflect on what was at stake during the interactions.

During the research period in SARIN and Gitcela and afterwards we have reflected on and analyzed our empirical material on a continual basis. These reflections have been guided by the heuristic developed by Clarke (2005) that places the 'situation' as the unit of analysis. Thus our analytical goal has been to comprehend the elements inherent in the situational setup and understand the relations and dynamics involved. It has been of importance to us not to reproduce preconceived views on 'engineering practice' and thereby establish sharp boundaries between the 'text' and 'con-text' in our study. Thus we tried not to focus our attention on the 'technical' or make preconceived separations between professional and non-professional work practices among the engineers. Our ambition has – on the contrary – been to investigate how 'engineering practice' is produced and reproduced by taking our point of departure in the practices enacted in situations played out in SARIN and Gitcela. Our study has set out to investigate the individual, collective, organizational, institutional, cultural, material, historic and discursive elements of the situation and their interplay. The methods of investigation put to use in this effort thus aims to describe the formative elements and dynamics of the situations.

Our analysis of the situations in SARIN and Gitcela are of cause guided by the focus of our research. We thus entered SARIN and Gitcela in order to study 'engineering practices'. It must, however, be realized that engineering practices are both constitutive and consequential: Engineering is performed and shaped by the actions of engineers, but engineering is also an enactment of practices within a tradition. Engineering is a profession with a history; a domain that includes and excludes practices and a field of continual contestation, and negotiation in regard to the concept of 'engineering'. The 'situation' is thus always populated by discourses that inform the actions, transformations and relations that we study. Clarke's criticism of traditional approaches within the 'Grounded Theory'-tradition has pointed to this. Consequentially we chose to supplement our study of 'engineering practices' in SARIN and Gitcela with a discourse analysis of 'challenge perceptions' and 'response strategies' in relation to engineering practice (Buch 2012). This analysis teases out how the concept of engineering is problematized in a number of 'practical texts', memoranda, position papers and scholarly works. However, space does not allow us to present our discourse theoretical research here. We will thus delimit our presentation to our ethnographies in SARIN and Gitcela and focus mainly on presenting the elements in the situations that are essential in illuminating teamwork and understandings of (engineering) professionalism.

Engineering work practices in SARIN and Gitcela

SARIN is an engineering consultancy company that provides consulting services regarding environmental and energy issues, planning and construction of infrastructures and developmental cooperation in relation to the third world. Around 1,300 professionals – mainly engineers – are employed at SARIN. The head quarters of SARIN is situated in the vicinity of Copenhagen in Denmark, but SARIN also have local offices in other cities in Denmark and many employees are assigned to projects all over the world.

Copenhagen was the hosting city of the international climate summit COP15 in 2009. This event spurred a lot of public and political attention about climate changes due to the emission of greenhouse gases into the atmosphere. Until this event the conservative Danish government had given little focus to climate problems. In fact the Danish government sponsored the prominent 'climate change denier' Bjørn Lomborg and had made dramatic cuts in the public environmental initiatives. But in the preparation faze of the summit in Copenhagen this all changed. Suddenly the Danish government withdrew its sponsorship to Lomborgs research and recognized the severe climate challenges we are facing. This change of policy towards the climate problems was accompanied by new visions about clean-tech and environmental services as drivers for economic growth and employment in Denmark. These vision and the high expectations in relation to achieving global agreements on climate issues raised an atmosphere of optimism and encouraged the companies within the environmental service sector to launch new initiatives. This is the backdrop for the initiatives taken by SARIN in 2008. The company decided to establish a new division with a focus on climate change. Previously the company had been supplying services that were 'reactive' in relation to climate change – e.g. planning and dimensioning infrastructure facilities that could deal with flooding. Now, a new division should develop 'proactive' climate solutions – solutions that could monitor and reduce emissions of greenhouse gases and document the 'carbon footprint' of consumers, households, products, companies, regions, etc. A dedicated COO was put in charge of this new division and he recruited a team of 'holistically minded' engineers that should develop new types of accounts that could specify business units' total 'carbon footprint' by measuring the direct and indirect emissions due to the unit's activities. He was struck by the fact that heating and transportation could only account for a fraction of the total carbon emission. Other components integral to companies manufacturing processes have a considerable impact that is not accounted for. The account should thus develop procedures that can measure the quantities of carbon emission due to a company's totality of activities. A law-enforced regulation of companies' carbon emissions would surely introduce emissions as an economic parameter. If climate quotas come to play an increasing role in the pursuit of emission reductions more accurate climate accounts should be developed in order for companies to monitor their footprints.

