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CONSTRUCTIONS, COMMUNITIES AND CODEBOOKS

A Case of Knowledge Transfer in Aker Oil and Gas

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BETA -
From Theories of Innovation to Technological Policies

2001

24728 words

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I would like to thank:

My supervisor at BETA, Antoine Bureth, for his extreme patience, good advice and invaluable help in all phases of my work on the thesis.

All respondents in the case study, both at Aker Stord and Aker Engineering, for their time and willingness to share their knowledge. I hope my interpretation of the interviews is acceptable.

The people at Aker Engineering whose offices I stopped by, and the people I talked to in the corridors and at lunch, for their contribution to my general understanding.

The management in Aker Engineering and Aker Stord, and especially Toril Benum and Trond Haga, for allowing me to do the case study, and for their assistance in setting up interviews.

Cecilie and Paul for a nice time in Strasbourg, and to Håvard and my parents, for being extremely supportive the last weeks, when my mood shifted from frustration to apathy.

Abstract

This thesis investigates context specific properties of codebooks, which is a concept introduced by Cowan, David and Foray, in their paper published in Industrial and Corporate Change, June 2000. The conditions for transfer of knowledge using codebooks between professional communities are explored. To do this, a case study from the Norwegian Offshore Industry is used. Open-ended interviews have been carried out in Aker Engineering and Aker Stord. Both companies belong to Aker Maritime's business area, Aker Oil and Gas, which is a major actor in large development projects on the Norwegian Continental Shelf.

Recent contributions inside the field of knowledge economy and knowledge management have called attention to the complex cognitive elements of perceiving knowledge. Hence, possibilities of interpretation and utilization of knowledge embedded in a codebook are dependent on the temporal, spatial, social and cultural context, in which knowledge is created, communicated and de-codified.

The case does primarily consider the steel process in offshore development projects. That is, the transfer of technological knowledge from the structural engineering disciplines, to pre-fabrication and assembly of the structure at the yard, not including special equipment and piping. Codebooks used in this transfer are mainly the package of steel drawings and a 3D-computer model of the structure.

Transfer of technological knowledge from the engineering phases to the fabrication phases in a development project is a case of knowledge transfer between two professional communities. Engineers responsible for design (the design community) have very different priorities, professional norms and perceptions of "appropriate" knowledge than the operators responsible for the actual production of the offshore structure (the production community). As a result, the design community and the production community associate different knowledge with the codebooks.

The thesis investigates how an intersection of cognitive contexts between the two communities is necessary to secure efficient transfer of knowledge through engineering drawings. A total overlap in contexts is however not desirable, as this necessitates similar competences and background knowledge. Different skills are needed for the two communities to attend to their dissimilar responsibilities in the execution of a project.

Stabilization and, to some degree, standardization of language (the symbolic representation in the drawings) and the knowledge itself (the technical solutions) are seen as imperative for unambiguous interpretation of knowledge embedded in the codebook.

Due to insufficiency in intersection of cognitive contexts, resulting from limits in the stabilization and standardization of language and technical solution, mistakes, shortcomings and interpretation problems are frequently experienced on the drawings. Since the two communities are located far apart geographically direct personal interaction between the communities is largely restricted. Hence, mediators become important in the transfer of the codebook.

Two categories mediators are identified. Mediators I hold intermediate functions in a project. They provide additional flexibility to the rather rigid knowledge, embedded and manifested in written documents. Moreover they function as interpreters and co-ordinators of knowledge. Mediators II have primarily long-term functions as mediators, and contribute to enhance and develop the intersection of cognitive contexts, and have caused what the respondents called 'reduction in cultural differences' between the communities.

Key words:
Codebooks, Knowledge transfer, Communities, Norwegian Offshore Construction Industry

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1. Introduction

This essay is written as a final thesis in the Master Study, Society, Science and Technology in Europe, which is carried out as an inter-European co-operation between several European universities[1]. The study uses the interdisciplinary field of Science and Technology Studies (STS) as its framework, where scientific and technological practices are viewed as social and cultural processes. This approach is a reaction on the view of scientific and technological knowledge as privileged, objective and universal (Asdal et. al.: 2001: 10). Instead, knowledge is seen as dependent on the context it was created. Hence, scientific and technological development must be examined using social, economical, cultural and political aspects.

It is with this motivation I have chosen to make the terrifying leap into the world of knowledge about technological knowledge. Lately, it has become widely recognised that knowledge as a resource has grown to be crucial for the competitive position of the individual company[2]. The capability to continuously be able to identify and solve new problems is described to be the only true competitive advantage a company can have (Reich: 1991).

All economies, even primitive ones, may be regarded as knowledge-based. Knowledge has always been a fundamental resource in the survival of societies, creating conditions for the relationship between producers and consumers. In the Post-Fordist era, however, knowledge has come to obtain a whole new position in the economy. While the Fordist paradigm was characterized by scale-economy, and the attempt to reduce the dependency of the individual worker's skills through division of labour, the contemporary economy has met new and different challenges. According to Lundvall and Johnson (1994: 25), there has been a

[1] The co-operation is included in The European Inter University Association on Society, Science and Technology (ESST). More information about the ESST co-operation is found on the Internet site: http://www.esst.uio.no
[2] See for instance Lundvall and Johnson (1994: 23) Nonaka (1994: 14)

shift from mass production towards a demand for custom-made products[3]. They describe the 'ideal type' of production system as flexible specialisation. Holistic thinking and the ability to rapidly adjust to continuous changes in the demand structure are required because of larger uncertainty and complexity in production.

Moreover, the recent innovations in Information and Communication Technologies (ICT) have dramatically changed the possibilities for handling, diffusing and storing[4] information[5]. This has in turn resulted in a renewed attention towards the relationships between information and knowledge. Questions like how it is possible to transfer knowledge reduced to information, and the feasibility of retrieval and reproduction of knowledge in another time or place has become central.

The essay investigates these possibilities of reducing knowledge to information, or what is called codification of knowledge, and the conditions it happens under. More specifically, the following is a discussion around the concept of the codebook[6] and its context dependent properties. Transfer of technical knowledge (using a codebook) between two different contexts, or what may be called communities, is explored. The starting point of this essay is that all knowledge is dependent on the context it is created, communicated and utilized in. To what degree the codebook is dependent on such context specific properties, and obstacles and conditions for efficient transfer of knowledge, are explored using a case study.

The case was found in the Norwegian Offshore Industry, in a company frequently functioning as prime contractor in large development projects; Aker Maritime's business area

[3] There is, however, a discussion going on regarding how much the structure of the industry really has changed in the Post-Fordist era. Much industry still is based on large-scale production and division of labour. See for instance Webster (1995)
[4] At least, the short term storing capacity has increased. Steinmueller (1998: 13) does however raise a paradox of the digital memory. Paper as storage can last for a long time, the limited time of a computer system does however affect the long-term storing capacity.
[5] See for instance Lundvall and Johnson (1994: 25) and Cowan and Foray (1997: 609)
[6] This concept was only recently introduced in the Cowan et al paper published in the June 2000 special issue of Industrial and Cooperate Change. This article was written in connection to the TIPIK project ('Technology and Infrastructure Policy in the Knowledge-based Economy – The Impact of the Tendency Toward Codification of Knowledge) which was funded by the European Commission.

Aker Oil and Gas. As prime contractor they are responsible for planning, design, analyses, part fabrication and assembly of large offshore constructions, like floating platform solutions. A project is divided into several phases, where some are carried out in an engineering company and others at an offshore yard[7]. In the transition between design and production, the worked up knowledge must be transferred from the design teams to the production teams. This knowledge is transferred through the use of codebooks. Interviews were carried out in Aker's major engineering company in the Oslo area, Aker Engineering and in the large offshore yard on the west coast of Norway, Aker Stord.

In Chapter 2, the methodology of the thesis is presented. The empirical work, and how the results are presented in the essay are focused on. Chapter 3 describes the theoretical foundation, on which the discussion to come is based. The chapter briefly look at some important contributions in the economical literature, treating knowledge as a context specific property. Moreover, the codebook concept, as Cowan et. al. (2000) define it is included, and will serve as starting point for the examination of the codebook as carrier of knowledge across community boundaries.

The remaining part of the essay considers the case study, and is a discussion around the empirical material. Chapter 4 places the offshore construction industry and the work of Aker Oil and Gas in a social and historical context. Further, in Chapter 5, the package of engineering drawings and 3D-computer model are identified as the most important codebooks in the transfer of knowledge between the design and production communities. Moreover, know-what, as non-trivial in the visualisation of drawings is treated. In Chapter 6, the language and knowledge associated with the codebook is looked at, in order to explore the context specific properties of the codebook. This is typically knowledge related to categories

[7] Some tasks are also transferred to sub-contractors. This is typically building of single modules, like the drilling module.

of know-how and know-who. The last chapters of the essay treat the conditions for transfer of knowledge using codebooks, related to this case. Chapter 7 touches on stabilization and standardization of language (the symbolic representation on the drawings) and the knowledge itself (technical solutions). Finally, Chapter 8 treats the need for additional contact beyond the codebooks, in order to establish a shared context where knowledge can be transferred.

Appendix includes a more thorough description of the Norwegian Offshore Sector and the execution of EPC(I) projects in Aker Oil and Gas. In addition a translated version of the interview guide, used in the case, is attached.

2. Methodology

Regarding the time available and the possibilities for any contribution on the field, a case study is chosen in order to examine the concept of the codebook. The concept is rather new, and very little empirical work is done on how codebooks are used in practice. The findings are off course very dependent on the context they were obtained in. Hence, great caution must be shown in generalizing the results. As Stake illustrates it: ‘The purpose of case study is not to represent the world, but to represent the case’ (1994: 240). The case may however give some indications on the usefulness of concepts like tacit knowledge and the use of codebooks in this particular industry.

The case study was performed as a qualitative investigation, where open-ended interviews were carried out. Kempton holds that this approach is recommended when the interviewer have little understanding of the ‘native concepts’ (1991: 184). The qualitative method gave more room for flexibility in the examination of the vague concepts investigated. Hence, for the purpose of this thesis it was more beneficial than a questionnaire. As a first approach to the subject, I wanted to explore the depth of the area, and in this process find relevant questions, rather than general answers to the wrong questions. A natural extension to this investigation would certainly have been a more quantitative study. To find to what extent the results obtained are prevailing in the communities. The limited number of interviews in this study naturally makes the findings dependent on personal opinions of single individuals. A quantitative investigation was however impossible to accomplish in the short time available.

Nine “formal” interviews were carried out, following a rough guide prepared in advance. This guide was simply used to point out the direction of the conversation. Follow-up of new and interesting issues touched in the interviews created unpredicted courses, which often was much more constructive than the guide itself. The rough interview guide is translated into English, and included in Section A.6 in the Appendix.

Three engineers were interviewed from Aker Egnineering. All respondents were experienced designers, and had a close relationship to the codebooks used in transfer of knowledge between the two communities. Further, two of the engineers had experience as leaders for the structural discipline in a project. At least two of them[8] had been stationed at the production yard for longer periods of time, and were rather familiar with the activities at the yard during the fabrication phases. Since engineers without knowledge of the fabrication process were not represented in the interviews, the general opinions of these persons may not be covered sufficiently.

The six remaining interviews were carried out at the offshore yard, Aker Stord. I had the opportunity to speak to managers of several areas. Their work functions varied from head and coordinators of the engineering departments[9], preparers of the work foundation for operators, building managers and fabrication leader. All respondents had relatively long experience inside their profession and of the work at the yard. No persons currently

[8] One is now the leader of the structural discipline in the project currently run in the engineering company. The other one is a structural engineer.

[9] The engineering departments at Aker Stord is mainly concerned with area engineering inside the structure and piping disciplines.

functioning as welders or sheet metal workers were interviewed. This may be seen as a weakness of the interview selection. However, many of the respondents had substantial knowledge of the operators' everyday work, and must be regarded as belonging to the production community.

All interviews were taped, and they took place at the regular working place of the respondents. The interviews were prearranged, and more or less set up by representatives of the companies. Since I lacked the necessary know-who to contact these respondents myself, this seemed to be the most practical way to go. I had, however, the opportunity to state the functions of the people I wanted to talk to.

The interviews were made in Norwegian. For quotations to be included in this essay, they had to be translated. All quotations are, however, directly translated from the tapes, keeping as much of the word-for-word citations as possible intact. My questions are written in italics to distinguish them from the informant responses. Square brackets denote clarifications deducted from the context. As the number of respondents is few, and can easily be recognized in the context, any obvious possibility of their identification is left out. Names or direct functional descriptions are therefore not put in relation to the quotations.

In the last months of my work with this essay, I had the opportunity to work at the engineering office in the Oslo area. Many informal discussions in the hallway and over lunch have in this manner contributed to my attitude towards the topic investigated. Some additional conversations were carried out for clarification of discoveries from the first round of interviews. Especially one interview, of a person heavily involved in the standardization work in the company, was valuable for clarification. The results presented in the following are, however, primarily deduced from the nine interviews described above.

The literature used as basis for this thesis ranges from economy, history, sociology and ethnography to linguistics and engineering. However, the main theoretical focus has its source in literature related to knowledge economy and some knowledge management. Even so, recent contributions in these fields are heavily influenced by cognitive psychology and sociology of scientific knowledge (Cowan et. al.: 2000: 215).

Much of the discussion in the following is based on results from the TIPIK project, where issues related to codification of knowledge has been focused on. In the next chapter a short introduction is given to the theoretical basis of this thesis.

3. Theoretical Part: About Knowledge as a Context Specific Attribute

This chapter explains the theoretical background, on which the discussion related to the case study is based. The following sections treat important contributions regarding knowledge in especially, economical literature. This, perhaps, simple and general theoretical introduction is necessary in order to establish a foundation, before the more case specific characteristics are discussed in the chapters to come.

To prove why context specific properties of knowledge are interesting, it has been necessary to give a brief introduction to the discussion concerning the difference between information and knowledge. This is treated in Section 3.1. Further, the notion of tacit knowledge is concentrated on in Section 3.2, before codified knowledge and the definition of the codebook is dealt with in Section 3.3. Last in the theoretical part, the context specific properties of knowledge are treated.

3.1 Information vs. Knowledge and the Cognitive Properties of Knowledge

The motivation for exploration of the topics of knowledge codification and codebooks lies in the conceptual division between information and knowledge. Lately, there has been a shift in how knowledge is treated in economic and managerial theories. While traditional theories have seen knowledge as a public good, more recent contributions have concentrated on obtaining more "realistic" models of knowledge. These attend to its complex and intricate properties, largely dependent on tacit and cognitive elements.

The treatment of knowledge as a public good is built on the assumptions of its non-excludable and non-rival qualities. The assumption of non-excludability rests on the idea that it is difficult to prevent another agent from using a piece of knowledge when it has been revealed. Hence, it becomes problematic to keep control over the knowledge flow, with leakage and imitation as results. The non-rival property of knowledge is assumed to reinforce this trend. It permits the same piece of knowledge to be used by an unlimited number of agents at the same time. That is, one agent's use of some knowledge does not exclude or deteriorate another agent's use of the same knowledge. Naturally, this decreases the incentives of producing new knowledge for private actors in the market. At the same time, these very qualities introduce large social advantages through significant spillover effects[10]. This generates what is called the knowledge dilemma[11], and in a free market it results in too little emphasis on knowledge creating activities by private actors.

In the above considerations, knowledge is more or less treated as equivalent to information, or more specifically, knowledge is seen as the accumulated stock of information. It is regarded equally available to everyone. All knowledge is assumed to be totally codified, and its transmission as information is seen as utterly unproblematic. Moreover, the properties of knowledge are regarded to be independent of the context in which it is created and diffused in. Recently, however, major effort has been made in a number of disciplines[12] in order to understand how knowledge differs from information.

[10] To some extent the incentives of the individual agent can be assumed to increase with the existence of means for appropriation (patents, copyrights etc.), but this will again limit the social advantages of the created knowledge.
[11] Foray, D. and Mairesse, J. (2000: 5) also mention the cumulative quality of technological and scientific knowledge as contributor to the knowledge dilemma.
[12] According to Amin and Cohendet (2000: 96), a number of authors in disciplines like economic history, industrial organization, sociology of organization, evolutionary theory and management science have started to question the "old" theories of the firm.

Instead of viewing knowledge as the accumulated stock of information, where all new messages contribute to this stock with some element of novelty, knowledge may be seen as a complex structure. Informational messages will possibly be adopted and included. However, a piece of information may just as well be disregarded if it does not fit with the overall perceptions and logical patterns of the receiver. Alternately, it may enforce a total reorganization of the knowledge structure, when it is of a 'nature that cannot be disbelieved' (Ancori et. al.: 2000: 262). In this fashion information will be piecemeal, fragmented and particular whereas knowledge is regarded to be structured and coherent[13].

Cowan et. al. (2000: 216) define information as 'a message containing structured data, the receipt of which causes some action by the recipient agent – without implying that the nature of that action is determined solely and uniquely by the message itself'[14]. The resulting action will be a result of how the agent interprets the message using his or her cognitive abilities. Also Nonaka (1994: 15-16) relates information to messages, which in turn can add to, restructure or change the knowledge held by an individual[15]. He describes knowledge as shaped by believes and commitments of its holder, and that this is what determine human action.

Accordingly, information obtains its meaning from the individual agent's cognitive abilities to perceive, associate, recognize patterns and build representations of the environment[16]. Nightingale (1998: 693) shows this ability with an example of how it is possible to understand the sentence: 'yxx cxn xndxrstxnd whxt x xm wrxtxng xvxn xf x rxplxcx xll thx vxcxls wxth xn 'x''. If 'x' had replaced only one specific letter in this

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[13] Steinmueller (1998: 4), on Malchup's late perception on the distinction between knowledge and information.

[14]Ancori et. al. (2000) divide data into 'stimulus' and 'messages', where the former is data obtained from the nature, and is thus organized ex post, while 'messages' already are organized by an other cognitive agent and is communicated through languages and classification. Hence, a 'message' is organized a priori. As this essay is focuses on the topic of codification, all data is communicated as messages in the knowledge transfer between different agents.

[15] Nonaka claims that individuals fundamentally create knowledge (Nonaka: 1994: 17). However, it is shaped and created in interaction with other individuals and the environment. Thus, the creation of knowledge is not undertaken by individuals operating in a vacuum.

sentence, the meaning could have been retrieved by simple logic. However, since ‘x’ substitutes all vocals, a more general pattern of recognition, through knowledge of the context in which the ‘x’es are placed, must be invoked.

In this essay I am going to relate to the definition of knowledge given by Cowan et. al. (2000: 216). They define knowledge as the ‘agent’s entire cognitive context’. This includes knowledge held by both individuals and by the collective, in which the individual plays a role. Through the interaction between individuals in some sort of community, knowledge is constantly created, redefined and transformed. When each individual is a part of a negotiation, resulting in new knowledge, he or she will simultaneously be corrected and guided through the impulses given from the collective. This collective knowledge is central in this essay. A more thorough discussion concerning communities with a common foundation of collective knowledge will be given in Section 3.4.

