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ABSTRACT

Knowledge production and learning in engineering is a local, situated, negotiated, and thoroughly social process. Although engineering work entails the construal, production, and application of artifacts and technical devices belonging to the "object world," the process of designing is a process of achieving consensus among real or virtual participants with different interests in the design, and those interests are vested in the local social practices of the involved engineers. The establishment of consensus is a "social world" activity that can be described as a collective learning achievement, and when this "social world" activity aims at establishing a consensus about technical devices, the generation and manufacture of "object world" phenomena are also rooted in social interest. Evidence supporting this thesis exists in discussions of the sociology of scientific knowledge and in empirical investigations of the learning processes that occurred as a team of seven engineers employed by a high-tech telecommunication company worked on a design project for the development of new facilities for telephone centrals. The investigation documented how the engineers were embedded in organizational culture stressing commercial aspects while being simultaneously united by their technical interests and problem-solving methods in a complex and self-referential system of shared values, commitments, beliefs, and emotions. (MN)

Anders Buch

LEARNING AND CONSTRUCTION IN ENGINEERING JOBS

This paper will give a short presentation of some of the themes involved in my research on learning and social practices in engineering. The bulk of the argument conveyed in the following will be to illustrate the local, situated, negotiated and thoroughly social character of knowledge production and learning in engineering. Although engineering work is concerned with the construal, production and application of artifacts and technical devices belonging to the "object world"[1] I will try to show that the process of designing is a process of achieving consensus among (real or virtual) participants with different interests in the design, and that those interest are vested in - or perhaps even constitutes - the local social practices of the involved engineers. The establishment of consensus is a "social world" activity that can be described as a collective learning achievement. And when this "social world" activity aims at establishing a consensus about the construal of artifacts and technical devices, the generation and manufacture of "object world" phenomena are nested or rooted in social interest as well.

Theoretical outlook and empirical studies

The point of departure of my analysis dates back to discussions in the sociology of scientific knowledge (SSK)[2]. During the last 3 decades the systematic study of natural science and technology has taken a "sociological turn". Scientific and technological knowledge has been the object of sociological investigations. Scientific discoveries and technological achievements should no longer be explained by reference to rationality or "the way nature is". Instead sociological explanations are put to use, stressing that knowledge and beliefs in science and technology should be analyzed and explained in a symmetrical and sociological way regardless of truth

[1] My use of the term "object world" is inspired by Louis L. Bucciarelli: Designing Engineers. MIT Press 1994

[2] Various positions in this debate are found in A. Pickering: Science as Practice and Culture. University of Chicago Press 1991

or falsehood, rationality or irrationality, success or failure[3]. This "impartial" stance allows sociologist and other social scientist to investigate the domain of science and engineering in the same way as they would have done, were they concerned with the study natives or the beliefs and habits of "ordinary people".

These methodological considerations are being put to use in my empirical study of engineering practices and in consequence informs my theoretical reflections on what a feasible theory of learning should look like. One criteria is that a theory of learning should be able to account for the every day learning of people doing their job at the office or in the lab or at the construction site or where ever they are engaged in work. My tentative bet is that learning is a process of differentiation or a process of constructing similarity relations, i.e. comparing instances of kinds, processes or events with one another to establish if they are the same or not. In this conception learning becomes a process of classification. The more you learn the more elaborate and distinct becomes your criteria or notions of "resemblance". As a matter of course this process of differentiation is informed by the learners individual cognitive and emotional capacities. But the learning is always imbedded in a social context or a practice. This last conviction is due to Wittgenstins argument about rule following outlined in his "Philsosophische Untersuchungen" and subsequently reformulated into a position known as "meaning finitism"[4]. In one formulation[5] of this stance it claims that:

1. The future applications of terms are open-ended
2. No act of classification is ever indefeasibly correct
3. All acts of classification are revisable
4. Successive applications of a kind term are not independent
5. The application of different kind terms are not independent of each other

"Meaning finitism" introduces interpretative flexibility into understanding. It underscores the significance and importance of factors other than rigid or brute facts, "nature", logic or rationality in understanding or *a fortiori* learning. The indeterminateness of interpretative flexibility is only a methodological vehicle for

[3] This stance is most clearly argued by "The Strong Program" in the sociology of scientific knowledge. The *locus classicus* is David Bloor: Knowledge and Social Imagery, Routledge & Kegan Paul, 1976

[4] David Bloor: Wittgenstein, Rules and Institutions, Routledge 1997

[5] Barry Barnes, David Bloor and John Henry: Scientific Knowledge, A sociological analysis, Athlone 1996, p. 55-59

cutting the bonds of traditional cognitive theories of learning. A feasible theory of learning need to point to other factors that limit interpretative flexibility and make learning possible. In this matter my bet is that the restriction of interpretative flexibility is due to mechanisms involved in social practices. My definition of social practices is still provisional although my intuition of what is at stake is quite strong: a practice is a temporally unfolded and spatially dispersed nexus of doings and sayings among individuals who embrace ends, projects, tasks, purposes, beliefs, emotions and moods[6]. The social mechanisms in the practices that restricts the interpretative flexibility is guided by the implicit and explicit interests and goals of the participants, but also by the deference emotions[7] in the groups of persons that constitute the practices.
By this token the study of social practices will convey something about the learning of the people engaged in the practices.