However, the climate summit turned out to be a disappointment. No global agreement was established and many criticized the Danish governments' handling of the negotiations taken place at the summit. The enthusiasm and optimism about the prospects of clean-tech industry and environmental service sector as drivers for economic growth fated. No prospects of regulation of companies' carbon emissions were in sight. SARIN's 'proactive' strategy was put on hold and the enthusiastic COO in charge of the strategy left the company in favor of a position within an environmental NGO. When we entered SARIN in 2011 the climate division was abolished and only a small group of four employees were engaged in developing and selling climate accounts. Although SARIN had given up the ambitious 'proactive' plan the group insisted on upholding the status of a team that was dedicated to develop climate accounts. Their insistence was tolerated, but it was made clear to the team members that their activities should be profitable – otherwise their jobs were in jeopardy. Each and every employee in SARIN (except employees in management positions and administration) should be able to refer 75 to 80 % of his or her work hours to customer financed projects. Time spend on other activities were considered 'unproductive' time. On a weekly basis the employees at SARIN had to fill out an electronic time sheet and refer work hours to projects. It was evident to all that the four members of the team were not able to fulfill this requirement. An insufficient number of customers were interested in SARIN's climate accounts. So, to uphold the 'efficiency standard' and account for their individual fulfillment of the 75 % profitable workload the team members had to sign up for work in other 'reactive' projects within SARIN.

Gitcela

Gitcela is a major Danish consultancy company. Once Gitcela considered itself an *engineering* consultancy company, but now its operations and specialisms also includes other domains. Gitcela has expanded by acquiring other companies and integrating them in Gitcela as sub-units. Besides traditional engineering consultancy services Gitcela thus provides consultancy in relation to brewery, food, work environment facilitation, health and safety and more. Gitcela is established as a foundation and it acquired its present name after the transition from engineering to general consulting. The foundation has also established a PhD-program that sponsors PhD-students. The objective of the PhD programme is to heighten the knowledge level in Gitcela in the competence areas that form the basis of the company's existence. Up to now 8 PhD degrees have been finished and 3 employees are at the moment working on their PhD projects. The foundation considers the programme to be vital for the continued development of the Gitcela as a knowledge-based company – transcending traditional disciplinary categories such as e.g. engineering. Around 700 persons are employed in Gitcela – many of them with a background in engineering, but also many with other professional backgrounds.

We had the opportunity to follow the start-up of a small project that aimed to develop a public website for janitors (and others – e.g. homeowners) who were concerned with new cellar practices – how to use and maintain cellars. In the summer of 2011 the Copenhagen area witnessed a massive rainfall that caused severe flooding problems and considerable numbers of cellars in private homes and apartment houses were damaged. Thus an investment fond decided to establish a public web page that could primarily be used by janitors as a guide for reestablishing and maintaining their cellars. Morten – a newly employed engineer in Gitcela in his 30'ies – was assigned as project manager of this small project. The objective of the assignment was – in collaboration with an external communication bureau – to gather professional knowledge about cellar maintenance. This knowledge should be transformed to guidelines that could be presented on a public web page. Morten should compile existing knowledge about cellar maintenance from the experts in Gitcela and from relevant external experts.

The website-project was a minor project in Gitcela. But we learned that it was quite typical of the way work was organized. Normally engineering projects are considered to be very structured and well defined with officially appointed project managers, project members, gant-charts, milestones, project committees, etc. But that was not the case with this small project as with most other projects in Gitcela. Only major projects in Gitcela are run in this way. Morten consulted his colleagues and internal and external experts as the project progressed and asked them to consider and solve well bounded and confined problems – small 'work-packages' defined by Morten. Thus Morten's colleagues in Gitcela were consulted sequentially and were not considered to take part in the general development of the project – they were more like individual sub-contractors. They stepped in and out of the project and made incremental contributions based on their professional specialisms and experiences from previous projects.