3.2 The Notion of Tacit Knowledge

Closely related to the discussion of knowledge and its cognitive properties is the distinction between tacit and codified knowledge. If knowledge cannot be confused with information, there has to exist some knowledge not easily transferable in the form of pure messages. This is what may be regarded to be the tacit dimension of knowledge.

Polanyi (1966: 4) was the first to introduce the concept of tacit knowledge in modern intellectual tradition. His famous and constantly quoted statement, ‘We know more than we can tell’ has come to give a converse to codified knowledge. Thus, tacit knowledge becomes something that is not possible to communicate verbally or in symbolic form, and is impossible for its holder to express or articulate. It is rooted in human action and experience, and may only be transferred between individuals or collectives through observation and “learning-by-

[16] See for instance Nigtingale (1998) and Amin and Cohendet (2000).

doing". As a result, tacit knowledge is extremely dependent on the context in which it is created, and the diffusion over large distances becomes problematical[17].

Nelson and Winter were among the first who introduced the concept of tacit knowledge as economical significant. They relate the concept to skilful performance, and claim that skills are frequently based on tacit knowledge, as 'the performer is not fully aware of the details of the performance and finds it difficult or impossible to articulate a full account of these details' (Nelson and Winter: 1982: 73). Their definition of skills includes both manual skills (for instance how to ride a bike) and cognitive skills (such as the ability to understand a language) (Ibid.: 79).

Likewise, Nonaka (1994: 16) divides tacit knowledge into two main categories of cognitive and technical elements. The cognitive elements are described as "mental models". They are the perception, from which understanding is obtained through manipulation and interpretation of external impulses and mental feedback loops[18]. These models include schemata, paradigms and beliefs, which govern the individual's perception and definition of the world. This tacit knowledge must always be present in order to understand information, and is therefore a condition for understanding codes. Hence, if people are to share or transfer tacit as well as codified knowledge, some shared comprehension of tacit cognitive elements has to exist. Technical knowledge, on the other hand, is more related to manual skills. These skills are concrete know-how, techniques and crafts, which apply in a certain context.

That a piece of knowledge is tacit in one time and place does not mean that it necessarily needs to be universally tacit. This is particularly true for certain types of tacit, technical elements of knowledge, where a technique or know-how may be possible to express and articulate, even if it has stayed tacit in a specific setting. Cowan et. al. aspire to a more nuanced interpretation of the concepts of tacit and codified knowledge. They claim that the

[17] The tacit characteristics of especially skill-based knowledge cause its "stickiness". This is assumed to be the

knowledge's state as tacit in one context does not necessarily mean that it has never been codified anywhere, or that it is impossible to ever codify it. Very little knowledge is thought to be tacit in nature, but sooner unarticulated in a specific context[19]. Rather, incentives through costs and benefits of articulating a certain body of knowledge matters.

3.3 Codification of Knowledge and the Concept of the Codebook

Codification of knowledge is the process of making knowledge possible to communicate through formal and systematic language. Or as Cowan and Foray (1997: 596) define it, knowledge codification is 'the process of conversion of knowledge into messages which can then be processed as information'. In the same paper (602) they introduce the practice of knowledge codification to include the generation of languages, models and messages. This definition gives that codification of knowledge is related to the transformation and modelling of pre-existent knowledge, and the expression of these models through messages, using an accommodated language.

Codified knowledge in general does not demand a specific medium, such as written documents, in order to be communicated. Some messages are however modelled using very particular languages and symbolic representations, and will therefore require special methods and media in order to secure communication and transfer. Typical examples are representations of knowledge arranged through tables or drawings. In addition, the storage in some sort of media, like a written document, will ease the retrieval of the codified knowledge at a later stage in time, or facilitate diffusion of the knowledge to a larger audience. In the next chapters of this essay, use of codified knowledge in the form of drawings or 3D-computer models is further investigated.

reason for more rapid diffusion of knowledge inside clusters than outside.

[18] A more thorough treatment of the cognitive elements is found in the previous section of this essay.

[19] Cowan et al presuppose that in order for some knowledge to be articulated it has to have been previously codified. Unarticulated knowledge, on the other hand, may have been formerly codified or not.

Cowan et. al. (2000: 225) introduced the notion of the codebook in their paper on knowledge codification and tacitness, published in the journal, Industrial and Corporate Change, from June 2000. They use the codebook to describe what might be considered a dictionary, and also to comprise the codified knowledge itself, represented in written documents. In this manner, the codebook is thought to create a self-referential situation, where all new codified knowledge becomes added to the existing codebook, and the codification of new knowledge relies on the already codified knowledge. Trough the constant introduction of new documents in the codebook, modelling tools and language of the pre-existing codebook will be continually negotiated whenever a new piece of knowledge is codified. This will again result in a collective stabilization of the understanding of the codebook. Hence, the codebook will generate a standard and become an authority in the context of which it is acknowledged.

As the main function of a code must be its de-codification, the recipient's ability to successfully read the codes becomes utterly important. In order to understand and utilize knowledge represented in the codes, the reader must have the ability to interpret them, and to link them to general patterns of association through his or her cognitive abilities. Hence, the temporal, spatial, cultural and social context where the knowledge is obtained and exchanged becomes imperative for the discussion. This is treated in the next section.

3.4 Language, Modelling and the Context Specific Properties of Codebooks

In this section, the context specific properties of the codebook are further discussed. These properties are linked to the tacit cognitive abilities of understanding a language and the way the codified knowledge is modelled.

As described in the previous section, codification necessitates the creation of models, languages and messages. The creation of models and language is crucial for the formulation of messages. Hence, knowledge of relevant languages and methods of modelling is a condition for the understanding of the codebook, as well as the creation of new pieces of codified knowledge. Languages and models are mainly embedded in the codebooks through their principal function in the writing of messages. It is through continuous writing of new documents to be included in the codebook, that the language and models eventually becomes stabilized. Consequently, it is an interactive bond between the three, which gives the self-referential situation of a codebook, mentioned in the previous section.

Steinmueller (1998: 2) points out the close relationship between knowledge and language, and how the generative and adaptive properties related to knowledge, also applies for language. In order to illustrate this connection, he uses native speakers of a language as an example. Native speakers are able to hear sentences for the first time and still associate and extract meaning from the communication process, due to their knowledge of the language. That is, the mind models, related to the cognitive tacit elements described by Nonaka, will be implicit in the language. In this manner, language can act as cognitive representation. Through the creation and common understanding of a language, perception of the articulated models and messages may be enabled.

In order to use language as a common foundation for understanding documents in the codebook, its vocabulary and structure must have become stabilized. Before this stabilization language takes place, understanding of various concepts will be diffuse and fluid, and misunderstandings may occur. The process of making language into an instrument for cognitive representation is largely dependent on transforming explicit knowledge about concepts into “tacit” knowledge, so that the holder is not focally aware of what he or she knows (about how to interpret language)[20].

[20] Nonaka (1994) p. 18 uses Anderson’s ACD models, obtained in cognitive psychology, to describe the importance of tacit knowledge, or as he calls it, “procedural knowledge” in the development of cognitive skills. Anderson states that declarative knowledge (what Nonaka calls explicit knowledge) must be transformed into procedural knowledge if cognitive skills are to develop.

The perception of language is largely dependent on social negotiation. It has to be mutual recognition between the communicating agents, and their perception of the language's structure and vocabulary must be similar. This converging negotiation process may be a time consuming matter, as it is built on tacit elements related to human cognition. The socialization process is a continuous process of adapting individual knowledge to the collective knowledge. This is obtained because every individual constantly senses and picks up of signals in interaction with other individuals. It is based on collective tacit knowledge like shared norms, values, perception and mind models. Through this common knowledge, a common framework is built, in which it is possible to ascribe similar meaning to language.

The creation and stabilization of a language may however also be obtained through what Nonaka calls internalization. The perception of language may be initialised by education, training or other explicit sources of knowledge, like the conscious creation of a new codebook. When a new language is formally created or implemented, at least parts of the knowledge must be regarded as explicit. In order to be fully capable of assigning the same meaning to the language, the collective have to make this knowledge tacit.

Even if the language and models used to express codified knowledge have to be stabilized in order to secure efficient transfer of knowledge, this must not be confused with the completion of the codebook. Instead, it is constantly negotiated, as new bodies of codified knowledge are continually added to it. Hence the knowledge related to the codebook is fundamentally dynamic.

It is the introduction of a second agent in the codification process that calls for mutual understanding, perception and what may be called worldview, stressed as important in the above. The absorptive capacities and cognitive abilities of the receiver must always be kept in mind when codifying a piece of knowledge. Through the introduction of this second agent in the case of knowledge transfer, communication of codes is dependent on the building of shared languages and classification. The foundation of mutual understanding has to be socially negotiated through a long-term process of building a community of individuals, which share a basis of cognitive tacit knowledge. This knowledge is related to a worldview built up through common norms, believes and basic assumptions.

With the above in mind, a community is the stabilized context, in which knowledge can be transmitted. Its members have got sufficient qualifications to understand the meaning of knowledge either it is tacit or codified[21]. Moreover, communities are the places where new models and languages are progressively tested, validated and compared (Ancori et. al.: 2000: 283).

In the following, transfer of codified knowledge between two professional communities is explored. The norms of such a professional community are largely related to what is considered good working practice and craftsmanship. These norms give important guidelines for behaviour, ways of prioritising and attitude towards the contents of written material. Knowledge of these behavioural rules and attitudes are often a criterion for acceptance as a community member. The above discussion gives that the existence of a joint language is particularly important for the existence of a community. The language will serve as a common cognitive representation in the communication of knowledge.

Since communities become the context in which codified knowledge is understood, transfer of knowledge through the use of codebooks must be dependent on how members of a community relate to the codebook. Cowan et. al. (2000: 225) describe the dictionary included in the codebook as used by agents for the purpose of understanding the written documents. The building of this dictionary is a condition for efficient use of the codebook. The dictionary itself can, however, not be regarded to be more than a manual, embracing a list of words or symbols and their equivalents, and must primarily be considered as instructive in understanding the vocabulary used. Hence, use of the dictionary as support for comprehension of codified messages is dependent upon some minimum knowledge of the language and models as cognitive representations. A consequential understanding of the codebook is therefore not obtainable, even if the content of the dictionary may be available. However, when Cowan et. al. include the dictionary in the codebook concept, it indicates how the codebook is more than pure information in written messages. On the contrary, it must also include the cognitive context in which knowledge is associated and linked to general patterns.

As a result, any codebook will have some context dependent properties. These properties are linked to the sending and receiving agents' relationship to the applied language and ways of modelling codified knowledge. Hence, the understanding and perception of knowledge embedded in codebooks are always dependent on the community where it is de-codified. Ancori et. al. (2000: 265) summarize the context specific properties of knowledge in three proposals: Knowledge is dependent on the cognitive abilities of its holder. It cannot be separated from the communication process through which it is exchanged, and finally, knowledge demands knowledge in order to be acquired and exchanged. All these proposals points towards the need of a community, where its members share a common knowledge base and a foundation for perception of codified knowledge. This acknowledgement of the context dependency of creating and reading codes is based on the recognition of a fundamental difference between information and knowledge, and the admittance that knowledge cannot travel freely.

With the above in mind, transfer of knowledge between members of the same community seems to be rather unproblematic. What happens, however, when successful performance in a company depends in transfer of codes between two different professional

[21] Off course tacit knowledge may take longer time to learn than knowledge related to codified documents in a stabilized context. But nevertheless the community will provide a common framework wherein both tacit and codified knowledge might be transferred.

communities? And when these communities are located in different geographical sites, which restricts the personal interaction between creators and readers of the codes?

4. A Case of Knowledge Transfer in the Norwegian Offshore Construction Industry

With the theoretical background from previous sections in mind, this thesis will explore how codebooks can be used in the transfer of knowledge between two different communities. To do this, a case study in the Norwegian Offshore Construction Industry is chosen.

Since the first production of oil commenced at the Norwegian Continental Shelf in the beginning of the 1970s, the offshore industry has become extremely important for the country's economy and welfare. Today, the sector contributes to about 20%[22] of the Gross National Product. The income from petroleum related activities is however extremely sensitive to the oil price and to the dollar exchange rate. In order to protect Norway's future welfare, a petroleum fund has been established. Its main purpose is to be a buffer in case of failure in the inland economy, long-lasting decline in oil prices and in anticipation of smaller investments in the oil sector and an ageing population.

In the future, new development projects are assumed to be smaller gas fields, found in locations with difficult access, like large water depths. The possibilities for profitable exploitation of these fields are much smaller than in the large oil field development projects of the 1970s and 1980s. To overcome these challenges, the industry must develop advanced technological solutions using considerably fewer man-hours than in the past.

In the beginning of the 1990s a new contract form became common in the industry. The overall management and co-ordination responsibility of large projects were transferred

[22] In 2000 22% of the Gross National Product came from petroleum related industry.

from the oil company to a prime contractor. In these EP, EPC and EPCI[23] contracts, the prime contractor is responsible of the total execution of a project, including design, procurement, fabrication, assembly and possibly installation of an offshore structure (for instance a floating production platform). This involves new challenges for the prime contractors, especially in the interface between engineering and fabrication. These phases are generally carried out at different sites. After the completion of the early phases, carried out in an engineering company, the project usually moves, with all its built up knowledge, to an offshore yard. In this transfer of knowledge, codebooks are used.

The case considered has been carried out in Aker Oil and Gas, which is one of Norway's three relevant prime contractors in large offshore development projects. Aker Oil and Gas is one of two business areas in the concern, Aker Maritime[24]. The interviews were performed in two of the daughter companies heavily involved in execution of EPC(I) concepts: Aker Engineering, which a major engineering company located in the Oslo area, and Aker Stord, which is a large offshore yard and a cornerstone company in a rather small society in Western Norway.

The concern has long traditions in the Norwegian maritime industry. Akers Mekaniske Verksted was heavily involved and a major actor in the engineering industry from it was founded in 1841. The company functioned as a shipyard until the Aker group gradually adapted to the offshore construction industry in the period from 1960 to 1980. Through a number of reorganizations, fusions and takeovers the concern has slowly shaped into today's Aker Maritime. In 1956 the concern became co-partner in the yard at Stord, which had been functioning as a shipyard since World War 2. Today, Aker Stord is fully owned by the concern, and has become Aker's main yard in the execution of EPC(I) contracts.

[23] The acronym stands for Engineering, Procurement, Construction and Installation
[24] More information about the company is found on their Internet site: http://www.akermar.com.

Before the introduction of the new contract form, the employees of Aker Engineering and Aker Stord had limited contact. However, in order to overcome the new challenges of the EPC(I) contracts, the collaboration between the companies have become more or less permanent[25].

More on the history and prospects of the petroleum related industry in Norway, together with a more detailed description of EPC(I) projects and execution of large development projects, is given in the Appendix, Section A.1 to A5.

The two companies have very different relations to the structure to be built. Whereas personnel in the engineering company are responsible for large parts of the structural design, Aker Stord is the fabricator of the structure, with basis in the concept created in design. These very different experiences establish different abilities of perceiving and associating patterns to codified knowledge[26]. Inside each company there are groups with very similar skills and basic assumptions. Through time, a partly tacit knowledge base of behavioural rules and norms for good craftsmanship has been built up. This conditional common worldview becomes the basis for communities, where the members share important cognitive skills. In this essay, two such communities are considered. One is the community of engineers; designers, analysers, modellers and drawers, which have been called the design community in the following. For this particular study, the design community is limited to comprise personnel normally seated in the engineering company. The other community considered have been called the production community. It is considered to include personnel directly involved in the fabrication work, for instance operators, supervisors and building managers. Not included in these categories are people sitting in intermediate positions, where some of them function as

[25] Both companies can take smaller assignments on their own, and sub-contractors are usually involved in large EPC(I) contracts. However, as a prime contractor the two companies share profits and risks, and function as a unit in permanent collaboration to the outside world. In Appendix the consequences of a recent reorganisation where the main responsibility for providing engineering and design services in new development project have been moved to a sister company, Aker Offshore Partner. The respondents saw however Aker Engineering as a parallel supplier of such services in the future.

mediators of knowledge. Chapter 8 describes their important position in the transfer of knowledge.

Codebooks are used to accomplish the transfer of technical knowledge when the project is moved from the engineering company to the offshore yard. The knowledge to be transferred is much too complex and comprehensive to be transferred directly by personal interaction or oral communication. In large EPC(I) projects several hundred persons are usually involved. Hence, the size of the built up project memory becomes comprehensive. Co-ordination and management of technical knowledge must be possible, to secure the quality of the finished structure. In addition, the ideas to be transferred are mainly visual models of the structure. To pass on such symbolic representations, drawings are invaluable, and are used both in the creation and in the communication of knowledge.

On the basis of the already written, this essay seeks to explore how technical knowledge is transferred from the design community to the production community by the use of codebooks. Or formulated differently, to investigate how and if the two communities are able to obtain and utilize the same technical knowledge, communicated through written codes.

The point of departure have been that knowledge is created, used and interpreted in a cognitive context, determined by the historical, cultural and spatial situation of a community. Hence, each individual's understanding of a written message or a code is always dependent on the tacit cognitive knowledge, governed by his or her relationship to a community, and its collective memory. The existence of inherently tacit qualities of knowledge, largely touched in the Cowan et. al. (2000) paper, are not given particularly consideration in the following. It is however assumed that there are, at least, some elements of tacit cognitive knowledge shared in a community, which decide how the codebook is read. This knowledge should be tacit, because, as Ancori et. al. (2000: 272) claims: 'when attending to what is articulated, we

[26] More on the associated knowledge of each community is included in Section 6.2.

cannot at the same time focus on the process that makes us articulate what we know'[27]. Not touching the question of the inherently tacit qualities of knowledge, the essay is rather considering how communities with different background knowledge (both tacit and codified) associate knowledge differently, and what is needed for technical knowledge to cross the context border.

In Chapter 5, the package of drawings and the 3D-computer model are identified as the most important codebooks in the transfer of technical knowledge between the design and production community.

The context specific properties of codebooks are especially dealt with in Chapter 6. How oral language, related to the symbolic representation on the drawings is perceived, and how knowledge associated with the drawings is different in the two communities is explored further.

Stabilization of language and methods of modelling was mentioned in the theoretical chapter as a necessity for the consistent de-codification of knowledge embedded in the codebook. In Chapter 7 stabilization and standardization of the representing language and the knowledge itself, represented through technical solutions, is treated. Moreover, the consequential path dependency, resulting from such stabilization is treated.

In the final chapter, the need for additional contact beyond the codebooks is looked into, and how people in intermediate positions can be regarded as mediators in the transfer process.

In the case study, the steel process has been concentrated on. Hence, it is the transfer of knowledge related to the steel structure itself that is followed. The investigation of other important processes in EPC(I) contracts, for instance electrical and mechanical equipment, piping, processing and safety, are not investigated in this essay.

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[27] This goes for both technical and cognitive tacit knowledge.