In my empirical investigations I aim at studying learning processes as they take place during work. The focus is directed on learning *in situ*, i.e. I am trying to capture situations where engineers are engaged in informal learning processes, e.g. discussing a technical problem or planning or coordinating their work[8]. This setting constitutes an ideal bounded activity that can be analyzed thoroughly through transcriptions of the recorded conversations. The interpretation of the learning episodes is informed by previous interviews with (some of) the participating engineers. And the episodes are discusses with some of the participants afterwards. The context in which the learning takes place (the company, the department) is reflected via interviews with the people who work there, through field studies and observations. Likewise some of the engineers background (career trajectories, ambitions, prospects etc.) is brought into focus in individual interviews.

I am conducting a major case study at a high-tech telecommunication company. I am studying a team of engineers (7 engineers) working on a design project for the development of new facilities for telephone centrals. By the end of spring 1998 I have followed the engineers day to day activities on a regular basis throughout a year, interviewing them, shadowing them during work, joining them in team

[6] For an extended construal of a Wittgensteinian conception of "social practice" see Theodore R. Schatzki: Social Practices, A Wittgensteinian Approach to Human Activity and the Social.

[7] This concept is analysed in depths by Thomas J. Scheff: Microsociology, Discourse, Emotions and Social Structure, The University of Chicago Press, 1990

[8] This approach is inspired by Julian E. Orrs work, e.g. Talking about Machines, An Ethnography of a Modern Job, ILR Press, 1996.

meetings, having lunch with them in their breaks and so on. The purpose of this research has been to become familiar with the special practice characterizing this group of engineers. In the following I will try to illustrate my theoretical point by analyzing a meeting I attended last year.

Learning at work

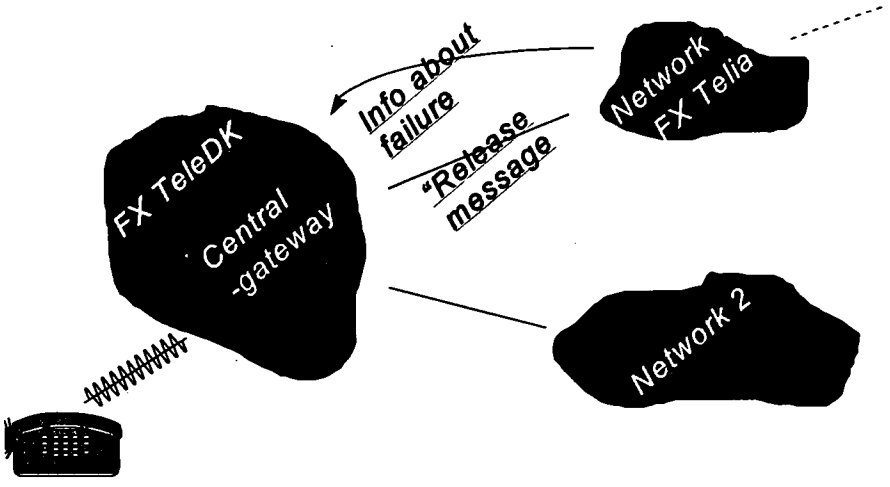
In November last year I attended a "product committee" meeting in the company. A lot of engineers in the company - spread around on 10-15 locations in the world - work on developing, designing, programming and testing software for specific facilities in telephone centrals. It is very important that the proposed solutions to the problems are coordinated, because every change or new facility in the telephone network is likely to affect the whole network. In consequence every change or new feature in the network must be evaluated and sanctioned by a "product committee" of specialist. These specialist are "old timers" in the company and they have a lot of experience with the network. Often the members of the product committee are referred to as "heroes" , because their technical expertise and system knowledge is profound and wide-ranging. In a way the members of the product committee inhabits a supreme status among most engineers in the company. One of the engineers I followed is a "hero" .

