Codify or Collaborate?

From Expert Systems to Systems of Experts for Knowledge Creation in Manufacturing

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Abstract

Academics and business professionals currently show a significant interest in understanding the management of knowledge and the roles to be played herein by information and communication technology (ICT). In this paper we take a closer look at one of the primary issues raised when supporting the management of knowledge, how to understand the role of codifying implicit knowledge as opposed to the role of collaboration and networking in processes of knowledge creation. Two exhibits illustrating an unsuccessful and a successful process of knowledge exploration and exploitation are presented and discussed. It is concluded that distinguishing between a cognitive and a community perspective on the management of knowledge can be enriched by more carefully considering both technological and organisational issues.

1. Introduction

Has the Information and Communication Technology (ICT) community hijacked the emergent field that focuses on the management of knowledge and have issues related to human resource management and organisational theory as a whole been largely ignored? This position, when compared with the academic debates that exist within the field of organisational learning, has been propounded by a number of social science researchers recently, and has been supported by in-depth analysis of contemporary literature within both of these fields (Scarbrough and Swan, 1999; Scarbrough et al., 1999). It is suggested that the current debate within the literature focuses on the management of knowledge from a cognitive perspective emphasising the codification and textual transfer of objectively defined concepts and facts with technology being the crucial success factor (Swan et al., 1999). It is further argued that a community model can provide a more appropriate perspective, focusing on the formation and reproduction of social networks facilitating transfer of tacit/implicit as well as explicit knowledge (Swan et al., 1999). In this paper we attempt to explore and extend the implications of these assertions further.

We suggest that investigating how to support the management of knowledge cannot sensibly at this stage be dealt with as one discussion. We cannot assume that knowledge is managed in a similar fashion in all organisational settings, across sectors and company sizes. Importantly, neither do we perceive ICT as one technological “black box”. Furthermore, in supporting the management of knowledge, we believe it to be highly problematic a priori to assume certain allocations of

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functionality between humans and technology as well as between manual and computer-based information technologies. Successful use of ICT necessarily relies on a complex pattern of manual and technologically driven activities. Aspects of an ICT system will be manual e.g. forms, classification schemes, boards, notes, written procedures etc, and inherently other aspects will be computer-based.

In order to frame this argument, we investigate the issue of codifying knowledge versus collaborating in the context of the creation and formalisation of new knowledge in two highly specialised manufacturing settings. The paper highlights how radically different perspectives on the way in which socio-technical issues should be accommodated and blended can affect the likelihood of successful technological innovation and support for the management of knowledge. The two cases discuss the relationship between the creation of knowledge and the process of embedding that knowledge in systems that are subsequently deployed in the organisation. Exhibit A (Snis, 1997) is the case of a problem of quality control within a highly specialised thermal spraying process in a Swedish manufacturing organisation. The organisation found it impossible to improve quality of the end product through conventional process optimisation. In order therefore to enhance the quality the organisation chose to develop an expert system that would overcome these problems. Exhibit B (Sørensen, 1994; Carstensen and Sørensen, 1996) is the case of a Danish manufacturing organisation where the introduction of Computer-Aided Design workstations as a replacement for conventional paper-based design had created the need for reuse of specifications. In order to support distributed storage and retrieval of specifications, an ad hoc, informal group of people in the organisation developed a substantive classification scheme codifying components of the instruments the organisation produced. These two cases can be accommodated largely within the classification scheme developed by (Swan et al., 1999) which highlights the cognitive and the community approach to the management of knowledge. We conclude that the codification of knowledge can successfully lead to new technological support only if the codification is based on a collaboratively established consensus reflected in the community model. We also however draw upon results from the field of computer supported collaborative work (CSCW), and emphasise that interdependent actors bringing different skills to highly complex technical work processes will have different perspectives (Schmidt and Simone, 1996). Classification as a social process is therefore subject to continuous renegotiation (Bowker and Star, 1991).