5. The Codebook: Transfer of Knowledge Using Drawings and 3D Models

Codebooks used in the transfer of knowledge from the design community to the production community are mainly the 3D-computer model and a package of drawings. These codebooks are symbolic representations of the structure concept, and they are carriers of the technological knowledge created in the design community. Their main function is to form the foundation for the practical building of the structure, which is to be carried out by the production community. In this section, the content and framing of the written documents in the codebook are further described. It is argued how pictorial statements are important in creation and transfer of codified knowledge. Moreover, the need for deep knowledge to visualise know-what, carried in complex engineering drawings is discussed, and how the introduction of 3D-computer models has simplified the visualisation.

Ferguson (1992) insists that visual thinking is of principal importance, both in the making and in the handling of engineering knowledge. Many of the necessary tasks in engineering design cannot be reduced to verbal descriptions. On the contrary, creation, treatment and communication of engineering knowledge demand visual and non-verbal processes. These are processes where elements are manipulated and assembled as if the finished structure already exists. In this, the symbolic representation in the drawings or in the 3D-computer model is a vital tool for visualization. Pictorial statements are used to describe knowledge difficult or impossible to communicate verbally. Drawings have the ability to give straightforward and relatively complete descriptions of objects, which are difficult to articulate, unless enormous and complicated verbal rings are used (Ivins: 1953: 160). As such, they are extremely important in the communication of engineering knowledge. They show a mirror of the visual knowledge of the individual creator of knowledge. For this purpose, codification of knowledge using pictorial statements is invaluable in the creation and transfer of knowledge. For knowledge creating purposes, they are used in the individual's cognitive processing and in discussion with other members of the design community. Moreover, they are necessary in the transfer of knowledge of very complex systems from the design community to the production community.

The drawing as a tool for visualization and learning has a long history inside the engineering world. Through the art of printing, it became possible to obtain exact duplicates of drawings and diagrams, as well as written text. Ivins (1953) claims that this possibility for visual recognition through exact 'repeatable pictorial statements has been crucial for the rise of modern technology and science. He holds that exact copying of drawings introduced logical symbols for sensual experience 'without which rational thought and analysis are impossible' (Irvins: 1975: 13). From the 15th century repeatable pictures, the engineering drawing has evolved through many phases, until the orthographic projection used today gradually came into general use in the 19th century (Ferguson: 1992: 83). Before this, the designer's knowledge was transferred directly to the production community through the foreman or the shop owner. As a result, the finished product naturally became a result of the joint decisions and negotiations between the designer and the producer. In many ways, the engineering drawing introduced a distance between the two communities, when it became possible to communicate relatively independently of personal interaction, through codified messages. The decisions were now mostly made in the engineering departments, and through the gradual acceptance of the drawing as a promoter of knowledge, the codebook obtained its authority.

The drawings and 3D-computer models are what Cowan et. al. (2000: 230) call articulated and thus codified knowledge. The codebook is openly defined and referred to in usual knowledge making and knowledge using activities. In this essay, these codebooks are concentrated on, rather than displaced codebooks where the knowledge is not manifested.

5.1 The package of drawings

As mentioned above, today's steel engineering drawing is orthographic, and shows plain two-dimensional surfaces. The structure may be seen from several views, in order to make the reader able to visualize the finished product. Usually the main view is the plane from above. That is, the deck floor shown from above and lateral views of bulkheads. In addition, details are often seen from one or both sides.

Perspective views are generally easier to visualize than the orthographic drawings, since they show the complete and assembled object as a three-dimensional structure. However, a perspective view will not show the exact shape of details and components. As they introduce substantial ambiguity, perspective drawings are generally unfit for engineering purposes (Ferguson: 1992: 92). Nevertheless, views showing three-dimensional perspectives of the structure are usually included in the drawing package, where they act as visualization support for the reader. The general characteristic of these drawings makes them accessible to a number of users. They show an illustration of the structure corresponding to how most people expect it to look like. This kind of representation is related to knowledge of considerable "width". Ancori et. al. (2000: 269) link this width to the degree of generality of knowledge, and the number of users who have got sufficient understanding of codes and language in order to use it.

Depending on the phase of the project, different types supplementary information is included on the orthographic drawings. A design drawing typically contains symbols showing; measures, dimensions (like plate thickness or pipe diameter), material quality, weld types and references to notes in the margin. Since all parts of the structure will not fit on a sheet of A3 paper, at least not with the needed degree of detailing, references to other detail drawings are extensively used. This information gives an experienced reader necessary knowledge about the structure in a relatively short amount of time. For an untrained eye, however, lines describing the structure edges are easily confused with lines describing measures and dimensions. The more detailed the drawings are, with intricate splits and references to other drawings, the more knowledge of how the symbolic language is constructed and how the systems are interrelated is needed. Hence, the intuitive understanding of these drawings is related to deep knowledge, or what Dreyfus et. al. (1986: 30-35) call "expertise". In Chapter 3 the close relationship between language and knowledge was pointed out. When the language representing knowledge becomes intricate and relies on deep knowledge, like in the case of engineering drawings, the individual's cognitive abilities of associating language with general patterns become especially evident. This ability to read a drawing was described in one of the interviews:

> Some are incredibly good at it, while others have larger problems seeing the totality in such a drawing. For them, a three-dimensional picture on the front page is of huge support. You see how [the finished product] is to turn out immediately, and it becomes easier to go through the drawings. *Is the understanding of the drawings something you get through experience, or is it almost like a congenital skill?* You obtain it through experience, but it is definitely a skill. Some see it extremely fast. Others never see it.

The ability to convey technical knowledge into mental visualisation models is mainly related to the ability to acquire know-what from the drawings[28]. Nevertheless, as a consequence of what is written above, perception of this know-what is not at all trivial and universal. On the contrary, the reader must relate to stored knowledge of substantial depth and complexity. As a consequence, it takes a lot of tacit skills and long training to be able to read a package of

[28] Know-what is described as knowledge about facts, or what is normally called information (Johnson and Lundvall: 2001: 12). This know-what is however closely related to knowledge about how to build the structure. This is explored in Chapter 6.

drawings in an efficient manner. Actually, the reading and understanding of know-what embedded in the drawings requires substantial know-how.

The introduction of 3D-modelling tools has made the know-what carried in engineering drawings more available, since these tools give better possibilities for visualization for inexperienced readers. These possibilities are examined in the following section.

5.2 The 3D-Computer Model

The use of 3D-computer models is very important in the design work. These models are the prime carriers of knowledge, both internally in the design community, and in the transfer of knowledge to the production community. 3D-computer models and DAK systems were introduced in the middle of the 1980s, and already in the beginning of the 1990s they had become invaluable in the industry.

The complete 3D-computer model is a total representation of the structure in three-dimensions. All disciplines include their systems in the model, with the result that all sub-structures are incorporated. Through thoroughly defined interfaces and determination of each discipline's responsibility, the various systems can be built up simultaneously in split sites. New ways of interaction becomes available when people sitting at different geographical locations share the same computer model. Their communication is not longer restricted to oral communication or discussions of individual drawings over the phone.

Moreover, the 3D-computer model offers valuable visualisation aid in comparison to the two-dimensional orthographic drawings. As described in the previous section, comprehensive knowledge is often needed to gain access to even the know-what of such drawings. The three dimensional model, with its zooming and turning functions, makes it possible to carry out virtual tours in the structure to be built.

The respondents portrayed the introduction of 3D-computer models as particularly beneficial in the design community. Engineers seated in geographical locations far from the production hall have now the opportunity to obtain a better understanding of the totality of the structure they are designing. It is possible to see surroundings of single elements and to discover limitations in the design at an early stage. The 3D-computer model provides weight and inter-discipline clash checks, and a possibility to verify how everything fit together. One of the respondents in the design community did however remark that the model does not give a good indication of size:

> It is much easier to relate to size when you get out. I discovered that when I was at Stord, and was to design a structure to be placed in a certain area. I found the area in the 3D model and placed the structure, but it was always things I had overlooked when I got out and saw it in real life. So the best thing is to get out. But you do not always have the possibility. It is costly, and in the design phase things are not even built. Then you only got the 3D model to relate to.

For the production team, the 3D-computer model is useful in the planning of the fabrication. It can help the operators to obtain a general idea of the structure of the model, and helps with the preparation and the detail method. The operators are however not trained to use the 3D-computer models, but have to turn to site engineers or the work foundation team in order to enter it. The fabrication leader does not feel that the knowledge of how to use the model would help the progress or productivity of projects. It might contribute making work more interesting for some of the operators, but extra costs of training do not make it worth the effort. A three dimensional view follows the work package, and if the operators need to go into the model to turn it, the work foundation team and site engineers are able to help them.

These advantages of 3D-computer models contribute to the irreversible introduction of Computer Assisted Design (CAD) technology. Today, the execution of projects, where extremely complex structures are to be built, is unthinkable without the use of 3D models. A number of disadvantages are however experienced with the models. They involve large costs, since much hardware and own computer stations are needed. The costs are further increased, because the use of these systems demands additional support, administration and maintenance, and must be licensed from the program supplier[29]. Respondents from the design community described the costs as unreasonable high in smaller projects.

The high user threshold requires much training and experience before a user becomes familiar with the program. Because the modelling capacity in the engineering company is rather small[30], consultants have to be hired in manning peaks, and these are not always experienced to be loyal to the project. One respondent in the design community described the company strategy, where few drawers are kept on a permanent basis, and the consequential need for external consultants in the following way:

> In the accounts it is probably cheaper, but quality wise? Especially when you have to take in a lot of consultants, as in the last project, it is on the expense of quality, in addition to it being time demanding.

To secure the needed flexibility in CAD tools, they become relatively heavy computer programs. This leads to difficulties whenever large modifications are to be carried out in the model. As a result, the iteration process, necessary in the design process, might be reduced to fewer steps. In the creation of a design it is necessary to assume something and then verify it.

[29] I have not been able to get any numbers on these costs. Anyhow, they would have to be compared to the advantages of using these kinds of tools in order to have any value in this connection. The task of quantifying and assessing knowledge definitely goes beyond the objective of this essay.

If it is not good enough you have to make a new assumption[31]. This may be a laborious process when the 3D model is to be used.

A large portion of the drawings is extracted from the 3D model. There exists an intelligent link toward drawing tools of the same package, which makes it easy to print ISO-views, arrangement drawings and elevation or plan drawings from the model. Whereas operation of 3D tools requires much knowledge, paper drawings, where measures, weld information and notes are explicitly added, are available to all. They can be used in general discussions and be brought to meetings without any additional effort. Hence, paper drawings are still necessary, because they increase the availability of knowledge[32].

Drawings from the 3D model are supplemented with drawings from 2D drawing tools. Especially in the early phases of a project, these tools can be useful in illustration of concepts, before the full model is created. Some standard drawings are used in every project. These may be drawings of general information, or of staircases, ladders or connections, and are separate from the 3D model. One of the most useful functions of the 3D model is the possible link to cutting tools. Fabrication data is directly extracted from the model, and the plates are guaranteed to have the same shape as planned in the model.

As described in the Section 3.4, the codebook must be regarded to be more than a simple collection of written documents. For the codebook to act as an authority, it has to be collectively accepted and adapted in the community it acts as carrier of knowledge. Accordingly, the possibility and nature of de-codification of knowledge becomes crucial, and

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[30] Only three or four persons permanently employed in the engineering company are described to master 3D modelling.

[31] This indicates that technical engineering work starts with the solution. Nightingale (1998) claims that this is why science and technology answers opposite questions. More on this is included in Section 8.3.

[32] This statement can off course be discussed, as the reading of an orthographic paper drawing requires deep knowledge, or know-how of understanding know-what. As a result, the availability of knowledge depends on the cognitive context where the drawings are to be de-codified. In this essay I assume that both members of the design and production community hold knowledge to read and to extract necessary knowledge from a package of drawings, especially when a 3D plot is available.

the concept is closely related to the conditions for utilizing this knowledge. In other words, the context where codified knowledge is created and de-codified must be incorporated as an essential characteristic of the codebook concept. Whenever knowledge is to be transferred across community boundaries, these context specific properties become significant. Hence, some knowledge about how to obtain appropriate knowledge from the codes must be shared by the involved communities.

In the following, important aspects linked to each community's perception and handling of knowledge embedded in the codebook, are explored. As stated above, the creation of a common cognitive context is an important condition for transfer of knowledge through the use of a codebook. In the chapters to come, three key elements related to the codebook are touched, namely interpretation, stabilization and flexibility.

In the above, it has been argued how even the pure know-what embedded in the drawings requires profound tacit cognitive abilities to be obtained. The following chapter will explore how the two communities associate knowledge, beyond know-what, with the contents of the codebook.

6. The Context Dependent Elements of the Codebook

In this chapter, the interpretation of the codebook is being further examined. As mentioned above, de-codification and perception of codified knowledge must be vital parameters of the codebook. This implies that the codebook is a context specific concept, where communities and their collective cognitive knowledge must be considered. As a consequence, the way people talk about, think about and understand the drawings must be important ingredients in the codebook concept[33]. In the following, these context specific parameters are explored further with the case in mind. To illustrate the context dependent properties of the codebook, differences in how the design and production communities associate language and different categories of knowledge, beyond the pure know-what, is considered.

6.1 The Use of Language

Related to the pictorial statements there is an oral language, which mirrors the knowledge embedded in the drawings. In Chapter 3, the close link between language and knowledge, and how language can function as cognitive representation, was established. Hence, the oral expressions must be closely related to the knowledge represented through the codebook.

The communities have developed a system of jargon, making it possible to express and discuss the drawings and the knowledge associated with the symbolic language[34]. This terminology is believed by all the respondents to be rather similar in both communities[35]. Over time and through the use of similar sets of drawings, the expressions have been passed on from one community to the other. This language is not only assumed to be a company specific characteristic, but rather a jargon typical for the whole industry. Extensive co-operation between customers and different levels of suppliers, where the alliances changes from project to project, has probably contributed to the diffusion of the oral language, as well as the symbolic language on the drawings[36].

Even if the words are similar, the meaning associated with them is assumed by the respondents to differ somewhat from the design community to the production community.

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[33] This is a result of the codebook being dependent on a great deal of tacit knowledge, through the cognitive abilities developed collectively by the community

[34] The knowledge associated with the drawings is explored further in the following section.

[35] Even if they felt that most terminology were common, two of the respondents, belonging to the production community, felt that some words and expressions differed. In addition, many of the respondents pointed out the design community's disposition towards English expressions. Often the official language in a project is English, and all documentation handed over to the customer has to be in English. Since most operators are more comfortable with Norwegian, some misunderstandings and conflicts related to the drawings have taken place. Creating an extra set of drawings in Norwegian, for the use in the production hall, has frequently solved this.

[36] The stabilization of the symbolic language on the drawings and 3D-computer model is treated in a later section of this essay.

This was especially pointed out by members of the production community and by the people in intermediate positions. Two of the respondents expressed the difference in connotation as:

> *Do you think that [the two communities] use the same words, but associate different meanings with them?* Yes. When you say fairleads, they say fairleads down here too. Just like it is written on the drawings. But it is not certain that they know what they are used for[37].

and:

> A person, who never has heard the word pos number before, has no idea what you are talking about. Then you have names on material and profile types and things that are professional language [in the production hall]. Off course, the drawers have to have knowledge of it, but I do not know if they have any relationship to it. If you tell a profile size or a profile type to an operator outside, he can picture the profile. But a drawer will generally have another opinion of what it is. Maybe he must look in a catalogue.

The similar language makes it possible to communicate across the organizational boundaries. With a drawing as a reference solutions may be discussed and the design might be supplemented. Generally, what is called mediators in this essay[38], secure the communication flow. As a result, there is little direct contact between the designers and the operators. This might be the reason why the difference in association to the terminology generally was seen as unproblematic. One on the respondents from the production community did however remark:

[37] That is, what their exact function is on the platform is, or how they are operated.

> Some of the terminology [the design community] uses are actually easy to misunderstand. They mean different things by the same words, and I think that this often has lead to misunderstandings. When both parties thought they had expressed themselves clearly, when they actually have answered different questions.

The associations related to the oral language, is obviously connected to experience and knowledge related to the objects this language is describing. Pfeffer (1990) remarks how language and symbolism are closely connected to culture. As the two communities have got very different relationships to the drawings or the finished construction, they also have very different conditions for linking general patterns to the description of them. As stated above, this comprehension must be strongly connected to the codebook concept, because it is inseparably linked to the contextual understanding of the knowledge it carries. In the following section, knowledge associated with the drawings by the two communities is further explored.

6.2 The codebook and the different knowledge associated

The codebook implies more than transfer of pure information (or know-what). Since the codebook concept must be regarded to embrace the context it is created and de-codified in, it will never be neutral or objective in transfer of knowledge. In the following, the difference in interpretation and knowledge associated with the codebook is discussed, with basis in the case. As shall be discovered, the two communities certainly interpret the codes in different ways, and do naturally relate different knowledge to it.

The drawings themselves are containers of very plain and specific facts about how the offshore construction is to be built. This knowledge is related to know-what, and was discussed in the previous chapter. The possibilities and character of visualization from two-

[38] The importance of mediators in the transfer of knowledge using the codebook is considered in Chapter 8.

dimensional drawings are however dependent on the reader's cognitive abilities. These cognitive abilities are again influenced by the relation the reader has to the know-what of the drawing and the construction to be build. Accordingly, knowledge associated to the contents of the drawings, beyond the pure know-what, becomes significant for their interpretation.

The background knowledge of the reader will commence a process of associating know-what to general patterns, which again forms the wider cognitive understanding of the drawing. These cognitive abilities are strongly influenced by past experience and social feedback from fellow community members. Hence, knowledge in the drawing will be interpreted very differently depending on the reader's social context and professional background. Accordingly, a designer or engineer must be assumed to associate very different knowledge to the codebooks, compared to the craftsman working in the production hall.

This acknowledgement may seem rather trivial or at least apparent. Nevertheless, in this conceptual discussion, this result is of significant consequence. It shows that the interpretation of information is dependent on the reader, and the context specific characteristics of the community the reader belongs to. If this is so, some tacit cognitive abilities must be operating, and the utilization of information is not at all universal or uncomplicated, as assumed in much traditional economical theory. To be discussed in the sections to come, differences in professional background, or what the respondents called "cultural differences", may lead to poor understanding of the other community's priorities.

The following statement, from a member of the design community, illustrates the fundamental different way of relating to the product:

> Sometimes it was difficult to stay up-to-date with status and the progress. In this respect we did not have total control with regards to quality. These things are supposed to be sorted out before the fabrication starts. But when we have EPCI contracts, some work with

> engineering and others with fabrication. The ones working with fabrication usually want to plan from behind, while we have a tendency to plan from ahead. Then, in the middle, it does not agree very well. Sometimes some months are missing.

The above quotation proposes a reason why the two communities are experienced to have conflicting considerations. They have different requirements to relate to, and indeed very different norms for good craftsmanship. As a result, there is a directional mismatch in the way the communities are thinking. This mismatch creates different cognitive contexts, and unlike conditions for the interpretation of knowledge. In the following, this is going to be deepened by looking at the knowledge each of the communities associate with the codebook, and their work related to the codebook. The prime target is to show that even if both communities understand the drawings, this understanding is not necessarily identical. Off course this may vary a great deal within the community. The degree of contact with the other community has most certainly a great impact on each individual's relationship to the other community's knowledge. Nevertheless, in the next sections, some of the aspects that may be regarded as characteristic for each community are looked at. To investigate this, the knowledge categorization introduced by Lundvall and Johnson (1994: 28) is used. The categorization consists of know-what, know-why, know-how and know-who[39].