Morten was assigned to the project as project manager – not because he had specific experiences or knowledge about cellars, but specifically because he did *not* have any specific knowledge about 'cellars'. Morten is trained as an engineer but his specialism has nothing to do with housing ventilation or any other engineering specialism relevant to the project. But he has an engineering degree from a Danish university that base its programs on the problem based and project structured learning model (PBL). Morten has thus learned to confront complex and ill-defined problems and work out solutions in small study teams formed around study projects. He is aware that his field of expertise lies somewhere else than most other engineers. The project-oriented approach from his university training has taught him to deal with complex problems in an unassisted way. To deal with the complexity, define the approach and frame the problem that are supposed to be solved he preferred to set up workshops and invite participants to give input. Morten does not consider this competence to be unique. It is something that anyone can learn easily, but he sees it as very effective in going about solving problems.

Morten was only recently employed in Gitcela. After finishing his master programme in engineering he took additional university courses in engineering subjects and finally enrolled in an industrial PhD-progamme in another company. However, he broke off his PhD-studies in order to start working in Gitcela. He considered this work to be more versatile, practical and fulfilling. With under a year of experiences in Gitcela Morten was put in charge of running the project. He had some good ideas about where to look for the relevant knowledge required for the project and how this knowledge should be disseminated, but he has no clear idea about the specificity of the kind of knowledge that should be gathered. When Morten was appointed project manager he was free to consult colleagues in any way he saw fit. This freedom was only given to him because of the small size of his project. For bigger projects the HR-department have developed a procedure for composing teams – in order to prevent 'gang-staffing'. 'Gang-staffing', i.e. composing teams based on personal relations and personal experiences, is a derogatory term used by management in Gitcela. 'Gang' in Danish means 'corridor' and 'gang-staffing' thus – in its more benign meaning – refers to an informal way of organizing. But it definitely also connotes the English meaning of 'gang'. By using this expression the management indicates that the composition of teams ought to be based on more objective and rational criteria – such as individual competence profiles that can match the projects needs for competencies and general considerations about resource spending. When we entered Gitcela for the first time management and HR had great ambitions to change the informal 'gang-staffing' way of organizing work to a more centralized and rational procedure. However, half a year later, it was difficult to trace the ambition in our interviews with HR-management. It had proven difficult to manage and control the manning of the projects – a lot of practical issues of logistics and personal relations turned out to make centralized project manning difficult. In addition the employees tried to sidestep the procedure by understating the size of new projects in order to prevent being assigned HR-procedures of team and project formations. The employees preferred the traditional personal network approach. Management, however, never officially gave up the ambition.

Discussion

SARIN and Gitcela are engineering consultancy companies; most of the employees at SARIN and Gitcela are doing engineering work and many of the employees in the two companies have academic degrees in engineering. So, obviously our study is about engineering work practices. That being said, our study also makes it clear that 'engineering' is not an unproblematic and static concept. From our studies it is clear that many interests, ambitions, visions, dreams, etc. are invested in this concept and that there are many ways of 'doing' engineering. Furthermore, our study draws attention to the situated and contingent character of engineering work practices - within organizational, historical and political settings. On a more specific level our study draws attention to some relational tensions within the situation. Situational analysis emphasizes the investigation of relations between actors, actants and discourses in order to identify issues and sites of contestation and controversy that are essential for the analysis of heterogeneous constellations. These relations are thus seen as the locus for power in action (Clarke 2005, 37). Highlighting these tensions and dissonances by drawing relational maps of the situations (Clarke 2005, 102 ff.) within our studies can help us to spread some light on how engineering practices are being enacted and where the (potential) lines of transformation of the practices can be found. Drawing on our ethnographies in SARIN and Gitcela we will discuss some problem areas that come to light as we analyze our empirical material.

The instrumentalization of engineering work in SARIN

The vision of the 'proactive' and 'holistic' engineering professionalism was a guiding ideal for the strategy taken by SARIN to become a major player in developing climate solutions. However, the 'responsive' principle of the management system was the effective logic organizing and structuring engineering work.