The next section covers the main theoretical perspectives used in this paper for analysing the management of knowledge. Section 3 presents Exhibit A and B, which are aspects of two case studies of knowledge codification and sharing from two manufacturing settings. Section 4 discusses the findings and relates them to contemporary knowledge management literature in a discussion of the role of ICT in supporting codification and collaboration. Section 5 concludes the paper.

2. Creating and Sharing Technical Knowledge

The management of knowledge implies the enhancement of learning and performance in organisations through processes and practices of creating, acquiring, sharing and using knowledge irrespective of where it resides (Scarbrough et al., 1999). In this paper we are primarily interested in the creation and sharing of knowledge within technical domains. In order to avoid a deep ontological or epistemological discussion of the distinctions between data, information and knowledge, we adapt the pragmatic contextual notion of the sharing of technical knowledge promoted by Scarbrough (1995). Here, it is argued that the sharing of technical knowledge primarily should be understood in terms of social interaction as opposed to discrete physical transfer. As argued by Newman and Newman (1985), information can be viewed as the answer to a question and knowledge represents the framework for asking the question. When information is interpreted and applied in a specific situation by human actors and hereby conceptualised to a certain level of abstraction, it can qualify as knowledge. Knowledge can not be managed separately from the people in whose heads it resides (Browning and Reiss, 1998a). Nonaka & Takeuchi (1995) distinguish between tacit and explicit knowledge and argue that the creation of knowledge is situational and dependent upon four modes of knowledge creation emerging as a result of the interaction between tacit and explicit knowledge: socialisation, combination, externalisation, and internalisation. In socialisation processes, individuals share tacit knowledge with each other. Combination characterises the combination of explicit knowledge through artefacts. Externalisation refers to the process by which tacit knowledge is made explicit, and internalisation is the process of converting explicit knowledge into individual tacit. Nonaka & Takeuchi (1995) further argue that knowledge creation is initiated at the individual level, moving up to the collective group level and finally reaches the organisational level.

Spender (1996; 1998) further emphasises the importance of the interaction between individual and social knowledge which both can be characterised as either explicit or implicit, i.e., tacit. He suggests four types of organisational knowledge: Individuals can have (1) *conscious* knowledge which is explicit, and (2) *automatic* knowledge which is implicit. Social knowledge can be (3) *objectified*, i.e., explicit, and (4) *collective*, i.e., implicit. Spender (1996) further argues that organisational knowledge is created in the dynamic interplay between individual, social, tacit and explicit knowledge, and he promotes collective knowledge, rather than individual knowledge, as the most strategically useful for the organisation. Knowledge will only be formalised if it has reached a certain state of acceptance and stability. The artefacts used are seen as the knowledge-mediating mechanisms for knowledge exchange. Individuals can exchange and combine knowledge through different media such as documents, telephone conversations, or computer-based mechanisms and networks. It is, however, important to stress the variety of possibilities for the transfer or mediation of technical knowledge, for example:- (1) *objectification* involving standardisation as a means of portability and universal applicability, (2) *professionalism*, where knowledge is communicated through learning and experience, and (3) *organisational sedimentation* where knowledge is communicated via rules, standards, routines and structures (Scarbrough, 1995). These three modes of knowledge communication denote increasing social control and decreasing degree of economic exchange (Scarbrough, 1995).

The use of technology as a means of codifying or objectifying knowledge with the purpose of communication across temporal and spatial boundaries in or across organisations has increasingly gained interest with the emergence of virtual and distributed organisations. Organisational procedures, handbooks and manuals have traditionally served as means of codifying and communicating knowledge (Schmidt, 1994; Alavi, 1999). However, they have also traditionally been accompanied by various means of interaction such as face-to-face discussions, mentoring, job rotation, and staff development which can be problematic to maintain when work activities increase in complexity (Carstensen and Sørensen, 1996). Technologies such as e-mail, groupware packages, hypertext systems, and intranets have in recent years been promoted as technologies for knowledge management (Kirn, 1997; Alavi, 1999; Scarbrough and Swan, 1999; Scarbrough et al., 1999). More specifically, a number of groupware applications have been carefully investigated (see for example, Orlikowski, 1992; Scarbrough et al., 1999; Robertson et al., 2000; Snis, 2000). It is, however, a substantial challenge to support the creation and sharing of knowledge amongst knowledge workers, and we can not hope for any simple technological solutions (Scarbrough et al., 1999; Swan et al., 2000). Even if we could, the mere availability of the technology would not necessarily imply successful use if any use at all (Orlikowski, 1992; Robertson et al., 2000). Successful knowledge management strategies require more than merely deploying the best technologies. According to Swan et al (2000) many of the existing approaches still remain technology-driven, merely "black-boxing" the technologies (Scarbrough, 1995).