The episode I will like to address is a situation where a newcomer (a young male engineer) has developed a facility for the telephone network. A Spanish customer (telephone company) had requested the company to deliver the facility. In accordance with the normal procedures in the product committee, the person who is applying for the acceptance of his solution is asked to explain the problem and his proposed solution to the committee. I will quote this presentation at length:

"There are two questions in this. And the one problem is about a customer, who would like to - ahhh - distinguish between networks that generates errors. Perhaps I should make a drawing. [he makes the drawing as he proceeds to explain the problem] Here we have two networks. Network 1 and network 2 that belongs to an operator or network operator and this one belongs to another. And this central is placed in its own network, witch have a subscribing customer and this customer calls up. And - ahhh - in connection with the setup of this call, an error occurs in a network out there. This network produces a release message backwards. And by the time this central - I will call it a gateway central - receives a release message, it would like to inform the subscribing customer, who made the call, that an error has occurred. But he would like to inform the customer that the error occurred in

another network, and not in his own network. If this is in Denmark, and a TeleDanmark subscriber was told that that it was Telia [Swedish telephone company] - that ahhhh made the error - and that the error was in another specific network.
[A technical description of how the network facility is construed follows]
The signal that detected the error can be rerouted to an announcement machine that can make an announcement to the subscribing customer. And this announcement can express what went wrong - that is: an error occurred in network 1 - as an example. "

The drawing made by the newcomer at the whiteboard is depicted below:



This problem and the suggested solution to it is discussed at length (20 minutes) by the participants:

The heroes are trying to identify and re-describe the newcomers presentation in a technical idiom that is more familiar with the way they use to deal with related problems. In a way they are trying to differentiate the entangled and complex statement given by the newcomer. The heroes are discussing the problem among themselves, putting forward hypotheses about what the problem is *really* all about and what kind of solutions can bee given to the problem.

One of the heroes comments that the problem is unclearly stated because one could imagine that one network could contain more than one network operator. So the responsibility for the occurring error cannot be located to one single operator if more operators are sharing a network. By now it is not quite clear what the definition of *a* network is. Another hero comments that a callroute can pass through more than one operator in a telephone central. Where should the blame for the occurring error be put? These questions and problems witch address the solution of the case clearly states that the posing of the case is not clearly defined. What does the Spanish customer (telephone company) *really* want? Does the customer want a solution that pinpoints the operator that produced the error or does the customer just want a solution that states that the problem is not due the his own central?

It appears that the customer has not specified these requirements clearly, but it would be tempting to suspect that the customer just want to avoid taking the blame for any errors occurring. How should the newcomer deal with this situation? He tries to make a differentiation of the problem:

"But, what about - ahhh - it seems to be a kind of a moral question - in relation to the customer. How they use their functionality - or is it? Is this something we should take into consideration? Or something that I should take into consideration - in regard to the customer. Should I go back and say - ahhh: 'I don't think this is quite right'. When they use it like this, because it is unfair that your own network causes problems, and that you - put the blame on some other operator"

This alternative avenue of discourse (a moral discourse) is taken up by one of the heroes. He tries to differentiate the problem even further by supplementing yet another line of argument:

"If one should look at it in a businesslike way, we should keep our mouths shut with arguments like this. We could sell the function to the customer. He [the customer/telephone company] will probably get complaints about it at some time or other from other operators. Then perhaps we could sell another function to them that didn't do this."

The subsequent discussion shows that the participants considers this "commercial discourse" as a branch of or subgroup of a moral discourse. There is a general agreement that "moral questions" cannot be dealt with in the solution of the problem. The newcomer tries to capture the essence of the debate when he says:

"I put an interpretation on.....ahhhh, that is partly due to the customers demands and partly due to my own interpretation, and this is one of the possibilities. But if the customer wants to combine a branchparameter with an existing branchparameter [i.e. the technical solution to the problem in line with the interpretations], and make some 'morally' correct...ahhhh....announcements backwards.....That is something that I can't....ahhhh....that is something that is not up to me to decide. Can I specify demands about this - I think not!"

By now the problem has been discussed by the group but it still remains to be decided weather the solution can be accepted by the product committee. One option is to accept the solution as a *standard*, i.e. as a solution that can be use and sold as a general product by the company. Another option is to accept the solution as a *marked function*, i.e. as a specific 'tailored' solution to a customer - in this case the Spanish telephone company. There are advantages and problems with either solution. If the solution is accepted as a *standard*, the company can sell the facility to other companies as well and make a profit; but the acceptance of a solution as a standard ties the responsibility for the solution closely to the company. The solution must be integrated in the company's general products and it is necessary to make sure that this facility does not block the way for further development of the system. Besides - if the solution causes 'moral' problems the company will be blamed. (*"We will be in trouble"* as one of the heroes remarked)

Alternatively the solution could be accepted as a *marked function*. This option will not allow the company to sell the product to other customers, but on the other hand the company will not be blamed.

It turned out that the product committee decided to accept the solution as a standard - but in a modified form. The newcomer had to go back to the customer to see if the customer would accept a solution that pinpointed the operator where the error really occurred. The product committee couldn't accept that the solution just announced that an error occurred in the next (closest) network.