6.2.1 The Design Community and the Drawings

For the design community, the function of the 3D-computer model or package of drawing is not merely the transfer of knowledge vertically. It is also important for transfer of knowledge inside the community, and in the creation of new knowledge. Drawings are used as

[39] Know-what is defined as facts, or what people usually regard as information. It can be broken down and communicated as data. Know-why refers to knowledge about principles, or why phenomena function in a specific way. It is typically related to theoretical knowledge, such as the scientific knowledge about why the

visualisation support in discussions around solutions, and are therefore essential in the iterative process towards the finished design. The codebook is implicitly the carrier of all knowledge created in the design phase of the project. Important requirements are integrated in the chosen solution, and the engineer responsible for the design of the individual element naturally associates this knowledge with the drawings. Because important knowledge often is hidden in separate calculations, the foundation, determining the design, is not necessarily obvious on a single drawing. Hence, other members of the design community must frequently confront the 3D model in order to understand how single elements are integrated in the complete structure. Even if knowledge about underlying requirements is hidden from designers not directly involved in the analyses, some is generally possible to understand from a package of drawings or a 3D model.

The starting point, and what occupies the design community is the functional requirements specified by the customer[40]. These requirements are the know-what of the design work. Specifications are given as technical statements about the platform performance in the form of amount oil or gas it is to produce, treatment and storage, and possibilities of drilling or other marine operations. In addition, environmental conditions and field specification, like water depth, are provided. References to industry standards, like NORSOK[41] and Norwegian Standard, or regulations given by classification companies are also regularly made.

The know-what must be combined with know-why to create a functional structure. Theoretical tools, like mathematical simulation models and scientific laws and principles are used in order to create solutions to secure the know-what described above. This combination is however seldom trivial. Whereas starting conditions are known in scientific problems, it is

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nature behaves as experienced. Know-how is skills and assessment related to practical or intellectual tasks, or in other words ‘the ability to do something’ (Lundvall and Johnson: 2001: 12).

[40] I.e. the oil company that function as operator on the oil or gas field to be developed.

[41] The NORSOK standard is further described in the Appendix.

the solution, or the know-what, that is known in technological work (Nightingale: 1998: 699). As a result, scientific principles are seldom directly adaptable in engineering. Scientific results are often obtained through the use of very strong assumptions and idealized circumstances. The complexity of the real world provides uncertain outcome of situations, and judgement must often be used where conflicting considerations appear. A great deal of know-how is therefore needed in the combination of know-what and know-why.

This know-how is related to skills, usually not articulated explicitly. It is acquired through experience, and to the assumption that similar problems have got similar solutions. Conversations with employees in Aker Engineering also called attention to the importance of know-who in the know-how. An essential advantage in the design work is to know who have performed similar tasks previously. One of the persons I talked to made the following pleasantry remark:

> We actually know very little. Most of the time we just run around, trying to find someone who has done what we are to do next.

Using know-who in the combination of know-what and know-why, depends on informal networks, probably even more than the formalized organisation hierarchy. Louis Bucciarelli (1988: 96-97) remarked, after observing engineers in knowledge creating processes, that informal negotiations, discussions, laughter, gossip and banter among members of a design group often are crucial in design work. This informal interaction is closely related to the existence of "communities of practice"[42]. These are groups of people connected by mutual commitment to specific activities, where practices are shared through informal and self-organized networks (Weger and Snyder: 139: 142). The importance of communities of

[42] To be explained in Chapter 8, informal interaction is important in the communication between the two communities as well. Communities of practice are investigated in for instance Wenger (1998).

practice in development of new knowledge is an interesting topic, possible to pursue in future investigations. There is however no room for further examination of the topic in this essay.

The quotation in the previous section considers the design community to ‘work from ahead’. After solutions have been identified, the problems are divided into smaller manageable problems. Logical sub-systems systems are identified, where the small pieces are put together in order to eventually reach the full puzzle, being a functional concept. In this work it can be difficult to keep track of the totality. This does not imply that no one in the design community is concerned with the totality of the structure. Interfaces between the systems are extremely important, and co-ordinators are responsible for the individual pieces of the design to fit. The above is rather meant as an illustration of the need to plan from ahead. If the small pieces are dysfunctional, it will be impossible to get the desired result in such a complex structure.

6.2.2 The Production Community and the Drawings

For the production community the totality is extremely important. The structural integrity and functional description of the structure are of secondary interest for their work. Instead it is imperative that the structure is easy to build, and that the health and safety of the operators involved in the fabrication is attended to. In contrast to the design community, the package of drawings does not represent an end product, but rather a starting point for the work. The drawings are merely a reference or a manual for the building of the real end product, the finished structure[43]. These conditions provide the production community with different priorities than the design community. The respondents described these priorities to be a close relationship to time limits and a need for production friendly solutions[44]. This does again

[43] In the fabrication work, the authority of the drawings is not possible to neglect.
[44] Production friendly solutions were described as availability for welding, installation and painting, and that it is possible to fabricate the structure under safe conditions.

require a feeling of totality, and, as the quotation in a section indicates, that they plan from behind.

A person connected to the production community will primarily acquire the know-what from the drawings. This knowledge is however closely connected to how it is possible to carry out the fabrication. The following quotation demonstrates how visualization of the contents on the drawings, not only is linked to know-what, but does also relate implicitly to know-how. Moreover, it shows the importance of totality in the planning of the work:

> A sheet metal worker with much experience can very easily visualize the object, how large area it is needed to build it, and how to build it for it to be production friendly for the people who follow him. It is a dialogue between the sheet metal worker and the welder. Both have to complete their work, but there has to exist a plan for how to go about to avoid extra work, like turning. There is a continuous communication between the two professions to carry out such a job. Persons with much experience can easily visualize how to do it from a drawing. But not all are equally experienced. The ones with experience from production see it easily. They learn about elevation and lines. But it demands some years in production, and you should have done a number of jobs before you can visualize it clearly.

The above quotation indicates the importance in knowledge only possible to learn from experience, or what Polanyi called tacit knowledge. This is the knowledge of hands, or learning-by-doing. Because of its tacit elements, it is not possible for the engineers to fully describe it, or to fully understand it without fabrication experience. In their issue on August 3rd, 1997, Wall Street Journal had an article on the skills of operators. The know-how of the operators was described in the following way: ‘Their indispensable knowledge comes from experience, from noticing and watching, and from their senses of timing and sequence.’ In this way, the knowledge related to the drawings reaches far beyond visualization of pure know-what.

It should however be mentioned, that the education of operators has increased significantly in the last 20 to 30 years. The education provides a foundation, on which more informal skills are learnt. More theoretical knowledge can provide explanations and know-why related to production methods, and give valuable introduction to reading of engineering drawings.

As mentioned above, the functional descriptions and the know-why in design are generally of secondary importance for the members of the production community[45]. They come in late in the process, and feel that there is little room for large modifications after the project has gone to fabrication. How the functionality of the structure is without significance for the production community's work is seen in the following quotation:

> We build a lot of tings here we have no idea what is used for. If it is aquaculture, a platform or for a rocket. We do not know what it is for. We just build it. You look at the drawing, build it and it is finished. It is always someone in the other end that knows what it is for. (…) If you get a good drawing you can build anything.

As a result, all necessary knowledge must be transferred through the package of drawings, which becomes the supreme authority in the building of the structure.

An example of the different knowledge related to the codebook is observable through the use of different set of drawings in design and fabrication. In the next section the shop drawings are going to be explained further.

[45] Off course there are individual differences, and some operators are engaged and ask questions regarding the chosen solutions.

6.3 An Example of the Different Knowledge Associated: The shop drawing[46]

The design drawings must be modified somewhat for it to be used as an authority during fabrication. Consequently, an extra set of drawings must be created for fabrication purposes. These are usually called fabrication drawings or shop drawings. The distinctive knowledge embedded in the shop drawings must obviously not differ from what have been decided in the design phase of the project, and in this manner the two sets of drawings are fundamentally equal. However, since they are the central authority in the building of the construction, the production drawings have to be extremely accurate in their representation. Certain elements have to be more thoroughly illustrated, and more details have to be included in the drawings. As a result, a single design drawing might be divided into four or five shop drawings.

Moreover, the NORSOK standard, usually imposed by the customer, gives instructions regarding traceability and documentation in fabrication. Each weld is given a number, for it to be possible to inspect that the work is done according to approved procedures. In contrast to the design drawing, where only weld seams crucial for the structural integrity or the fatigue resistance are shown, all weld seams must show on the shop drawing. For large plates or long beams, the purchased material may not be sufficient, and extra connections must be created. All connections must be shown, vital for the structural integrity or not. Further, each plate or beam is given a position number. This makes it possible to trace the individual piece of material, and to manage the composition of the modules in an orderly manner. Systems for location of the different elements and sequence for their installation

[46] In addition to the shop drawings, the working package consists of a list of materials, welding procedures describing the various weld types, a cutting foundation for beams and plates, time plans showing the different activities, man-hour estimates and how the work is to be reported. As a total the working package includes what to do, how to do it, when to do it and how to report it. The only documentation received from the design community that goes into this package, is however the drawing foundation, which is the most important source of knowledge regarding what the structure looks like and how to build it.

becomes possible. Since there is no need for this knowledge in the design phase of the project, it is not included in the design drawings.

The making of an additional set of drawings is off course time consuming. Several of the respondents remarked that it would be an advantage if only one set of drawings had been sufficient. To find a common format does however not seem to be an easy task. The communities have very different needs of knowledge in relation to the use of the drawings. While the production community needs detailed drawings, with inspection categories and numbers for tracing, the design community needs systems to have logical connections on the drawings. Hence, the design community will always wish to simplify the standards further, whereas the production community has a need for more detailed information of the drawings. A respondent from the design community remarked:

> To adjust the design drawing, in order for the same drawing to be used for additions for the production hall, without making new sheets, is not always very rational for the engineering community. Then you get a system, which is interconnected, divided into several drawings, there is some crosschecking that makes the work more difficult, or a bit more bothersome than they experience in the production hall.

After a recent reorganisation at the yard[47], where the operators have obtained more responsibility in their work, there is a belief that the operator competences will increase further, and that a simpler foundation than currently provided in the work package will be sufficient.

The different need in representation of knowledge in the drawings is an illustration on how knowledge associated with the codebook is essentially different in the two communities. Both the design and shop drawings show the conception of the construction to built. However, each community's distinctive relationship to the construction requests differences in representation of details and totality. This representation is dependent on the knowledge individual community's associates with the know-what of the drawings.

6.4 Consequences of the difference in associated knowledge

Above, it is discussed how the collective knowledge of each community is related to the activities undergone, and how different knowledge is naturally associated with the contents of the codebook. Hence, the interpretation of the codebook is dependent on the context it is created and de-codified in. This shows that not only the technical tacit skills differ in the two communities, but also the cognitive tacit knowledge.

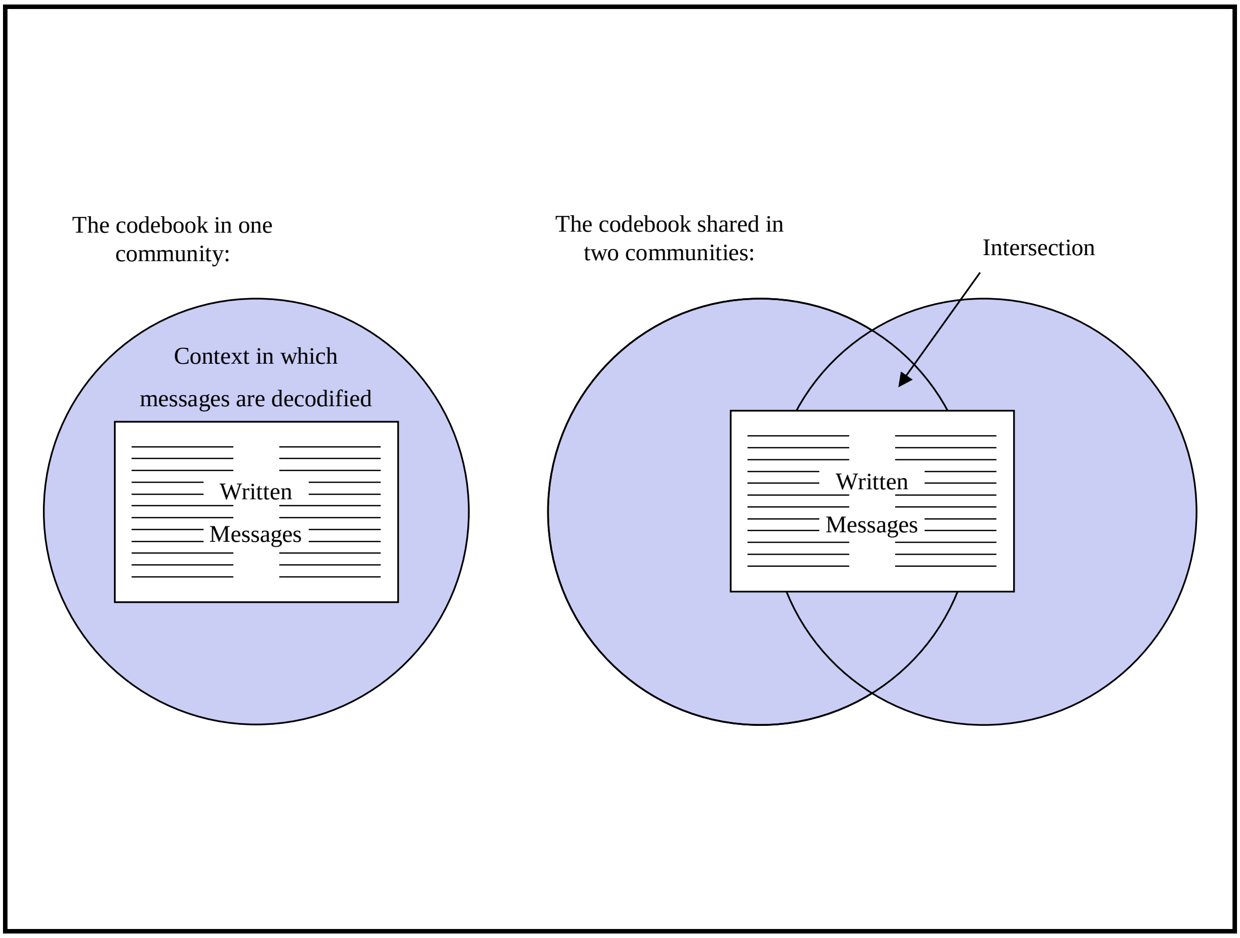
Cowan et. al. (2000) indicate that interpretation of knowledge embedded in the codebook is imperative, and if the codebook is to function as a reference or an authority, this interpretation should be more or less consistent. Likewise they argue, that the temporal, spatial, cultural and social context is an important consideration in the interpretation of codes. Because the nature of de-codification in a given community is important in the codebook concept, the context must be an equally important factor.

The conditions for de-codification and mutual interpretation becomes especially essential when the knowledge to be transferred is created and de-codified in different contexts, or communities. When knowledge is to be diffused inside a community, where members share a common worldview and important collective cognitive abilities, the context specific elements of the codebook are of secondary interest. However, when knowledge must be transferred from one community to another, as the case considered in this essay, differences in perception and association of knowledge in each community must be regarded. Knowledge associated with the codebook is linked to the interpretation of the documents it

[47] See Section A.5 in Appendix for further description

includes, and care must be taken when creating knowledge to be de-codified in another community, in order to avoid misinterpretation and misunderstandings.

In the figure below, the codebook as a context specific concept is illustrated. When the written documents of the codebook are interpreted in the very context it is created, few problems should be expected. However, in the case where knowledge is to be transferred across community boundaries, there have to exist some kind of intersection between the two contexts, where consistent interpretation of the codebook can occur.



The distinctive characteristics of each community have however a function related to the community's responsibilities in the execution chain of a project, and essential knowledge must be protected. These are the same characteristics that lead to differences in interpretation of codes. If a situation of total overlap of contexts had been desirable, i.e. that the knowledge of the two communities had become more or less identical, there would have been no initial need for knowledge transfer across the community boundaries.

In the following, possibilities for an intersection of cognitive contexts between the communities are explored. If the codebooks are to function as carriers of knowledge, the two communities must share knowledge of how to read engineering drawings. This implies that language on the drawings, as cognitive representation, must have stabilized in both communities, for it to serve in unambiguous statements. This is treated in Chapter 7. Moreover, the need for stabilization of the knowledge itself, the technical solutions, is considered. In the last chapter of this essay, the need for additional contact, as a result of failure in stabilization of languages and solutions to create a reliable intersection of cognitive contexts is investigated.

7. Stabilization of the Codebook and the Standardization Processes

For the codebook to have a function as carrier of codified knowledge, it has to be in active use and collectively acknowledged by both the design community and the production community. In this, the conditions for the communication process are significant, and as argued above, an intersection of cognitive contexts must exist. The design and production communities have different references and different conditions for understanding and utilizing knowledge. It is therefore extremely important that the knowledge to be transferred is recognisable, and that interpretation is not ambiguous.

The first step in the creation of an intersection of contexts is to create a vocabulary and methods of modelling the knowledge (Cowan et. al.: 2000: 225). When this is accomplished it is possible to create messages, and thus codify pieces of knowledge to be diffused among persons, sharing the language as cognitive representation. Standardization of language is briefly considered in Section 7.1.

The respondents described the standardization of technical solutions as important in order to secure smooth transfer of knowledge. This becomes standardization of the knowledge carried by the codebook itself. Standardization of solutions is treated in Section 7.2.

In the stabilization of the codebook, some of the flexibility in the treatment and interpretation is lost. The increased recognition element in standardised language and technical solutions limits the possibilities of dealing with new and unfamiliar forms of knowledge. In Section 7.3, some aspects of path dependency of the codebook are considered.

Since the technical knowledge is created in the design community, it becomes necessary to establish efficient channels of formal and informal feedback. The last section of this chapter looks into feedback from the production community to the design community.

7.1 Standardization of language (the symbolic representation)

According to all respondents, the symbolic representation on the steel drawings, or what may be called the drawing language, is stabilized in the offshore construction industry. The language has developed over a long period of time, where more or less standardized symbols for different welds and details have been established. The stable character of the language contributes to a smoother process of knowledge transfer between the communities. The symbols in use are familiar, which makes their interpretation unambiguous. One respondent explains the stabilization of the language in the following way:

> It is a type of information that is supposed to show on a drawing. And how you show weld symbols becomes a language. Just like σ and τ are symbols that denote normal stress and shear stress in all books all the way back to the 19th century, it is a standard way of showing fillet weld and burn through. They do not change from year to year. To the degree it has been possible to simplify anything it has been tried.