As it turned out after the failure of the COP15 climate summit there were not taken any significant legislative steps to regulate companies' CO_2 emissions and SARIN's expectations of a bourgeoning market for climate accounts were proven wrong. In consequence SARIN dissolved the climate division and the COO left his position. The climate team was the only remaining trace of the grand strategy visible when we entered SARIN in 2011. The team members still shared the 'holistic' visions of the strategy and clinged to their team structure. Their professional identities as 'holistic' engineers had become interwoven with the their work with climate accounts and it was mandatory that they could continue their work in the team – in spite of the general abolishment of the 'proactive' climate agenda in SARIN and in spite of the general abolishment of a team organization of work in SARIN.

But how did their ‘holistic’ and ‘innovative’ engineering approach manifest itself in their work? It was, in fact, difficult to trace the holistic and innovative approach in the situation – except for the team members’ rhetoric’s! The developments of the climate accounts were construed in strictly instrumental ways. Figures in economic accounts were linked to emission tables and the fit between the categories of the accounts and the emission tables were refined, nuanced and optimized to give precession. During team meetings it was discussed how to find new markets for the climate accounts and how to market the product more effectively. But no general reflections about the product or the relevance and added value of the climate accounts for the costumers were entertained. Their apparent difficulties with selling their services to private companies were contributed to the lacking legislative regulation of carbon emissions and the team put their trust in the new socialist government to take initiatives. Although the rhetoric was all about ‘holistic’ and ‘innovative’ engineering the engineering practice remained instrumental and narrowly technical. Taking into account that some of the team members were trained in the proclaimed ‘holistic’ oriented engineering programs of innovation and sustainability this could seem to be a paradox.

It is, however, important to take the general features of the situation into account. The requirements of the invoicing system limited the horizons of the engineers to short-term projects that responded directly to customers needs. Every week 75-80 % of the work hours had to be invoiced. Henrik faced the consequences of the invoicing system and slowly drifted away from the team. He engaged in more ‘reactive’ engineering projects in other divisions of SARIN in order to satisfy the invoicing requirements. John was more ‘faithful’ to his holistic engineering professionalism, but he had to start working part time and supplement his job with teaching activities. Sebastian and Nille kept their full time positions but ‘shopped around’ in other divisions of SARIN in order to fulfill their work norms. Thus the general structure of work organization embodied in the invoicing system encouraged an individualistic, non-reflective and instrumental approach to engineering work and tampered ‘holistic’ and ‘innovative’ approaches. At team meetings the participants only had time to divide assignments among themselves and to reflect on potential costumers to whom they could sell their existing services and concepts.

The persistence of ‘gang-staffing’ in Gitcela

The small website-project was no anomaly in Gitcela. It was a minor project, but so were many projects. It was propelled by Morten, a determined young project manager, who interacted with experienced engineers that could contribute to the development of the project. The project did not include the experienced engineers from the start, but they were invited to solve minor assignments as the project progressed. Morten was in charge and he had made a plan for the progression of the project and the division of labor among the involved parties. Morten did in fact manage the project by using the conventional and widely accepted network approach that the managers derogatively called ‘gang-staffing’. He was capable of identifying specific engineering competencies among his fellows and he was quite clear about framing the requests to the experienced engineers in ways that were comprehensive and attractive to them. They willingly worked long hours or brought back work to their homes in order to make their contributions within the specified deadlines. It was quite clear that most engineers preferred this decentralized project management style to the more regulated and centralized project models suggested for the bigger projects. Morten’s project management approach was appreciated and found appropriate because he understood how engineering problems should be framed in order for the experience engineers to go about delivering professional inputs and solutions.

Morten – being trained as an engineer – understood the engineering ethos. He shared the same professional ‘object world cosmology’ (Bucciarelli 1994) as the rest of the experienced engineers. This cosmology describes a domain of thoughts, actions and values that guide the work of the engineers and their way of seeing the world. In the cosmology of the ‘object world’ precision, decidability, rigor, unambiguousness, consistency, usefulness, determinism, rationality, mechanistic models, reductionism, value-freedom, results, achievements, autonomy and individualism, are all held in high esteem. Most of these ideals are inherited from the scientific worldview that Shapin describes (Shapin 2008). The values are produced through basic education in engineering that stresses scientific methods, disciplinarily and individual achievements and reproduced in the engineering work culture.