Interests, practice and learning

This episode took place one afternoon in the company. What can this episode tell us about how engineers learn at work? To answer this question it is necessary to look at the positions and roles taken by the participants in the episode.

As previously mentioned the heroes are "old-timers" with a lot of technical expertise. They are highly esteemed by all engineers in the company and carry an aura of integrity and professionalism. One of the heroes described the function of the product committee as follows:

"The product committee tries to look at things from the perspective of a standard.....So this is always a consideration that needs to take place when a project presents a product for the product committee and says: 'have a look at this'. The product committee will say: 'of course, but we look at it from the perspective of the standard'. And the temporal perspective of the product committee is infinite. We don't look one project ahead, we don't look two projects ahead, when we look ahead we range over an infinite number of projects."

The product committee and the heroes are considered impartial. Their position is considered to be disinterested and with a *sub specie aeternitatis* dimension. They are the technological guardians of the system and the true heirs of the engineering profession. In a way they symbolize an ideal engineering role. Of course they are employees at of the company and they are working to establish a profit for the company, but they have gained a functional role in the company that allows them to integrate and combine the organizational restrains of their work with the professional engineering codex of the disentangled, neutral, rational expert.

The newcomer plays another role in this episode. He is the protagonist of the project that need to find a solution to a given problem. The interest of the project is to deliver solutions to the customer within a specified time period to earn a profit. The newcomer has become enrolled in the pursuit of the project and made a partisan of the customers and the projects interest. The fulfillment of his role in the project is to submit a solution to the problem that satisfies the specifications and demands of the customer.

It is obvious that the newcomer is in a dilemma. His interest are split into two poles. Being a engineer himself he pays deference to the heroes - they symbolize what any engineer should be proud of. On the other hand his success within the project will depend on his ability to pass a solution that satisfies the customers wishes. He is forced to mediate and negotiate his solution between conflicting interests. Now, what can be done to manage this situation? It seems as if the collective establishment of professional engineers, symbolized by and through the heroes in the committee, are envisaging a way out of the dilemma. By discussing the problem and giving voices to different and opposing interest, the problem is being canvassed and positioned among different real and virtual interests. Some of these interests are

virtual in the sense that they are real and present in the company, but not embodied by any of the participants in the discussion. It is obvious that the "commercial discourse" introduced and voiced into the debate by one of the heroes is a mere rhetorical way of positioning and identifying an interest stance that is an important and compelling line of argument in the company - although the heroes are not the "stakeholders" of this discourse. Similarly the "moral discourse" is not considered to be a proper or integral part of the problem setup. The overall purpose of the debate is to reframe the problem to exclude "noise" or irrelevant considerations, i.e. to focus the problem in the technical discourse. During the debate 3 competing ways of discussing the problem become manifest. 1) The commercial discourse - 'How shall we deal with this problem to gain a profit for the company' is dismissed. The division of labor in the company relegates these considerations to other organizational units of the company. 2) Likewise 'the moral discourse' is not allowed - at least it has to be transformed into a technical idiom. This transformation translates a general moral question into a question about the integrity of the engineering profession. 3) The technical discourse on the other hand appears to be the best way to deal with the problem. The engineering profession has institutionalized this discourse as the 'right' way to solve problems.

In general it seems that engineers employed in industry are embedded in two cultures. The organizational culture stresses commercial aspects, but engineers are often more deeply committed to their technical communities. Belonging to a profession, being subjects of a community of engineers, doing technical work, etc. constitutes a social practice that reflectively enforces standards and institutions among the practitioners. The engineers are united by their technical interests and problem solving methods in a complex and self-referential system of shared values, commitments, beliefs, emotions, etc. The episode illustrates the mechanisms in this system. The issue is not *only* to define and solve a problem, but also to reproduce cultural values in the engineering community. The discussion in the product committee can be analyzed as a reenactment of potential and substantial discrepancies in attitudes and approaches to work. Conflicting positions are given voices in order to identify potential opposition to the preferred technical discourse. These positions are soon dismissed and the superiority of the technical discourse is being reaffirmed

The episode shows how a community of engineers are reproducing and mutually reaffirming their practice. The newcomer on the other hand is in a dilemma. His loyalty and deference to the heroes is evidenced by his conclusion that he can't deal with 'moral questions'. At the same time he is enrolled in a project, trying to deliver a solution that can satisfy the customer, i.e. a solution that can put the blame for a occurring error on another operator. It seems that the newcomer is learning how to

cope with this dilemma by simply leaving it up to the customer to decide what to do with the functionality. He is taking part in an ongoing collective learning process of knowledge manufacturing, production of technological facts, reproduction of consensus and problem solving within the engineering community.

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