With the introduction of CAD tools, and especially 3D modelling programs, simplification of the drawing language was attempted. Today, the drawings have retrieved many of the characteristics from the manual drawings. The difficulties in changing the drawing features imply that a stabilized language, with some irreversibility, have existed for some time.

Whenever new knowledge is to be expressed on the drawings, a more realistic illustration of the object is usually shown, in addition to the formal symbol. This may for instance apply in cases that require specific performance of welds, where a detailed illustration of the shape and appearance of the weld seam can be given.

In Chapter 3 of this essay, the close relationship between knowledge and language, pointed out by Steinmueller (1998: 2), is mentioned. For this relationship to be plausible, the stabilized language must adopt the generative and adaptive properties characterizing knowledge. Respondents illustrated these properties by describing the flexibility in the configuration of the symbolic representations. Like a native speaker of a language can maintain credibility and meaning in their language, even with some flexibility in sentence structure, this is also the case in articulation of knowledge through engineering drawings. An experienced reader of steel drawings explained how it is possible to understand the know-what to be expressed, even when it is represented in alternative styles on a drawing. This flexibility makes it possible to read steel drawings from other sectors in the construction industry and drawings from foreign countries, even if the symbolic representation differs slightly.

Respondents indicated, however, the usefulness of a guideline, expressing choices made in the drawing production, to avoid misunderstandings in the transfer of knowledge. The possibilities of misinterpretation are further reduced when the drawings are in accordance with given standards. In the offshore industry, the NORSOK standard has formalized the drawing language, where a CAD symbol library is put up. Moreover, Norsk Standard gives a common steel standard for the entire construction industry[48]. A drawer in Aker Engineering criticized, especially, the NORSOK standard for providing too much flexibility. He claimed that a more consistent company standard is needed to save work in the knowledge transfer. An Aker drawing standard exists. However, it is not updated, and seldom used and referred to. In each project a large amount of consultants are hired as drawers. For Aker to have the possibility to impose and control a consistent drawing standard, such a standard must exist and be in general use.

7.2 Standardization of Solutions

The respondents remarked the importance of standardized technical solutions as important in the transfer of knowledge. If the codebook is to function as an authority in both communities, the knowledge on the drawings has to be recognizable as “good” or “proper”. As a result of differences in associated knowledge and priorities, commonly accepted knowledge in the two communities differs. Hence, it is not necessarily evident what proper knowledge is on a general basis, and the existence of standardized solutions become important. In the following the standardization of knowledge of drawings, the technical solutions, is treated.

Even if offshore structures are custom-made products, norms and experiences related to good or successful technical solutions are recognized and reused in future projects[49]. It

[48] Norsk Standard is a collection of Norwegian standards co-ordinated by Norsk Standardiserings Forbund. The steel standards have been developed as a joint effort, where all interested partners are invited to join. In the development of steel standards Norsk Standardiserings Forbund seeks support at their professional organ, Norges Byggstandardiseringsråd. More information is found in the web site: http://www.standard.no

[49] Many authors have remarked that functionality, or the success of a technological artefact, is merely a matter of subjective perception. We think that something function or not because we have a predetermined opinion of how it is going to function, and in what relations it is going to function. The belief that the success of a technological artefact is a matter of social construction is described by the Social Construction of Technology theory (SCOT). Wiebe Bijker describes this theory further in the book: Of Bicycles, Bakelites, and Bulbs (1995). In this context, the functionality or success of the offshore construction will be related to the collective opinion and understanding of what the purpose of its use is, and how this purpose is achieved in the two communities.

becomes a socialization and combination[50] process of stabilizing and standardizing knowledge.

Codified knowledge is structured through combination, where old concepts, explicit best practices and drawings are used as templates. Through communication with other members of the community, agreement related to the conditions for how to obtain solutions is reached. Furthermore, this process depends on tacit expectations of good knowledge and tacit know-how, shared and developed through socialization. A respondent belonging to the design community described the stabilization process of technical solutions:

> Often you made some drawings 15 years ago. When the next project comes along you take the drawings and you want to pursue them, and not start all over. Usually you see that it is possible to do something different here, and that it is possible to do something different here. And then the project is over, and you take it further into the next project. Maybe we should do it somewhat different there, and experience summons that this is not a good way to do things. And this goes on. I feel that for every project it is done fewer changes and the standards are locked or established.

These standards become company specific to some extent. Best practices during design are largely dependent on the individual company's earlier experience, and are related to the production methods on the yard.

[50] Nonaka (1994: 19) describes the four modes of knowledge conversion: socialization, combination, externalization and internalization. It is through these processes that new knowledge is created. Socialization is the conversion from tacit to tacit knowledge. The only way this is possible is through interaction between individuals with common references in a specific context. Nonaka states that this is possible even without a common language. Socialization is usually what is usually connected to organizational cultures. Combination is social processes of combining explicit knowledge. Structuring, sorting, adding and re-categorizing obtain this. This is what commonly is regarded to be organizational learning. Externalization is converting from tacit to explicit knowledge, and internalization is the conversion from explicit to tacit knowledge.

7.2.1 The Standardization Work in Aker Oil and Gas

An effort to standardise the solutions further has been pursued in Aker Oil and Gas during the last years. In addition to standards of technical solutions, standards for requirements and working procedures have been engaged in.

The profitability of a development project is dependent on a smooth execution under strict time limits. Hence, it is important that technical solutions communicated by the drawings are recognisable. If solutions are standardized and recognized as suitable knowledge, misunderstandings and mistakes are more easily avoided, and the work in the production hall slides better. In hectic phases of a project, several operations are executed simultaneously, and every delay in production soon becomes very expensive.

From the company's point of view, the central motivation factor in the standardization work have been the possibility to control knowledge, both related to solutions and the way people work in order to obtain these solutions. The hope is that if this knowledge is controllable, it will be possible to optimise it as well.

All daughter companies belonging to Aker Oil and Gas have been included in the standardization work. A temporary matrix organisation was build up, ensuring that representatives from all companies were present in each work group[51]. In this way, experience from all parts of the execution chain of a development project was represented.

Four or five reference projects were used as templates in the standardization process. This made the already existent codebook a basis for the work to be done. The work itself consisted in representing knowledge and best practices into specific standardized solutions. Most of this knowledge is based on experience, and a lot of it is tacit in general. Through this process, however, this knowledge were converted into codified form via its implementation in particular solutions. The knowledge is stored and shared through codes, but the process cannot be regarded as complete externalization[52], as the principles cannot easily be generalised. Nevertheless, a process of externalising knowledge has been initiated, and new knowledge about how knowledge is used has been created. This insight may be a good foundation for the tracing of inefficient practices and optimization of routines, if it is used critically.

In this manner it becomes possible to extract, diffuse and, to some extent, control embodied knowledge[53]. Further, the partly externalised knowledge is combined with the already external knowledge included in rules, regulations and industrial standards. The result become particular standardised solutions that comprise best practices and fabrication friendliness, at the same time as they secure structural integrity.

These standardized technical solutions combine knowledge recognised as important in both the design and production community. When arguments for a given solution have been pronounced and accepted in both communities, and the solution is acknowledged as reasonable, its reuse becomes uncomplicated. In this way, a shared approved knowledge base develops across the boundary between the two communities, and a common contextual intersection, where knowledge can be transferred, grows. Hence, standardization of solutions, or what can be regarded to be the knowledge itself, becomes important for the codebook to function as an authority in the transfer of knowledge between communities. In contrast, the standardization of knowledge inside one community is a more natural process, related to the process of establishing the community itself, and less focus must be placed on a common context for understanding knowledge. The existence of explicit defined special solutions is not conclusive, as the codebook becomes a standard where knowledge can be validated on a

[51] Different work groups carried out the total standardization work, where each group had responsibility for the standardization inside a given professional area, for instance steel, piping and electro.
[52] See footnote 49 for explanation of externalization.

general basis. However, dependent on the nature and magnitude of intersection of contexts, such specific solutions might be essential to secure efficient knowledge transfer between communities.

Since much of the knowledge incorporated in the new standards is experience-based and tacit, experienced technical staff has been especially central in the standardization work. In this work these persons have naturally obtained much defining power, where the resulting codebook becomes a seemingly independent source of authority, and develops into what is regarded as prioritised knowledge. The result may be path dependency where the legitimate knowledge of the community is based on single persons' conceptions. I have not got the opportunity to go further into this question in this essay.

For the explicit standards to achieve their potential, it is necessary to take care in their implementation. They must be integrated in the routines and practices of, especially, the design community, where new technical knowledge is created. That is, some of the knowledge related to the knowledge of standards has to be internalized to become collective tacit knowledge. To what degree the implementation has been successful is however somewhat unclear. According to a respondent heavily involved in the standardization process, the success in the individual company has been dependent on what he called "cultural differences". He maintained that the incorporation process had been smoother in companies with a tradition following standardized solutions or working methods, and where a lot of them were already socialized in. Very few of the people I talked to in the engineering company had any knowledge of the standardization work, and people who had heard of the work itself had hardly any idea of what it was about. This may indicate that even if a lot of standards are used in the daily work, they are not necessarily the exact standards formalized through the committee work.

[53] Embodied knowledge may be defined as individual hands-on-experience, or learning-by-doing (Lam: 1998:

The ease and control of implementation is dependent on the nature of the standards. Whereas working methods can be characterized as only partly structured, where there might be problems of controlling and govern the implementation, particular solutions can be regarded as more structured. The single solutions are integrated in the libraries of the 3D-computer modelling programs, and become easily accessible to the users. Moreover, the physical drawings can be controlled more easily than working methods. More about standardized solutions and computer libraries are included in the following section.

7.2.2 Modelling Libraries and Knowledge Based Objects

In order to utilise important experience and to secure standardized solutions, the company is engaged in creating a system of what is called knowledge-based engineering[54]. This is a system that atomises the design output after a specification of input. An interface towards drawing tools and structural and hydrodynamic analysis programs exits, and the proposed structure is transformed into a 3D model.

The intention is to divide the total structure into smaller and more manageable units, which can be defined as knowledge based objects, and that are possible to represent using a computer programming language. These are the standardized building blocks that can be assembled to comprise sub-structures in a system hierarchy.

An example of a knowledge-based object may be a connection or a joint between elements. Dependent on the conditions and context the joint is placed in, it obtains different properties. That is, the behaviour of the object does to a certain degree adapt to a given situation. Its properties and design are decided from a combination of built up experience in the company, and rules or regulations imposed by the government. In this way production friendliness, functionality and structural integrity are secured in standardised solutions. The

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collection of knowledge-based objects will be included into reusable libraries available to all modellers.

As indicated in the previous section the use of an object library will to some extent externalise tacit knowledge embedded in competences and skills of individuals. The knowledge does not become fully codified and cannot be generalised uncritically to other applications. However, the process creating such a library releases bits of personal tacit knowledge held by individuals in the communities, and make it directly available to "everybody". In this way, the specific solutions included in the knowledge-based objects will reflect the built up knowledge in the company, seemingly independent of individuals[55].

The establishment of knowledge-based engineering has introduced possibilities of managing technical knowledge. The potential black boxing of knowledge might however also host some dangers, if not caution is shown. When knowledge is included as standardised objects in the codebooks, they obtain authority as correct and recognised knowledge in the communities. Decision processes, previously made by the individual engineer or designer, are left to computer programs[56]. In the long run, this can lead to important know-how and general understanding being lost in the design community. One of the respondents expressed his concern in the following manner:

> In the last projects 3D tools have been more and more common in use, and more things are included in the 3D tools. I think history shows that these tools are relatively heavy, and that black boxes are created. Even if you are able to visualise it on a screen, much

[54] Company internal reports are used as reference in the description of the technical details included in this section.
[55] The knowledge will off course be dependent on the individuals who have created it, and are therefore not universal or true knowledge, free off all contexts.
[56] Ferguson (1992: 37-39) describes how design requires continually judgement. This knowledge is related to know-how of the design community, and important elements of this knowledge must be regarded tacit. Ferguson remarks how these small, but frequent decisions are largely left to computer programs, and that elements fatal for the success of the design are decided on a general basis, done by the programmer.

> information behind it does not show very well. In the end it is a question of quality, and the totality is not necessarily attended through a 3D tool. An engineer is dependent on seeing things in a context, and to do this he must see the systems.

Introduction of new knowledge, materials and fabrication methods at the yard results in continually development of standardized solutions. In this way, the codebook will never be fully stabilized, and some flexibility will always remain. Nevertheless there is a chance of path dependency connected to the stabilization and standardization of solutions and working methods. This will be treated in the next section.

7.3 The codebook and path dependency

Stabilization of language and standardization of solutions creates path dependency. In order for knowledge to be recognizable, new concepts must be built on old ones, and experience-based and competence in the company is exploited. The target is to reduce uncertainty in the transfer of knowledge (Tidd et. al.: 1997: 106), and to create an intersection of cognitive contexts between the two communities. A respondents put it: ‘It is not necessary to invent the gun powder all over’, when it is possible to build on already existent knowledge. Hence, the organizational knowledge is cumulative.

There is however some dangers linked to stabilization of knowledge and path dependency. The tacit knowledge stabilizing in the communities introduces cognitive limits of challenging existent paths. As a result, flexibility in interpretation decreases, and the community members become less capable of acquiring and transmitting knowledge not easily fitted into the codes (Arrow: 1974: 56). Hence, the possibilities to pursue alternative solutions, radical changes and creativity might be lost.

Furthermore, there is a danger of uncritical generalization of solutions in situations they were not originally intended for. Black boxing of knowledge may occur, where the practitioners of knowledge do not fully understand the background for the solutions chosen. Solutions generalized without full awareness of the consequences can result in inefficient routines, where no one actually knows their origin.

A situation of path dependency is however a comfortable one. For a community to break out of its settled routines and generally accepted norms, it has to touch on fundamental conflicts, power balances and the belief system of the community as whole. Needless to say, this must be a painful process related to uncertainty and alienation. Moreover, new common frameworks for understanding must be built, and with them a structure of new languages and models for the use in codification purposes. In the case of knowledge transfer between communities, a new intersection of cognitive contexts must be created. Hence, the incentives of the development, adaptation and exploration of entirely new codebooks built on new languages and models are often low.

The respondents generally remarked the difficulties in changing routines. Especially in large projects, where many people are involved, modification of built-in routines is clearly complicated:

> Things we cannot live with we have to change. But some can be possible to live with, even if it is cumbersome. It is often more costly to change the routines now than to wait until later, because it is often 30-40 men in design not sharing your opinion. It is a lot of people involved of you are to change routines like that.

The standardization work in the company has given a possibility for review of these questions. Making knowledge about knowledge used partly explicit makes it possible to consciously treat standardization questions and to identify possible inefficient routines. As described above, one challenge may however be the implementation of the new and reviewed standards.

The topic of stability of the codebook and the possibilities of path dependency are comprehensive ones. In this essay I have unfortunately not had the opportunity to go very deep into their essence. The time available, (both respondents' and mine) have been rather limited. In addition, the space available for its treatment has restricted a deep examination of the topics.

7.4 Efficiency of Feedback

Feedback from the production community gives the design community possibilities to learn about the context they transmit knowledge to, and to include criteria of production friendliness, important for the production community, in the technological solutions. Hence, feedback becomes imperative in the process of making an intersection of contexts.

The use of codebooks in the knowledge transfer limits human interaction, and therefore the possibilities of direct feedback. In addition, the large geographical distance between the engineering company and yard increases this trend. As a result the feedback process becomes more challenging.

The production community feels that it may be problematic to get feedback of inconvenient and unpractical solutions through to the design community. In the short run, the large number of persons working in certain disciplines may hinder diffusion of messages. One respondent from the production community described:

> It is possible to give feedback directly [to the person responsible]. The name is written on the drawing. And say that this is very inconvenient for us and maybe a simple matter for you. However, what is important is to get this through to everybody. It is a bit tedious to

> get through to the community. Next week we get a similar case from the person sitting next to him.

The quotation shows how each person becomes a carrier of organisational memory, and, at least in the short run it becomes difficult to share the knowledge held by individuals. However, as shall be explored further in Section 8.2, know-who and informal networks across the organisation may assist in finding the proper person to communicate feedback to in order for it to be diffused rapidly inside the community.

More long-term learning may be inhibited by the large turnover of personnel between projects, which is a consequence of all projects building up its own provisional organisation. New and inexperienced persons fill the positions of experienced engineers, designers and drawers, as they advance to more “important”, administrative positions. This advancement is imperative in the hierarchical structure of the company, and is the outward signal and a reward for good work. The diffusion of experimental knowledge becomes even more complicated when the project has to hire many consultants in periods of heavy workload. They have often experiences from other companies, and these “best-practices” are not necessarily directly adaptable to the production methods of the yard.

Members of the design community equally remarked how more active participation from the production community, especially in the early phases of design, would have given improved possibilities of including fabrication priorities into the design. Moreover, respondents from the design community expressed that they felt feedback from fabrication community seldom is put into system. Instead, feedback is given in the form of single messages. Changes may be implemented in individual drawings, but the general learning effect is limited.

Feedback is further complicated by the communities' initial differences in associated knowledge, treated in Chapter 6. The two communities have different anticipations to how feedback is given, which can lead to difficulties in the communication process. Especially respondents from the production community expressed the communities' different relations to written versus oral feedback:

> I feel that out in the production hall we depend much more on spoken communication. When we take people from us and put them inside a design community, and sit and discuss solutions, the designers do not take this seriously if it is not in writing. If you do not adapt to their practices or routines on how things are to be reported, like a description on working procedures etc. Then they do not take it into account.

The design community faces very strict documentation requirements, both from the customer and from the government. If not adequate documentation is available they may experience considerable juridical difficulties in the finishing stages of the project. However, during fabrication, time is not always sufficient to follow accurate routines. Frequently, solutions must be accessible on very short notice, and in such a context, there might not be time to wait for a written confirmation. Both communities feel that they generally obtain little understanding regarding their requirements, priorities and ways of communicating, and that there are important lessons to learn from both sides[57].

In order to secure experience transfer between projects, the company tries to organize and categorize feedback in written reports. In general, the respondents felt that knowledge attained from these reports is rather limited. They are normally stored in shelves and not used

[57] A respondent from the production community gave an example on how the production community had chosen a number of skilled persons to give input during design. They had been present in brainstorming sessions at meetings, and thought their contributions would be taken into account. However, when the drawings and the 3D model became available, the solutions did not show as expected. The engineers had understood their input as

actively. The time necessary to extract knowledge from them exceeds the time available for such activities. Moreover, written reports seldom are able to communicate all knowledge related to for instance know-how, where much tacit technical knowledge is included. A respondent described the possibilities of successful experience transfer through written reports in the following words:

> *To what degree is transfer of experience between projects rewarding?* I have to say to a very limited degree. The experience is in people's head. The transfer of experience only function when a person is reassigned from one project to another and share the experience with the people they work with. Nobody reads huge documents on how the last project was.

Furthermore, exchange of experience often happens on management level, and the knowledge is seldom passed through to the people actually doing design and analyses in the design community. As a respondent expressed:

> I have not seen much more of experience transfer than what I have learnt myself, and what we have discussed between us.