Conclusion

Our stories of engineering work practices in SARIN and Gitcela points to significant values and dynamics in engineering work. In SARIN the new visions for ‘holistic’ and ‘proactive’ engineering work practices had a hard time. The newly recruited engineers with a background in the progressive Innovation and Sustainability Programme had difficulties in enacting their ‘holistic’ approaches within the work organization of SARIN. The team organization was abolished and replaced by the traditional invoicing system that measured work and achievements in strict terms of individual profitability. Although it was tolerated that the four 'holistic' engineers conjoined in a team structure this collective work practice was not supported by the fundamental incentive structure of the company. In the SARIN case the initial visions of collective work organization that should support 'holistic' and 'proactive' work practices were abandoned and substituted by traditional individualistic forms of work organization – regulated by the fundamental incentive mechanisms of the invoicing system.

As for Gitcela, the story is slightly different. Managements' efforts to prevent 'gang-staffing' could be interpreted as a means to install more collective work practices in project teams. This is however not a feasible interpretation. There is no evidence that the managers in Gitcela had intentions about altering traditional engineering work practices to make them more 'holistic' or 'proactive' – as was the case in SARIN. The ambition to prevent 'gang-staffing' was spurred by vision of centralized rational management of resources – to prevent uneven workloads and undesirable depletion of the human resources. The engineers, on the other hand, preferred a decentralized and deregulated mode of work organization. 'Gang-staffing' is a predominant mode of organizing in the (engineering) consultancy sector. It was the fallback mode of organizing in SARIN after the collapse of climate venture and it is a persistent mode of organizing in Gitcela – capable of surviving reforms initiated by management.

In both SARIN and Gitcela we witness initiatives to reform work organization – to install more collective modes of organizing engineering work practices. In the case of Gitcela through centralized and rule governed team initiatives developed by top-management and implemented by HR management. And in the case of SARIN through the ambitions of establishing more innovative and proactive modes of work practices by recruiting 'holistic' engineers. In both cases we witness the failure of the initiatives. No doubt the failures can be contributed to many circumstances and the contingencies in the two cases are prevalent. As we have spelled out in the previous accounts one significant element, though, can be found in the predominant way that work is organized and assessed in the (engineering) consultancy sector. Individualized accounting systems and performance assessment measured in relation to individual profit contribution does, obviously, not stimulate collective work practices. But another significant component for understanding the failure of the reform initiatives has to do with the inherent individualistic ethos of the engineering profession. Like science, engineering give priority to individual performance and achievement and degrades collective accomplishments. No doubt science and engineering are collective endeavors, but collectivity is construed in terms of individuals *coordination* among highly specialized individuals that exchange information in predefined patterns of labor division. The engineering projects are thus seen as sequential series of tasks or 'work packages' where engineers of different specialization contribute with incremental solutions to predefined sub-problems. These individual contributions are – on a formal level – orchestrated and compiled by the skilled project manager, or more fundamentally on the informal level, by each engineers' coordination efforts in negotiating problems and solutions in the heterogeneous engineering practices. Ethnographic studies of engineering work conducted by James Trevelyan (2007) corroborate this observation. Trevelyan findings suggest that engineering work is characterized by coordinating efforts in relation to clients, managers, fellow-engineers and others. He writes:

"Technical coordination can be described as working with and influencing other people so they conscientiously perform some necessary work in accordance with a mutually agreed schedule. This usually requires three different phases of interaction:
<u>*Phase 1: Commissioning the work.*</u> *The coordinator negotiates an agreement on what has to be done and when it has to be performed.*
<u>*Phase 2: Execution of the work.*</u> *Usually it is necessary to be present for some of the time while the work is being done to check that the results (perhaps intermediate) turn out as expected. […] when the results are unexpected, time and resource limitations or lack of technical understanding may necessitate compromises in the requirements. If possible, the coordinator needs to be able to foresee the technical and other consequences of such a compromise.*
<u>*Phase 3: Checking the work.*</u> *The final result needs to be carefully checked to make sure no futher work or rectification is needed."* (Trevelyan 2007, 194)

Trevelyan's investigations thus demonstrate that the prevailing mode of construing collective work processes in engineering is through coordination. Formal coordination – executed by project management, line officers or central HRM officers are of cause common in engineering work. But more pertinently – as the SARIN and Gitcela-cases illustrate – informal and local coordination dominates engineering work practices. "Coordination usually involves one-on-one relationships with superiors, clients, peers, subordinates, and outsiders." (Frevelyan 2007, 191).