The quotations above show how a significant part of the knowledge in the communities in question is tacit. It is not possible to model everything into written messages, especially when the knowledge is to be transferred between contexts[58].

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advice rather than instructions, because nothing had been given in writing. Through this, important lessons were learnt on how the design community communicate and understand feedback.

[58] Even inside a community much technical tacit knowledge is embedded. If it is fundamentally tacit or possible to codify somewhere or sometime (see Cowan et. al. 2000), it seems to be no functional or efficient way of codifying it in this particular context here and now.

In Section 8.2.1 the role of, what I have chosen to call, mediators II is explained. They are persons who have spent longer periods of time in the opposite community. Hence, they have the possibility to be engaged in active interaction, and to obtain a constructive dialogue for exchange of experience and creation of new knowledge in the interface between the two communities. This new knowledge, these persons take back with them and share with other members of their own community. In the long run this has contributed to what the respondents call decrease in cultural differences.

8. The Need for Personal Contact

As argued for above, an intersection of cognitive context must be built for knowledge carried by the codebook to be efficiently transferred. The respondents held that the package of drawings in principle is self-explanatory.[59] Hence, stabilization of language and technical solutions in the drawings has achieved a situation where some intersection between contexts has been obtained. This stabilization is described in the previous chapter.

Limitations in the stabilized intersection of cognitive contexts are however frequently experienced, and when language and solutions on the drawings are illogical or deviates from the stabilized standards, problems of interpretation and misunderstandings may occur. The limited time available in design reinforces the initial uncertainty in the planning of complex offshore constructions. The extreme time pressure, together with large turnover in design, often resulting in lack of personnel with adequate experience, reduces the possibilities of a perfect deliverance, with pure mistakes and shortcomings in the drawings as results. One respondent described the problems of interpretation as the reason why additional contact between the communities is needed:

> We need personal contact too, because we read the drawings differently. It is reasonable enough that it is drawn in a certain way, but we perceive it a bit differently. To get a common understanding of what they show on a drawing I think we need to have some contact. They have a different perspective and other conditions than we have.

These mistakes or interpretation problems happen rather frequently, especially in the beginning of the pre-fabrication phase. Even more problems are anticipated if the drawing standard has been changed somewhat due to new collaboration partners or new computer tools. The codebook in its current form does not cover all aspects of knowledge built up in the design phase, and collective knowledge in the design community does generally not include important production experience. Hence, at least some personal interaction between the members of the two communities is required. Since the two communities are located far apart geographically, it becomes more difficult to transfer tacit knowledge, as the everyday personal interaction is strongly restricted. As a result, mediators become especially central in the transfer of codified knowledge.

8.1 The Mediators

A mediator is defined in this essay to be a person with far-reaching knowledge of both communities. They have a central role in the common understanding and interpretation of the codebook. As a result, they operate as organisational memory in misunderstandings or conflicts. They may also function as co-ordinators and possessors of important know-who; in communication of problems they are not capable of handling themselves. In this case, two types of mediators are identified.

[59] This is presupposed that the package of design drawings and contents of the 3D-computer model have been converted into a package of shop drawings.

The first category of mediators treated in this essay is directly involved in the de-codification process of the codebook. They handle mistakes, shortcomings and misunderstandings related to the package of drawings in real time, and are invaluable for the execution of the project. The second category is persons, who secure overlap between the project phases, both from the fabrication community in the design phase, and from the design community in fabrication. They have a more long-term role, and are responsible for further stabilization of intersection of contexts, or a reduction in what the respondents chose to call "cultural differences".

Even if a mediator most probably is more involved in one community, he or she has had the possibility to obtain an understanding of the other community's norms, values and priorities. This is acquired through participation in the other community's activities, and through interaction with the other community's members.

8.2 Mediators I

It is rarely possible to achieve extensive personal interaction between designers and operators during a project. Since interaction is limited, people who actually have had the possibility to undergo a socialization process with both communities are of great value. Through the knowledge of both communities, mediators obtain the role of interpreters and coordinators of codified knowledge. As such, they are invaluable in the transfer of knowledge between the two communities. They are also important in the definition of knowledge, and partly responsible for the way knowledge is understood in situations of uncertainty. Fabrication drawers, the members of the work foundation team and the site engineers have been included in the mediator I category. This does not mean that all of them constantly function as mediators. They do however have intermediate roles between the communities, and may function as mediators dependent on the problem occurring.

Operators have limited know-why related to design. They have little knowledge of the calculations behind the chosen solutions, and are therefore not capable of initiating large modifications to the original design themselves. Only small alterations compared to the drawings are possible without to consulting mediators. One respondent from the production community said:

> Flexibility? On primary steel, nothing. On secondary steel nuances. If you make changes they should be communicated. Maybe you move a profile, but this profile has usually got a function where it was supposed to be located. Maybe it is a backing up something. This is why changes must be clarified before they are carried out.

People in intermediate positions become important as mediators when difficulties arise during fabrication. It may be difficulties in interpretation of drawings, illogical solutions, but also pure mistakes, shortcomings or problems with access for welding or painting. Because of the small flexibility operators experience during fabrication, difficulties must be communicated to the mediators. Through this, mediators become interpreters of knowledge. They have the authority to answer questions whenever the codebook presents insufficient knowledge. Trough this interpretation they become creators of new knowledge directly applicable to a given solution. Hence, they contribute with needed flexibility not obtainable in materialised knowledge, represented by written codes.

Dependent on the incoming matter, a decision on how to get past the obstacle is made. If there are smaller problems, directly related to interpretation, or minor technical difficulties, the mediators are able to solve them on site. Respondents in the production community described any difficulty, not needed to communicate back to design, as advantageous. Time is extremely important in an offshore construction project, and the smooth execution of a construction is a condition for success. In addition, a mediator often understands the production community's needs and priorities better than engineers or drawers in the design community. Through their possibility to solve simple difficulties, mediators are extremely important knowledge creators in the project. Hence, they become important as organisational memory through their combined experience and understanding of knowledge specific to each community.

In situations interpreted by the mediators to be too difficult to handle locally on the yard, it becomes necessary to communicate the problems back to the design community. Who possess the adequate knowledge in the design community is not always well defined or obvious. As a result know-who held by the mediators become extremely important. They know who will provide a satisfactory solution to individual problems, and who to communicate with in order to get proper information. As a result, much of the communication between the production community and design is arranged through the mediators.

This co-ordinator role becomes a role of selection. It is a selection of whom and of what. Most often personal and informal relationships are preferred in the selection of whom. Properties like trust, mutual respect and ease of communication, or what the respondents chose to call 'to speak the same language', were described as important. It becomes a matter of finding persons who grasp the nature of the problems easily, and who contribute to simple and not time consuming solutions[60]. In addition, it becomes an interpretation and selection of what knowledge it is necessary to communicate.

In the following, a more through description of the specific functions of intermediate personnel regarded as mediators is offered. These include fabrication drawers, members of the work foundation team and site engineers.

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[60] This is very often people called mediators II in this essay. Informal networks are further discussed in the next section.

8.2.1 Fabrication Drawers

Fabrication drawers convert the package of design drawings into shop drawings. Thus, they transform and interpret knowledge in design drawings into relevant knowledge needed by the production community. Most fabrication drawers have extensive experience from the production community. Many of them have functioned as site engineers[61], and some have a background as operators. Through their experience they become holders of organizational memory, which make them able to understand what the production community needs in the building of a structure. Simultaneously, they have a close relationship to the drawings, and as one of the respondents from the production community remarked: 'I am sure they sit there and design some too'[62].

Their function does actually not include trouble shooting as a result of direct interaction with operators. However, to secure that projects run more smoothly, the company seeks to make some of the functional boundaries less visible. One of the respondents commented on how it was advantageous if operators could communicate difficulties directly to the fabrication drawers. Direct communication between operators and fabrication drawers requires less interpretation, as one link is cut. In the future the work foundation team may however fulfil the role as direct communicators between the design and production communities.

8.2.2 Work Foundation Team ("arbeidsgrunnlagsteamet")

The work foundation team is a relatively new function, introduced in the recent reorganisation at the yard. The reorganisation was initiated to give the individual operator more

[61] The role of site engineers is described later in this section.

[62] In the later stages of a project (when it is moved to the yard) some of the design is left to the engineers at the yard. In this work, the fabrication drawers have an important role in design. With their usual fabrication

responsibility. Instead of dedicated supervisors leading the work, operators are divided into working groups, with full responsibility of the part structure to be built[63]. In this, the newly established work foundation team is responsible for dividing the finished shop drawings and total workload into logical work packages. These packages, they mediate to the teams of operators, in the right order and according to time schedule. The teams of operators are supplied with sufficient know-what and equipment to complete a specific job: plans, method descriptions, drawings, material, area and equipment.

In the early phases of the project, one or several dedicated persons from the work foundation team are located in design. Accordingly, he or she gets first-hand knowledge of the design model. Through this active participation in design, the team members become carriers of project memory. Hence, they become very important when minor problems are to be solved during fabrication. At the same time, they have the opportunity to make acquaintances in the design community. These contacts become important whenever obstacles, not possible to get past locally at the site, occur during fabrication. Respondents from the work foundation team explained that they had extensive contact with both communities, often several times a day. In their work they carry portable phones, because it may be needed to call up members of the design community, when inspecting the production hall.

The members of the work foundation team are largely chosen because of their professional background. Generally they have considerable experience from both communities. As explained above, this experience grants both know-who and project memory. A respondent from the work foundation team expressed:

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experience, they get an advantageous position as mediators, when it comes to interpretation of knowledge embedded in the drawings.

[63] The reorganization is described further in the Appendix.

> We are supposed to be an intermediary between engineering and production, and we are very involved in both camps really. I guess it is not a complete coincidence that we are placed here, with our background.

Since the establishment of the work foundation team is relatively recent, their role has not been completely clarified. Today they are intended to have a function in the preparation of the work foundation. Accordingly, operators are primarily meant to contact the team members in case of problems related to this foundation. It may be difficulties of interpretation, solutions that look unfamiliar or illogical, and when mistakes on the drawings are suspected, or it may be pure shortcomings.

8.2.3 Site Engineers

A site engineer is engineering's extended arm into fabrication in a project. Organizationally they belong to the engineering team of the project. They are usually engineers locally employed at the yard, but in some projects site engineers have been brought from the engineering company[64]. They are located at the yard to follow up production, and have generally not had a function in the design phases of the project. They are to handle technical problems that come up during the fabrication phase. If the solutions described on the drawings are discovered by the operators to be impossible or impractical by the operators, they are to contact the site engineer.

In this way, site engineers become the trouble-shooters and the technical support of the production community. Site engineers with design experience may be able to solve minor technical problems themselves, and precious time can be saved. Generally, however, they

[64] One of the respondents remarked: 'I would think that this is the best place to learn "production" for a engineering person.'

have little experience with calculations and analyses, and are often more practical in their focus than the pure design engineers.

The site engineers are present at the yard, and function as organizational memory through the interpretation of drawings and definition of solutions. Regardless if they chose to solve the problem locally, or if they pass them on to the design community, interpretation regarding the nature of the problem must be made. They make choices and evaluations concerning the severity of a specific problem, for instance if it threatens the structural integrity. Hence, even if a matrix is defined, in order to determine what problems site engineers can handle locally, it is still up to the site engineers to categorize the problem.

To stop production can be, and usually is very costly. Hence the respondents described and the savings made by good trouble-shooters to be significant. A respondent of the production community expressed:

> They can give the solution straight away. The sketch is only made for information, but you never see it. This is what we want, because the response is fast. What we want is just to bring the engineer outside and get a yes or a no. It would be wrong to say that it is always mistakes or shortcomings. But it is a problem not clarified. Like if you have a collision. It is everything from turning a valve because you cannot fit it in. Things impossible to see in a 3D-model. And when you try to turn it around, it leads to consequences for a ladder, or something placed next to it. Then you get practical, good solutions on it. We usually have suggestions, but stressed areas sometimes make it impossible to weld.

With the above in mind, the work foundation team is responsible for shortcomings and problems related directly to the fabrication foundation, while site engineers have got a more technical trouble-shooter role. The practical difference between the two functions is however much more gradual. Contact towards the engineering community was described as a joint effort between the two functions. Whenever problems occur, solutions are frequently obtained through discussions between them. Moreover, decisions to involve the design team, as a result of problems being too severe to solve in site, are often taken in agreement between the two. Naturally the co-operation between the work foundation team and the site engineer will dependent on the individuals who hold the positions in every project. A respondent in an intermediate position explained:

> Who contacts engineering depend on whom has got the time, and how well you know the details. If you have to bring it back to engineering to get it clarified. In cases of small modifications we decide what to do ourselves. Often, we have cases where the site engineer and I discuss, and where we agree on how to do it. This is good enough. In these cases the occurrences are not large enough to involve engineering.

Since the work foundation team is a quite new function, their role will probably evolve over time. Hence, it is too early to say how the work foundation team will find a more stabilized mediator role in the time to come.

Regarding what is said above, people who fulfil the mediator role are directly involved in the everyday knowledge transfer activities in a project. Through their interpreting, memory holding and co-ordination activities, they must be regarded as a part of the codebook. They are needed in the transfer of knowledge on a regular basis, often several times each day. Whereas knowledge embedded in the drawings has limited flexibility, after it is manifested in written codes, the mediators contribute with additional flexibility in their interpretation and search of accommodated solutions.

8.3 Advantages of Permanent Co-operation and Mediators II

According to the respondents, substantial cultural differences between Aker Engineering and Aker Stord were experienced in the past. Before the introduction of EPC(I) contracts, there were separate contracts for engineering and design, and the oil company had the leading role as co-ordinators in the knowledge transfer between all sub-contractors. Knowledge of other communities' obligations, ways of work and priorities was limited. One respondent from the production community describes this distance in the following words:

> Off course there were some contact before as well, but there was more distance. We were experts on our field, and they were experts, and very good on their field. It was not a lot of questions. We got a design drawing and were to build it regardless. We were at different levels. We did not understand their language, and they did not understand our language. When somebody said that we cannot do this because we will get a fatigue problem, we wondered if they were exhausted over there. We just did what was explained on the drawing, and transformed it into something we could use, make. It had to be that way, because [the design community] had said so.

With the introduction of EPC(I) contracts in the beginning of the 1990s, the engineering companies and offshore yards of Aker Oil and Gas was forced to take on a more or less permanent co-operation. Over the last decade, this co-operation has provided a possibility to stabilize the relationship between Aker Engineering and Aker Stord, and to obtain stabilized and standardized languages and technical solutions, described in Chapter 7. Moreover, the introduction of EPC(I) contracts, where profits and risks are shared, created incentives for a smooth transition in the interface between engineering and fabrication, and hence the creation of an intersection of cognitive contexts.[65]

Naturally, knowledge embedded in each community still is fundamentally different, since it is directly related to the activities undergone. However, increased communication has taken place, and the mutual trust and respect between the communities has increased. The contract form has promoted comprehensive exchange of personnel. People from the design community have had the opportunity to visit the yard for longer periods at the time, and through this, experience fabrication on site. At the same time, individuals with production experience from the yard are present in the early design phases in all projects, to influence the design towards more fabrication friendly solutions. This exchange of personnel has been extremely helpful in the process creating an intersection of contexts. The persons who have had the opportunity to get acquainted with the opposite community through such exchange of personnel are called mediators II in the following.

8.3.1 Mediators II

In each project, central personnel in design get the opportunity to follow the project to the yard. They have responsibility for the so-called follow-up engineering, and work with fabrication related issues on site[66]. They follow up modification, changes and any alterations that come in the later phases of the project. As stated above, there always come some updates to the design due to unexpected problems in fabrication.

The project tries to limit the number of engineers from the Oslo office sent to Aker Stord[67]. Very large costs are related to remote stationing of personnel, and large strain is

[65] See appendix for a more thorough description of the history of the offshore construction industry.
[66] E.g. in the transfer of design drawings into shop drawings
[67] Typically, if 100 engineers are working on the structural discipline during design, maybe 5 to 10 will get the opportunity to follow the project to the fabrication site.

imposed on the individual, as a result of long periods away from home and family. One of the respondents from the design community talked about his stationing away:

> It was supposed to last for a short period of time, but it was prolonged. Then I got an arrangement to work here some days each week. But it definitely is strenuous. If it is possible to work it out both family wise and work wise it is acceptable, and if the period is not prolonged too much. But it has a tendency to do that. The reason why I have chosen to go has little to do with the place itself. It is more the project. I think it is interesting and informative to follow the project to the end. Both when it comes to fabrication and professionally. I take these things back with me.

When a design engineer is located at the yard, he or she has got a good opportunity to see how the production community functions, and to obtain a dialogue with operators and site engineers. This personal contact is very difficult to achieve when seated 500 kilometres apart, even with the new communication tools available. Closeness, personal contact and an opportunity to see how the structure is built gives a design engineer a better understanding of the production community's challenges, and fabrication technical insight. One respondent from the production community described this:

> I think the [design engineers] who have had some contact with production, and who have worn safety boots have more ballast than someone who has only made drawings in an office. People from engineering who came to the production hall when we contacted them were surprised when they saw how it looked. And they were even the ones drawing it. To go out and see things live, and to get some impulses is helpful for the work they do in the future.

In this way, these engineers become carriers of organizational memory in two respects. First, they are the continuation of design in the current project. They know the history of the design and hold the know-why and the know-how related to choices made throughout the engineering phase:

> They know the whole history. Instead of the engineers on the yard starting to dig and find out why certain solutions were chosen, it often is sufficient just to ask the person who designed it, and you will get the answer straight away.

In addition, they obtain a more long-term function as organisational memory. What they learn about production methods and fabrication friendly solutions, they take with them back to the design community. In this way, they contribute to the stabilization of an intersection of contexts. They have a function as carries of feedback, where the result have proven to be much more beneficial than exchange of written documents treating knowledge transfer, which is described in Section 7.4.

A lot of personal initiative is generally necessary in order to get an opportunity to follow the project to the yard. Very few engineers are sent in each project, and very often people who have already been located at the yard in previous projects are chosen. The company has had some exchange programs in order to give more engineers the opportunity to obtain fabrication experience. However, it is mostly the nature of the contracts that has contributed to locating engineers temporary at the yard.

Personal initiative is also required at the yard, and decides how much design engineers learn during their stay. Indifferent engineers have got the opportunity to stay in their offices, and to have minimal contact with the production community. One of the engineers expressed:

> You cannot sit there and think that they will com and explain anything to you. You have to present the problem and say: 'Does this function?' You get feedback, and you dig yourself, and get familiar with how things are produced. You must be active yourself. It is not enough just to go to the yard. You have to be a little engaged in what they are doing.

Likewise, members of the work foundation team, engineers with production experience and sometimes fabrication drawers are located in design in the early stages of a project. Some of them are experienced operators who have finished engineering school[68]. Their main role is to influence the design community towards a more production friendly design.

Through being located in the other community, people from both the design community and the production community get an opportunity to build informal networks across the organization.