Construing collective work practices as processes of coordination among individuals has consequences. It seems to presuppose that problems are well-defined and that solutions can be most effectively obtained by sequencing individuals' skills and knowledge. It thus construes collective work in a metrics of means-end relations and installs criteria of efficiency and production as the telos of collective work. Rabinow and Bennett (2012, 49-50) characterize this mode of collective work as means-ends maximization:

"Expert knowledge is structured and functional only when that which counts as a problem is given in advance, stabilized, and not subject to further questioning. In emergent situations, however, neither goals nor problems are settled, and so technical expertise cannot be effectively marshaled without some adjustment. In many instances, obviously, when goals and problems become settled, technical expertise must be given a useful place within an assemblage. Said another way, routinization is normal but qualitatively different from states of emergence or innovation."

Seeing the prevalence of coordinative work within engineering work practices helps us understand why the 'holistic' engineers at SARIN had to resort to instrumental modes of work. The philosophy of the previous management regime in SARIN wanted to replace the narrow technical rationality of traditional engineering and employ new breeds of holistic, innovative and proactive engineers that can transcend disciplinary bonds and address the complex and ill-defined new problems of the climate change agenda. Due to the COP15 disappointment and an insufficient level of market demands for climate accounts this philosophy was abandoned and coordination – being the preferred mode of collective work organization in engineering – was reintroduced as the 'natural' fallback position.

In closing this chapter it is worth briefly to contrast coordinative work processes to other modes of collective work. On a conceptual level Lin and Bayerlein (2006) has contrasted and compared coordinative work practices to more cooperative and collaborative work practices. Although it is not possible to classify engineering work practices as inherently *either* coordinative *or* cooperative *or* collaborative it is useful to consider the contrastive scheme as an analytic and ideal typical means of differentiation between modes of work practices. Lin and Bayerlein contrast coordination, cooperation and collaboration according to five dimensions: social interaction, scope, autonomy, dynamics and temporality.

	Coordination	Cooperation	Collaboration
Social interaction	Few	Mixed	Rich
Scope	Narrow	Mixed	Broad
Autonomy	Low	Mixed	High
Dynamic	Low	Moderate	High
Temporality	Discrete	Mixed	Ongoing

Tabel 1 Lin & Bayerlein 2006, 65

The dimension of *social interaction* describes how relational dependency is construed in collective work processes. In contrast to collaborative work processes coordination seem to favor modes of symbolic imagination and structural alignment over direct social interaction. Engineering is characterized by high degrees of symbolic formalization and the work processes are structurally aligned by the telos of efficiency and production. These characteristics make it possible – and even stimulate – a high degree of division of labor and minimization of social interaction. Secondly, in relation to *scope*, Lin and Bayerlein (2006, 66) state that:

"*Coordination focuses on problem solving, which requires mostly cognitive contributions. In contrast, collaboration focuses on broader issues and asks for more that cognate resources from the contributors. […] Since collaboration always takes situative and historical contexts into account, people can search in a bigger problem space, add their personal concerns in, and develop a solution meaningful to them."*

Engineering has traditionally shunned ill-defined and complex problems and vigorously tried to simplify complexity in order to define problems that are amendable to standardized technical and mathematical problem solving – and thereby relegated non-technical dimensions and aspects of problems. Thirdly, compared to collaboration and cooperation coordination gives a restricted *autonomy* for participants to determine "*the goal, the division of labor, the procedure, and the outcome [of work]. Coordination hardly encourages new solutions, but collaboration places strong emphasis on them." (op.cit.)* Fourthly, the *dynamics* of collective work processes are low in coordinative work as opposed to collaborative work. Coordinative work is structured along rational linearity and, fiftly, *temporal* linearity that only calls for participants to consult with each other at specific times and venues in the work process.

We think that Lin and Bayerlein's conceptual framework of types of collective work processes is suggestive for further research in pointing to tensions in engineering work. Our ethnographies and Trevelyan's research clearly shows that coordinative work practices are predominant in engineering work practices. But it is interesting that ambitions in the (engineering) consultancy companies about fostering innovation and interdisciplinary ('holism') among engineers that can deal with the complexity of real life problems seemingly sets ideals about collaborative work practices that are at odds with the traditional professional ideals of engineers. It is easy to discard calls for 'holism' and more collaborative work practices in engineering as mere rhetoric's on behalf of industry. We do, however, think that the tensions we have pointed to, are of a profound nature that needs more attention in future research on engineering professionalism and engineering education.

Literature

Barley, S. & Kunda, G. (2001): Bringing Work Back In, in *Organization Science, vol. 12(1), pp. 75 - 96*

Biagioli, M. (ed.) (1999): *The Science Studies Reader*, London, Routledge

Bucciarelli, L. (1994): *Designing Engineers*, Boston, MIT Press

Buch, A. (2002): *Social Theory of Learning* – (in Danish), Frederiksberg, Roskilde Universitetsforlag

Buch, A. (2012): *Governing Engineering*, in Steen Hyldgaard Christensen et al.: *Engineering, Development and Philosophy: American, Chinese and European Perspectives* (Philosophy of Engineering and Technology), Dordrecht, Springer

Christensen, S. (2012): Academic Drift in European Professional Engineering Education: The End of Alternatives to the University?, in Christensen, S. et al. (eds.): *Engineering, Development and Philosophy. American, Chinese and European Perspectives*, Dordrecht, Springer

Clarke, A. (2005): *Situational Analysis. Grounded Theory After the Postmodern Turn*, Thousand Oaks, SAGE

Epinion (2012): Attitudes towards engineering held by young people, adults and engineers, a survey commissioned by The Danish Society of Engineers (in Danish)

Gorman, M. (ed.) (2010): *Trading Zones and Interactional Expertise. Creating New Kinds of Collaboration*, Boston, MIT Press

Kaiser, D. (ed.) (2005): *Pedagogy and the Practice of Science. Historical and Contemporary Perspectives*, Boston, MIT Press

Layton, E. (1986): *The Revolt of the Engineers. Social Responsibility and the American Engineering Profession*, Baltimore, The Johns Hopkins University Press

Lin, Y. & Beyerlein, M. (2006): Communities of Practice: A Critical Perspective on Collaboration, in Michael M. Beyerlein, Susan T. Beyerlein, Frances A. Kennedy (ed.) *Innovation through Collaboration (Advances in Interdisciplinary Studies of Work Teams, Volume 12)*, Emerald Group Publishing Limited, pp.53-79

Meiksins, P. (1988): The "Revolt of the Engineer" Reconsidered, in *Technology and Culture, vol. 29(2), pp. 219 - 246*

Rabinow, P. & Bennett, G. (2012): *Designing Human Practices. An Experiment with Synthetic Biology*, Chicago, Chicago University Press

Shrum, W, Genuth, J. & Chompalov, I. (eds.) (2007): *Structures of Scientific Collaboration*, Boston, MIT Press

Shapin, S. (2008): *The Scientific Life. A Moral History of a Late Modern Vocation*, Chicago, Chicago University Press

Star, S. Leigh (1989): *Regions of the Mind: Brain Research and the Quest for Scientific Certainty*, Palo Alto, Stanford University Press.

Strauss, A. (1993): *Continual Permutations of Action*, New Brunswick, Aldine Transaction.

Trevelyan, J. (2007): Technical Coordination in Engineering Practice, in *Journal of Engineering Education*, 2007, pp. 191 – 204.

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[i] This paper is based on an our chapter in Tom Børsen & Lars Botin (in press): What is Techno-Anthroplogy, Aalborg

[ii] We have had the opportunity to perform site visits on a regular basis for almost one year between 2011 and 2012 in SARIN and Gitcela. During this period of time we participated in team meetings, joined the involved engineers when visiting costumers, internal and external partners or just followed the routines of work and interaction at the office, during lunch breaks, etc. We have made more formal interviews with team members; with executive officers and HR-officers. At SARIN the team members have in addition been doing 'snaplogs' (photo-snapshots and additional logs explaining the significance of their photos). We have made separate interviews with customers and other actors of importance to the arenas.

[iii] To honor the anonymity of the companies pseudonyms are use.