Informal networks provide relationships of mutual trust and respect, and a feeling that things are done properly, and even more importantly, done at all. Personal contact with members of the other community may reduce the professional distance in the communication process between the engineering and production. All respondents called attention to the importance of the personal, informal relationships with members of the opposite community:

> I think it is very important to know persons. That you have worked with them, had lunch with them, maybe been out on a pub together. That you have been in the community for some time. When we are split up and sent home, and we actually are to build what we have discussed and worked at for half a year. When you know people then, it is very favourable. It is much simpler to talk to them. You read between the lines what they are

[68] In the recent years the yard has had a program for further education, which offers engineering courses to technical drawers locally. This is a two-year program aimed at employees with technical collage of some kind, and with many years of experience from production of shop drawings or the follow-up of fabrication. The last year 10-15 technical drawers have joined this course in order to get a more formal engineering education.

> actually saying, and that is very important.

Especially in the start up of new projects when the organization and its formal contact network have not yet stabilized, informal contacts are of great help. As a member of the design community put it:

> When we start a new project, I know whom to call and ask. I have already done that in this project. Stord is building this module, and they have not begun their work yet. But I have started to call them. If we are to deliver a fabrication friendly model, I have told them that they have to look at this already. When you know each other it is easier to ask about different things. When you have work against the yard, you know whom to contact to ask about different problems.

Moreover, know-who is important in order to get a message across to the whole project. When mistakes or deviations repeats themselves on several drawings, it is essential to speak with someone you know can inform all actually involved in the design, or in the making of the drawings in question. It saves a lot of work, since the alternative would be to call all members of that discipline, which might be more than 50 in large projects, in order to be sure that they got the message.

The trusting relationship between individuals from the two communities has contributed to enhanced understanding and respect. Through this, the difference in qualifications can be turned into an advantage. Communication based on mutual respect was described to contribute exploitation and combination of the two communities' knowledge, in order to secure an improved total solution. A respondent from the design community remarked:

> They have been fabrication driven and we have been engineering driven, and in this way we have complemented each other. When you get a functional dialogue, and when one part does not dominate the relationship. Where you give and take, and where you have respect for each other.

Even if misunderstandings are more easily avoided with a person you know, which is important in order to obtain sufficient quality in the finished product, there is a possibility that surprise elements are lost. In the creation of tight bonds, rules are made up for the communication become uncomplicated. These are rules and norms linked to what is regarded to be good knowledge, accepted behaviour and how to avoid conflicts, and are related to the intersection of cognitive contexts. Hence, irreversibility is introduced through more or less tacit routines for how to communicate. Routines are seldom challenged in such networks. New community members, like young engineers, experience that it is difficult to be included in these informal and interdisciplinary networks. Who you know is extremely important in the company, and the personal initiative required for acceptance in the networks can sometimes seem prohibitive.

In the future, Aker Oil and Gas hopes to reduce costs and personal strain related to extensive travelling and exchange of personnel. A model of split location is considered, where the use of Information and Communication Technologies (ICT) is central. The use of 3D modelling tools allows persons at different geographical location to work at the same model. Additional contact can be secured by the use of video and teleconferences, e-mails and regular phone calls.

There is however some scepticism towards this way of working in both communities. The respondents feel that contact with persons and teams, sited at remote locations, is much harder than internally at the same location, even after the introduction of new ICT tools. One respondent expressed:

> I think it is better to be located in the same building when you work at the same project. Sometimes one floor is enough for the communication to become problematic.

Videoconferences gives the possibilities of more frequent meetings, and reduced stress and costs related to travelling. The respondents felt that the quality of video meetings was determined by its function. Meetings with a tight agenda, like status meetings, were experienced to function well. However, as a working session, where creativity, suggestions and brainstorming are expected, experience shows that videoconferences are poor tools. Another condition for the use of videoconferences were a previous personal relationship between the participators, expressed as:

> I think it is important that we have seen each other and established a dialogue. If not, it is difficult to meet for the first time in a videoconference. I don't see the point. It would seem strange and not right in a way.

The space limits of this essay restrict a further investigation of this topic, and make it impossible to use the rich empirical work obtained on the area. It is however an important topic, and would be interesting to examine as an extension of this thesis. The following questions can be imagined to be central: What are the long-term effects of reduction of personal, real-life interaction? Does the ICT tools give sufficient possibilities of stabilization of an intersection of cognitive contexts between the communities? How does the introduction of these ICT tools change knowledge, skills, communication, strategic behaviour, incentives and coordination?

8.4 The company responsibility in creating an intersection of contexts

For most engineers the 3D model or the package of drawings represent the end product of the project. Since only a small amount of the members of the design team are permitted to follow the project into the last fabrication and installation phases[69], especially young engineers feels that they have not got a complete impression of the stages following the design phase. This was not the case for the respondents from the design community in this case study, who had been stationed at the yard over considerable periods of time. Informal conversations with young engineers without this experience indicated how they, to a large extent, felt they had a distant relationship to the physical structure and the way it is build.

In his book, Engineering and the Mind's Eye (1992), Ferguson argues that there has been a shift in focus in the engineering disciplines in the last half of the 20th century. From the 16th century to the present the promoters of the mathematical and analytical sciences has put down great effort in convincing the world that natural sciences are the true and principal sources of new inventions and the driving force for increased prosperity (Shapin and Schaffer: 1985, Ferguson: 1992: 155). This perception has become generally accepted in the Western culture. During World War II the natural sciences position as true, objective knowledge became re-manifested. As a result the engineering schools have moved towards teaching more theoretical engineering, where non-verbal intuitive knowledge has stayed in the background. The analytical knowledge has got higher status and is easier to learn.

Ferguson does however maintain that modern engineering is dependent on this non-verbal knowledge. It is necessary for a designer to be familiar with the structure itself, as well as the functional requirements of the structure. In the same fashion, Nightingale argues that 'science answers the wrong question', and can therefore not be directly and linearly applied in technological challenges (1998: 690). Structures in a natural and real environment are always more complex than pure scientific laws, created under idealistic conditions. Ferguson express his concern towards the missing will of engineering schools to educate engineers with sufficient insight in practical problems, with all their complexity, in the following words:

> An engineering education that ignores its rich heritage of non-verbal learning will produce graduates who are dangerously ignorant of the myriad subtle ways in which the real world differs from the mathematical world their professors teach them.

An equal concern regarding the decreasing practical experience of young engineers was expressed by one of the interviewed managers of the production community:

> I think some of the younger engineers today have no practical experience before they start. The practical experience they have got lies so far from making a product that they have barely seen a welding rod (…) I think that even here, an urban environment with people not integrated in practical work is developing. This is a big challenge for the whole industry. I think we can get problems with the supply of labour. Labour with practical experience. Even here.

As a consequence of the above, it becomes the responsibility of the individual engineering firm to provide this knowledge. Such experience includes a great deal of tacit knowledge, and is only acquired trough observation in the field.

Likewise, only a very small fraction of the production community has far-reaching experience regarding how solutions are chosen in the design phases. The result is naturally a

[69] The relocation of large proportions of the design team from the engineering company is generally avoided because of large expenses and strain on personnel. The exchange of personnel is treated further in the next chapter.

poor understanding of design's priorities, and members of the design community occasionally feel that solutions chosen for structural reasons can be questioned because they cause some additional trouble in fabrication. Some feel that the production community does not always accept the strict criteria they must relate to, or that they do not acknowledge or understand that a designer is personally responsible for his or her design. When safety is at stake it can be severe to take chances. This sometimes leads to conservative solutions, which are not always fully understandable to the production community.

A solution previously discussed at the yard is rotation of personnel, where the members of the production community had some months in design in order to understand the requirements there, while designers had to stay at the yard for some months in order to get valuable production experience.

9. Conclusion

In the above, the context specific properties of codebooks have been explored, using a case of knowledge transfer between two different professional communities. The case was carried out in Aker Oil and Gas, where large development projects are dependent on knowledge transfer between the design community and the production community. Technological knowledge, built up in the design phase, is transferred to the fabrication team through codebooks in the form of a package of engineering drawings and a 3D-computer model.

It must be emphasized that the findings in this case study is context dependent as well as the knowledge it considers. Hence, the findings cannot automatically be generalized without additional examination of the general validity of the results.

Codebooks must be regarded to include more than the pure collection of written messages, represented by the package of drawings. Possibilities and nature of de-codification of written messages are imperative for the utilization of knowledge embedded in the drawings, and must be important characteristics of the codebook. The case shows that knowledge associated with the drawings is very different in the two communities. Different meaning is ascribed to the same jargon and to the contents of the drawings. The perception and possibilities of utilization of knowledge embedded in the drawings are largely dependent on the relation the members each community have to the codebook and the finished product, the offshore construction. Whereas the functional description and structural integrity is important factors for the design community, the production community is concerned by fabrication friendliness, and that the health and safety of operators are attended to during production. This creates different focus and priorities in relation to the knowledge on the drawing.

These findings substantiate that interpretation and association of codified knowledge is dependent on the tacit cognitive abilities of the reader, and hence the context in which the knowledge is created, communicated and de-codified. The community is such a context, where the members share a collective basis of cognitive tacit knowledge, rooted in certain collectively accepted assumptions. This is confirmed by the case, as professional background and involvement in a professional community, plays an essential part in the interpretation and association of knowledge, related to the reading of steel drawings. Accordingly, the creation of a context, where the knowledge of the codebook is interpreted and perceived in an intended way, becomes important. Hence, the context must be regarded as an essential characteristic of the codebook.

The conditions for de-codification and mutual interpretation becomes especially important when knowledge is created and utilized in different communities. To guarantee efficient transfer of knowledge, an intersection of cognitive contexts must be built up, where knowledge can be exchanged and understood. This intersection is related to what the respondents called reduction of cultural differences.

A total overlap in contexts is, however, not desirable, as this necessitates more or less identical knowledge, where the two communities hold similar competences and background knowledge. The differences in responsibility in the execution chain of a project, call for differences in skills and experiences in the design and production community.

Imperative in the creation of a sufficient intersection of contexts, to assure unambiguous interpretation of drawings, is the establishment of a stabilized language, where the language of the drawings must be regarded to be the symbolic representations and pictorial statements. In the offshore construction industry, the representation on drawings is more or less stabilized. This stabilization has caused the language to obtain generative and adaptive properties, which can be compared with properties of knowledge. In the case study, these properties are reflected in the flexibility in the representation and structure of the symbols on the drawing. To avoid problems of transfer, this flexibility should be minimized, and a consistent company standard is therefore desirable.

When knowledge is exchanged inside a community, acceptance of knowledge becomes a natural process of establishing and upgrading the collective knowledge base. However, when knowledge is transferred between communities the stabilization of the knowledge itself, the technical solutions, becomes imperative. This is a result of differences in associated knowledge, and the consequential difference in prioritising in the two communities. Particular solutions, including functional requirements, structural integrity and fabrication friendliness, are instead specified in standardized libraries. This standardization of solutions supports the establishment of an intersection of contexts, where solutions can be recognized as appropriate. In contrast to knowledge transfer inside a community, where recognition of knowledge can be validated on a general basis, in the case of knowledge transfer between communities, this is acquired through the definition of specific and standardized solutions[70].

The strict time limits in offshore development projects makes the standardization of codebooks especially critical. Mistakes, shortcomings and deviations from agreed standards do however lead to frequent problems of interpretation. This points to insufficiency in the above stabilization, and hence to limits in the intersection of cognitive contexts between the design and production community. To overcome these problems, additional contact between the communities is required. Since the geographical distance restricts personal interaction on a daily basis, mediators become inevitable as support in the knowledge transfer.

Mediators are defined as persons with far-reaching knowledge of both communities. This experience they have obtained from long-time interaction with the other community, where they have obtained an understanding of the community's norms, values and priorities. Two categories of mediators are identified.

Mediators I are involved as interpreters and co-ordinators in the direct transfer of knowledge. They are persons sitting in intermediate positions in a project, and are to be contacted by the operators, if difficulties occur during fabrication. Dependent on the severity of the problem, the mediators I make a decision to either solve the problem locally at the yard, or to communicate the problem back to the design community. Though this interpretation, mediators I become creators of knowledge and selectors of what to communicate, and if relevant, to whom it is to be communicated. Moreover, they introduce additional flexibility to the codebook, where the written messages have become rigid, through their physical manifestation in documents.

Mediators II are persons who have been stationed at the opposite community over longer periods of time. Through their experiences they serve as organisational memory in two

[70] The need of standardized solutions is off course dependent on to what degree a sufficient intersection of

respects. In the short term, mediators II function as extension of their own community's knowledge in project specific challenges, where they participate in clarification questions. Long-term effects of the knowledge these persons bring with them back to their own community are, however, probably just as important. In this respect, mediators II become carriers of feedback, and contribute to the enhancement of intersection of contexts, thorough their increased understanding of the other community's priorities. The respondents remarked this through their observation of reduction in cultural differences, caused by increased exchange of personnel between the communities.

There will always be a trade-off between stabilization in the intersection of cognitive contexts and flexibility in the codes. Stabilization of language, solutions and informal networks entail path dependency. Ultimately, loss of surprise effects and introduction of cognitive limits, which inhibit promotion of new knowledge, can be experienced.

Proposals for Further Work

The limits in time and space available in the work with this essay have made it impossible to fully explore all aspects interesting in relation to the case, and proposals for further work are given through the essay. These proposals are summarized in the following.

- The above is a qualitative investigation, based on a relatively small number of interviews. As a natural extension of this thesis, a quantitative investigation, to find to what degree the results of the thesis is general, is proposed.

- Literature suggests that Communities of Practice are extremely important in creation of new knowledge in organisations. In this case such communities can be identified

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contexts already exists.

both inside and across professional communities, and a further investigation of the importance of Communities of Practice, and how to support them had been interesting to pursue in the light of the case examined above.

- Persons with much experience and authorities inside a professional community are important for the creation of knowledge embedded in the codebook. A question of to what degree the codebook converts this knowledge into objective, privileged knowledge across community boundaries can be asked.

- To what degree does path dependency and black boxing of knowledge contribute to inefficient routines, and how can this be avoided?

- An investigation of how the use of ICT tools influence knowledge, skills, communication, strategic behaviour, incentives and coordination is proposed, in relations to the possibilities of working in split sites, and the consequential loss of direct personal contact between the communities (loss of the mediator II function).

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Appendix

In this appendix I have included a more complete description of the offshore construction industry. The appendix must be viewed as an illustrative chapter. Very few discussions are included, as the content of this chapter is not directly linked to the discussion of the codebook.

In Section A.1 I have tried to place the Norwegian Offshore Industry into an historical, economic and social context. From the early 1970s and until today, petroleum related industry has become extremely important for the Norwegian economy and welfare. In this section I present a short summary of the history and future prospects of the industry, and some facts related to the economical and social importance of the sector today.

Section A.2 and A.3 includes a description of recent changes in the contract form and in standardization work in the sector; the EPC(I) contracts and NORSOK work. These changes have been decisive in the shaping of today's petroleum industry, how development project on the Norwegian Continental Shelf is executed and the economical prospects of such projects.

Section A.4 briefly describes the execution of a large development project in the engineering company and offshore yard of this case study. Further, Section A.5 describes the recent reorganization at the fabrication division at the offshore yard.

Finally, in Section A.6 a translated version of the rough interview guide is included.

A.1 Norwegian Offshore Industry: History and Prospects[71]

The first trial drillings on the Norwegian Continental Shelf started in the late 60s. The first findings were however not commercially profitable. In the end of 1969 Phillips Petroleum

[71] References in this section is mainly http://www.museumsnett.no/ntm/no/utstillingene/olje/historie.htm and The Norwegian Ministry of Petroleum and Energy (2001). All numbers given are from these two references.

discovered the giant oil field Ekofisk, and in 1971 Norway's first oil production started at this field.

In order to control the country's natural resources the Norwegian Government got heavily involved already in the early phases of the search for petroleum occurrences outside the Norwegian coastline. Before the first trial drilling commenced the Parliament passed a law saying that the Norwegian State was the owner of all natural resources and that no search or exploration of sub-sea reserves was to take place on the Norwegian Continental Shelf without the approval of the King[72]. In 1972 the parliament decided that a Norwegian oil industry was to be developed. The State owned oil company Statoil was funded later that year, and the three Norwegian oil companies: Statoil, Norsk Hydro and Saga Petroleum were favored in the award of new licenses on The Norwegian Shelf. However, the lack of relevant competence needed to build up a petroleum related industry motivated the authorities to look abroad for expertise. Haraldsen (1997: 39-43) explains how the Norwegian Authorities were able to attract foreign capital at the same time as the national capabilities in the area were built up. Licenses for production on oil fields were combined with technology agreements, where the individual foreign oil company was committed to carry out research and development work in Norway. Through participation in such activities private companies, universities and public and private research institutes in Norway gradually built up the progressive competence they hold today[73]. At the same time, Norway's traditions as a shipping nation were essential for the existence of receiving capacity (Haraldsen: 1997: 44). Especially the yard and the engineering industries held central receiving competence, and did easily adapt to the challenges of the offshore industry.

[72] Which means the Government in practice.
[73] The competence was mainly obtained from English and American expertise.

The petroleum incomes have grown to become extremely important in the Norwegian economy. Whereas this sector only contributed to about 3% of the Gross National Product in 1975, the share has increased to 22% in year 2000. This corresponds to a Gross Product of 310.9 billion NOK. The earning potential is however very sensitive, and is especially reliant on the oil price and the dollar exchange rate.

A Norwegian petroleum fund was established in 1990 with the first transfer in 1996. To be included in this fund are the State’s annual net cash flow from petroleum activities and investment earnings. Its function is to be a buffer in case of economical recession, for instance as a result of a lasting drop in oil price or failure in the inland economy. Furthermore, it is defined to secure welfare on a more long-term basis, such as the future decrease in income from the petroleum sector cased by reduction in the production, or as a consequence of an ageing population. In the end of 2000 the petroleum fund constituted 386 billion NOK.

From the early 1970s Norway has grown to become the sixth largest oil producing and the thirst largest oil exporting country in the world. In addition, they are among the ten top world’s gas exporting countries[74]. In 2000 the production of oil reached its peak with 3.1 million barrels a day. This production level is assumed to persist until 2004 and then gradually decrease. Production of natural gas is however believed to increase and reach its peak in the period from 2002 until 2006[75].

Today there are a large number of suppliers in offshore-related industry, especially in floating production and sub-sea solutions and in seismology. In 2000 73,647 persons in Norway were employed in industry related to the production of oil and gas. This is about 3% of the total workforce in the country. The economical sensitivity of oil price and the dollar exchange rate large fluctuations do however influence the industry. History shows

[74] Numbers from 2000, reference Olje og energidepartementet (2001)

that a cyclic decline with large reduction in work force occurs approximately every fifth year. The last of these was experienced from August 1999 to August 2000 where there were heavy cuts in the workforce with a reduction of 15,872 employees. This decline was largely due to oil prices down to $10 a barrel and a reduction of investments on the Norwegian Self.

In the future, new discoveries are believed to be mostly smaller gas fields, which are assumed to be to be discovered at locations with difficult availability and at large water depths. In addition, the industry faces more international competition and prospects of low oil prices. The possibility of profits under these conditions is marginal in comparison to the large development projects of the 1970s and 1980s. Consequently, future projects demand advanced technological solutions produced using considerably fewer man-hours than in the past. It is usually in periods of decline the large innovations have been enforced in the usually conservative offshore industry. Now standardized and yet flexible solutions together with more efficient execution of development projects are called for in order to reduce investments. From the large concrete structures of the past floating structures[76] and sub-sea constructions are developed.

A.2 The EPC(I) Contracts

During the 1990s a new contact form has developed in the Norwegian Offshore Sector. These are usually called EP, EPC or ECPI contracts regarding which phases included in the contract, where the acronyms stand for Engineering, Procurement, Construction and Installation.

Earlier the oil companies distributed the different commissions to a collection of contractors, and were themselves responsible for the superior project management and the

[75] With a daily assumed production of 280 million Sm^3.

assembly of the offshore structure. In the new contact form a small number prime contractors are able to compete for the full execution of projects. Possible prime contractors are large companies, often with long traditions inside the industry, with enough resources to accomplish such a large assignment.

As the contract name portrays the prime contractor is to carry out both engineering and fabrication and do usually consist of, at least, an engineering company and an offshore yard. Dependent on the contract, the prime contractor is responsible for the planning, design, analyses, building, assembly and sometimes the installation of the offshore structure on the field. That is, they are accountable for the whole process and management in the project, including finding sub-contractors for tasks not possible to solve internally, the treatment interfaces and co-ordination of the work.

The EPC(I) contracts gives the contractor more responsibility and control in the design and fabrication phases. When these contracts were introduced during the 1990s the engineering industry also hoped to obtain more control over incomes and costs, with the aspiration of more profitable projects. However, with the opportunities of profit came the financial risks and requirements of development of new technical solutions and introduction of strict routines for project execution. Sadly the result have been devastating or the industry. So far the EPC(I) contracts have involved a large share of lump sum elements. With the large rivalry for every large offshore construction project, prize competition contributes to push the prize down towards a level with small possibilities of profits.

The engineering industry has had to obtain new knowledge of how to manage large projects, with all its interfaces. Respondents remarked how problems often occur when the project, with all its worked up knowledge, is to be transferred from the design site to the

[76] Typically Tension Leg Platforms, Semi-submersibles and Production Ships.

fabrication site. That is, a transfer from the engineering company to the offshore yard, which also involves a transfer of knowledge from the design community to the production community[77]. It becomes a co-ordination task, arranging who does what, when, and that nobody do either more or less than they are supposed to. According to the respondents, this seldom is accomplished in all links of the project chain. Additionally, misunderstandings are likely to occur because members of the different communities have different relations to the structure to be built, and "speak different languages"[78]. Earlier these problems were the oil company's to solve. In the recent total contracts such costs are transferred to the prime-contractor, who have worked up little experience dealing with such problems. One of the respondents explained the possibilities and risk of EPC(I) contracts in the following way:

> Some contracts only tell us that they are to develop a field out there. It is so and so deep, we are to bring it up from the hole and we are to produce so and so much. Make something that can do the job and you will get 5 billions for it. And it has to work. If it works you have done your job and you get your money. You are much freer, but it is actually a huge responsibility. It depends how efficient you have been in order for you anything to be left. It is small margins.

A.3 NORSOK[79]

As a result of the new challenges faced in the Norwegian Offshore Industry, the Norwegian Minister of Petroleum and Energy initiated a new forum in 1993. The purpose of this forum was to identify and implement efforts necessary in order to improve the competitiveness of the industry. Collaboration between the various actors in the industry

[77] How I have chosen to use these two professional communities in this essay is described in Chapter 4.
[78] This is explored in Chapter 6.

was set as a condition for the work, and a committee was put down, consisting of representatives from the oil companies, the supplier industry, research institutions and the authorities. Their work resulted in eight NORSOK reports presented in February 1995.

NORSOK stands for "norsk sokkels konkurranseposisjon" or in English "The Cooperative Standing of the Norwegian Offshore Sector". It is a collection of regulations, standards and propositions, and has as its intention to reduce the development and operation costs of the Norwegian offshore industry. With the motto: "Good enough is good enough" the industry hope to achieve a competitive advantage compared to the rest of Europe. The NORSOK work has been carried out in seven areas. Among these are collaboration between operator and contractor and standardization.

Enger[80] (1997) remarks how the new project execution model has transferred more responsibility from the operators to the main contractor. Hence, the result of the NORSOK work contributed to the new EPC(I) contracts, described in the previous section. He also remarks that: 'experience from several projects show that these companies were not adequately prepared for this new role'. Knowledge related to managing and coordinating a large-scale project, with numerous interfaces and work at several sites, is not unproblematic to build up. Rather, it is a capacity that takes considerable time and effort.

An objective of the NORSOK work has been to substitute the project specification restricted to the individual oil company, and sometimes even the particular project. The respondents did however remark that these intensions were not fully followed by the oil company, as they still do provide own specifications in numerous volumes[81].

One of the respondents described how the intended simplification and optimization from the NORSOK work sometimes actually has enhanced the costs in a project. The

[79] REFERENCES!! – http://www.nts.no/norsok/, http://www.olf.no/art/no_norsok/2000/0921/162226.html, http://www.epci.org/articles/beyond.html

[80] Executive Vice President of Norsk Hydro ASA

optimization in the structural discipline has mainly resulted in optimization in the usage of steel. This has not necessarily made the work simpler. The respondent described it as a trade off between the cost of steel and man-hours:

> I choose to say that NORSOK might have contributed to the bad economical results. The intension has been to do things cheaper, but either quality or standards have been lowered. I also feel that the customer has been clever enough to write rather diffuse specifications, which have made what we promise somewhat hidden. The specifications have probably been there all along, but I think that the interpretation of them have been a bit naïve.

All things considered, the conclusions after the NORSOK standards have been applied for half a decade are far from clear. The industry often emphasizes anticipated savings from recognition effects and predictability. The NORSOK process is described as an important driving power to promote cost efficiency and to increase the compatibility of the industry (Norges Forskningsråd: 2001). As a contrast NORSOK has been accused of contributing to the recent problems in the Norwegian Offshore Industry with lay-offs and the closing down of yards. Engen and Olsen (1999) wrote in a chronicle in the Norwegian newspaper Dagbladet how the NORSOK work had contributed to 'general agreement of both means and goals. It is this consensus we see the results of today, when parts of the yard industry is closed down'.

The success or failure of the NORSOK process is a shaded question, which I will not touch on further in this essay. A critical analysis of this process, with the basis in the

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[81] In the project many of my respondents in the design community worked at for the moment, the specifications particular for that project were more than 30 in addition to the NORSOK standards.

two concepts; technological trajectories and social construction of technology is carried out in a project leaded by Senior Researcher Odd Einar Olsen at Rogalandforskning[82].

A.4 The Execution of a EPC(I) Development Project in Aker Oil and Gas

In this essay I am looking at a typical prime contractor in the large development projects on the Norwegian Continental Shelf, Aker Oil and Gas. The company is a concern[83] including several daughter companies engaged in the industry. Central in the execution of a EPC(I) contract is however the co-operation between an engineering company and an offshore yard. This case study has concentrated on the Aker Egnineering, which is a major engineering company in the Oslo area, and Aker Stord, which is the concern’s yard located on the west coast of Norway. Whereas the engineering company is placed in a densely populated area and faces high turnover, the yard is a cornerstone company in a small society.

In the following I am giving a brief description on how a project is executed in Aker Oil and Gas. This case study focuses on the structural process, which includes design, analyses and building of the actual structure. This is only one of several processes in a development project, where other can be concerned with piping, process, electrical equipment etc. These are not covered in this essay. Hence, the description below is mainly applicable on events related to the structural process. In this part my main references have been respondents and company internal reports.

Formally it is Aker Stord that acquires large EPC(I) contracts, and that is the responsible part against the oil company. Dependent on the engineering capacity locally on the yard, one of the concern’s engineering companies are brought in, and a co-operation

[82] The project: NORSOK – en reell endringsprosess eller et symbol? En analyse av endring og innovasjon i ”del petroindustrielle kompleks”. For more information: http://program.forskningsradet.no/petropol/prosj12.php3.

[83] Aker Oil and Gas is a business area inside the concern Aker Maritime.

agreement is established between the two companies. Every project is carried out with basis in the company execution model for EPC(I) projects, which divides a project into different phases, where who is doing what and when is more or less defined.

Even if the customer[84] has given up its overall management and co-ordination responsibilities in the project in the new total contracts, they are still strongly influencing the technological development in the industry. They define the product functionality and technical specification, and chose what they consider to be the best offer from a number of concepts in a bidding between relevant contractors. At the same time, representatives from the oil company usually follow up the project work in order to secure the fulfilment of the contract.

With the introduction of the EPC(I) contracts in the early 90s, a more or less permanent co-operation between the engineering companies and the yards in the same concern commenced. Before this, the two companies had limited contact, and the distance between them of 500 kilometres was regarded extremely large. In this period the yard grew larger and became focused towards completion of development project after the part production phase[85]. Some detail analysis and design on secondary steel[86] were to be performed at the yard, and in this connection a lot of personnel were sent to Aker Engineering in Oslo to acquire knowledge held in the engineering company. In the same process, personnel from Aker Engineering were temporarily transferred to the yard in order to get a better understanding of the priorities in the production hall, and how fabrication friendly structures are accomplished.

Since then, the EPC(I) contract has contributed to widespread exchange of personnel. In these large contracts it is necessary to have some overlap of personnel in order to secure a smooth transition of the project, when the worked up project specific

[84] The oil company that function as the operator on the field to be developed

knowledge is to be transferred from the engineering company to the yard. As is further explored in Section 8.2, the possibilities of increased understanding, trust and respect is a great advantage, which has its source in the permanent co-operation. The company has had the possibility to stabilize and standardize solutions and methods of communication, and significant know-who can be developed. At the same time the possibilities of opportunistic behaviour has decreased, as both business units belongs to the same parent company, and both profits and costs are shared dependent on the participation and risks taken in the individual project. A respondent remarked:

> In the interface between engineering and fabrication you often end up in situations where things just have to be solved. It is definitely an advantage if you know each other sufficiently to at least find the best way to solve the problem. Generally somebody has to suffer, and then, the only thing is to reduce the damage. If you collaborate with somebody who has no understanding what the other party is doing, it often becomes very difficult.

Disadvantages related to permanent co-operation may however be possibilities of inefficient routines, which can be a result of practices not being challenged as in new constellations. One of the respondents in the design community did comment that the bureaucracy at the yard sometimes seemed slow and uncalled for in comparison with other yards the engineering company recently had worked with.

Even if the company execution model is the basis for all projects, an adjusted model dependent on the current capacity of the two units is created for each project. Usually Aker Engineering is responsible for the system definition phase, where design and all analysis of primary steel is to be completed, and some of the secondary steel is decided.

[85] The phase where fabrication of the individual parts naturally is carried out.
[86] The parts of the structure not critical for the integrity of the construction.

After this phase the project is moved to the Aker Stord together with all preliminary technical documentation related to the project. This documentation includes the 3D-computer model and possibly the package of design drawings issued for construction. These are identified to be the most important codebooks used in the transfer of knowledge from the design community to the production community in this essay (see Chapter 5).

If shop drawings have not already been prepared these are created from the design foundation given in the 3D computer model or from the package of drawings. The shop drawings are further discussed in Section 6.3. The work package is created at the yard; consisting of shop drawings, list of materials, welding procedures, cutting foundation for beams and plates, time plans and man-hour estimates. This package is delivered to the teams of operators, who carry out fabrication of individual parts and sub-structures, and finally the assembly of the total structure to be built at the site.

Recently the main parts of the engineering and design capacity in Aker Oil and Gas was moved to Stavanger, and Aker Offshore Partner. This company has traditionally done modification work on older offshore structures, and have only recently been involved in the detail engineering of new constructions of this scale.

In a new project the axis between Aker Engineering and Aker Stord has been re-established. In the future, the respondents saw Aker Engineering as a parallel provider of engineering services to Aker Offshore Partner in Stavanger.

A.5 The Recent Reorganization at Aker Stord

The yard has recently undergone a reorganization of its fabrication division. One of the main alterations in this reorganization was the introduction of the “arbeidsgrunnlagsteam”, which has been translated into “work foundation team” in the following.

Earlier, supervisors and foremen lead the work in the production hall, where they each had the responsibility for a team consisting of 15 to 20 operators. For every assignment, the supervisor investigated relevant drawings and decided how the fabrication of each structure was to be carried out. This they explained to their teams of operators, who completed the fabrication according to the given instructions.

After the introduction of the work foundation team, the new teams of operators, consisting of four to five persons, are supposed to take on the old responsibilities of the supervisor. They are expected to receive a work foundation including everything necessary in order to complete the given assignment. In the reorganization, the cut of some positions in the work chain is believed to reduce direct costs and make the execution less bureaucratic. The possibilities resulting from the increased responsibility of the individual operators may however show to be even more important. The company hopes for more initiative and motivation in the individual operator’s workday. In addition, the reorganization is a means to increase the knowledge and competence of the operators. A respondent involved in the reorganization process described the objectives in the following way:

> Earlier, each morning 7 o’clock, they [the operators] waited until the supervisor to came down and told them: ‘You are to do this and you are to do that, and when you finish you can come back to me to receive a new assignment’. The philosophy now is that they are to get a set of drawings and build a whole section or do some work, which can maybe last for 14 days: Come back when you finish. You have got this much time, and you know the routines. You know requirements and quality. Now you have to take initiative and plan your own day. If anyone is going on vacation or have to go away, he arranges it with the others, and makes sure that everything does not stop even if he is gone. This is the

philosophy.

In this way they hope to make more of the experience and knowledge of the individual operator. The teams of operators get new responsibilities in relations to organizing the work, overlap to the next shift and the communication with other team members or other teams.

The building of a new context, which the operators must relate to, is destined to take long time. The operators must be given the possibility to adapt to their new function. The communities they belong to, with given norms and rules for how to behave in a given situation, will probably undergo some important changes, and collective knowledge must get the opportunity to evolve. Hence, it is important that positive results are not expected too soon, together with a conclusion saying that the reorganization was unsuccessful.

Since this way of organizing a project is fairly new, it is too early to come to any conclusions related to its success. So far, at the current project, it has been some problems to follow the intentions of the reorganization. The work foundation team has not been able to have as much contact with the operator teams as presumed. Delivery problems related to the completion of working packages from engineering have required much attention, and the work foundation team has used a large amount of their time to administrate and to complete these packages. The work foundation team is only present in the day shift, and this further complicates the fulfilment of the original intentions, where the teams of operators are supposed to work directly towards the work foundation team. In the afternoon shift there is a site engineer present, who can handle engineering problems. If there are other problems or the site engineer is not present, the teams of operators have to wait until the next shift to get an answer and the production is stopped. In the long run, the intension is however to run the fabrication on one shift, and these problems will not occur.

A.6 Interview Guide

In this section the rough interview guide is included. As the original guide was in Norwegian it is translated. It must however be pointed out that this guide only was used as directional aid, and that the interviews often took sudden and interesting turns away from predetermined questions of this guide. The questions asked were also a critical evaluation of the function and company of the individual respondent.

Interview Guide for Case Study at Aker Oil and Gas, June 2001:

How is codebooks used in the transfer of knowledge between the design and production community in an offshore construction project (development project)

I am mainly concentrating on the transfer of steel drawings and the 3D computer model.

General questions of the practical execution of a project:

1. In what company do you work? What is this company's role in the concern? What role does it have in relations to new construction projects?
2. What has traditionally happened on the design/production side of a project?
3. When did EPC(I) project become common? Why? How are they executed in the company?
4. How has the NORSOK standard influenced the execution of projects?
5. How much has it influenced the local standards? The drawing and documentation methods?
6. What is your role in a project? What is your relationship to the codes/written documents transferred from design to fabrication?
7. What are advantages and disadvantages with more or less permanent co-operation between engineering company and offshore yard?

Creation and transfer of codes?

8. Which documents are transferred between the design and production community? What are their functions?
9. What is your relationship to the shop drawing and the extra information included in it? How are the shop drawings different from the design drawings?
10. What knowledge do you and the people you work with associate with the drawings (explain know-what, know-why, know-how and know-who)? Do you associate the same knowledge as in the design/production community? Why?
11. Do the members of the two communities understand the drawings in the same way?
12. Is the transfer of drawings sufficient enough to avoid misunderstandings?
13. If there has to be additional contact, who manage this contact?
14. What is the role of the site engineers and the work foundation team at the yard? What about the engineering company's representatives at the yard? Who are they

and what role do they have in the contact between the two communities?

15. Who are mediators of knowledge? Who are most important in the transfer of knowledge? Who does the communication go through?
16. Does the mediators have special abilities? What makes them capable of making such decisions?
17. Is it ever personnel with production experience in the design phases in Oslo? Do they have any percussion force?
18. Is the contact between the communities sufficient? Is something missing? Do you think misunderstandings would have been avoided with more contact?
19. Do you always understand the other community's priorities? If not, how do you think differently from them? Do they understand you?
20. Is it, or has there been a cultural difference between the two communities?
21. Who do you speak with in the other community? Do you feel that they speak the same language as you?
22. To what degree is local jargon and expressions used when referring to the drawings? Is this jargon similar in design and fabrication?
23. Has the same words got the same meaning?
24. Is it any disadvantages with the remote locations? What problems could be avoided if the two teams were located at the same site?
25. Why are the teams located this far apart?
26. Are informal relations important across organizational boundaries? How have such relations come into being?
27. What happens when mistakes, shortcomings or impractical solutions is discovered during fabrication?
28. Who makes the decisions on what must be done?
29. Are there pure interpretation problems, or is it mainly shortcomings and pure mistakes that are communicated back to design?
30. How has the language related to the drawings developed? Is it a result of development inside the community or of external influence?

Routines and local authorities

31. To what degree does rules, regulations and industry standards decide the local standards for transfer of knowledge in the company?
32. To what degree does new documents/drawings build on old documents/standards? Is it simple to introduce new knowledge? Is it easy to change routines if they are inefficient?
33. How are documents reused in new projects?
34. In unforeseen situations does the production community give any feedback? Are there any routines for such feedback? What channels does such feedback go through? Does the feedback reach the designers?
35. To what degree is experience transfer successful? Do the same problems often repeat themselves?
36. Does written information have more percussion force than oral transfer? If yes, why and what are the consequences?

Standardised drawings and the use of ICT

37. How has 3D models helped design to easier visualise the structure?
38. To what degree are the drawings standardised? Have there been any changes after the introduction of electronic aids?
39. What are the advantages/disadvantages of standardised drawings and electronic

drawings tools?

40. Have the standardization resulted in special languages? Is it easier to understand the drawings or how you speak about the drawings when they are standardised? Is it still necessary with special basis knowledge in order to understand them?
41. Is it easier to relate to other companies using standardised drawings? Are the same standards more or less used?
42. Have introduction of tools like e-mail, phone or videoconferences made direct communication with the design/production community simpler? Do you use such tools?
43. What are advantages and disadvantages with videoconferences? Do you have meetings more frequently?
44. Is ICT tools used to diffuse information internally in the divisions?