Swan et al. (2000) formulate two distinct perspectives on knowledge management for innovation, the *cognitive* and the *community* model. The community model is formulated as a critique of the predominant cognitive model perspective within the technology driven research field (Scarbrough et al., 1999; Swan et al., 2000). The cognitive model denotes a perspective where valuable knowledge is conceived as being captured and codified from individuals, packaged, transmitted and processed through the use of IT, and hence disseminated and used by other individuals in new contexts. In this perspective, knowledge can also be exploited through the recycling of existing knowledge "owned" and "experienced" by individuals in cognitive networks. Here, information and communication technologies are seen as critical success factors. In contrast, the community model portrays the management of knowledge as socially constructed through interaction within communities of practice. Communities of practice consists of collections of individuals, between whom there is collaboration and negotiation. Knowledge creation and learning are processes making sense of knowledge in social activities deeply rooted in daily work practice. Within the community model, information and communication technology can play a role, even though it is not seen as a critical success factor. Table 1 summarises the main characteristics of the cognitive and the community model. Alavi (1999) formulates three perspectives on knowledge management. The information-based perspective where knowledge is perceived in terms of individuals making sense of vast amounts of information, and the technology-based perspective focusing on the application of ICTs, such as intranets, data warehousing and expert systems, for managing knowledge, characterise similar phenomena as the cognitive model. Alavi's culture-based perspective demonstrates features similar to the community model, in its focus on collective learning and the sharing of common values. Further work is however needed to establish closer links between these two distinct strands of work.

Reviewing the literature, we find that the distinction between a cognitive and a community model appropriately describes the two main approaches both to knowledge management, but in particular to a debate of the role of ICT in the management of knowledge. The cognitive model, focusing on the crucial role of technology as the mediator of codified knowledge, represents the technologist view and leaves us with the message to support knowledge management by codification. The community model, focusing on social interaction and negotiation, promotes a message of supporting collaboration from the perspective of the contextually aware social sciences. When considering issues related to the creation and sharing of technical knowledge, and to the role of technical and organisational measures in doing so, we are left with the question of who to trust? The technologist touting the splendour of technology, or the social scientists questioning this view? We will in the following seek to critically reappraise the analytical distinction between the cognitive and the community model by analysing and discussing two cases of knowledge creation and sharing for innovation within manufacturing. We will seek to follow the principle of focusing on the goals instead of the means, and not automatically granting actors more explanatory status than artefacts (Monteiro, 2000).

Table 1: Two contrasting views of the KM process from (Swan et al., 1999).

Cognitive Model	Community Model
• Knowledge for innovation is equal to objectively defined concepts and facts. • Knowledge can be codified and transferred through text: information systems have a crucial role. • Gains from KM include exploitation through the recycling of existing knowledge. • The primary function of KM is to codify and capture knowledge. • The critical success factor is technology. • The dominant metaphors are the human memory and the jigsaw (fitting pieces of knowledge together to produce a bigger picture in predictable ways)	• Knowledge for innovation is socially constructed and based on experience • Knowledge can be tacit and is transferred through participation in social networks including occupational groups and teams. • Gains from KM include exploration through the sharing and synthesis of knowledge among different social groups and communities • The primary function of KM is to encourage knowledge-sharing through networking • The critical success factor is trust and collaboration. • The dominant metaphors are the human community and the kaleidoscope (creative interactions producing new knowledge in sometimes unpredictable ways)

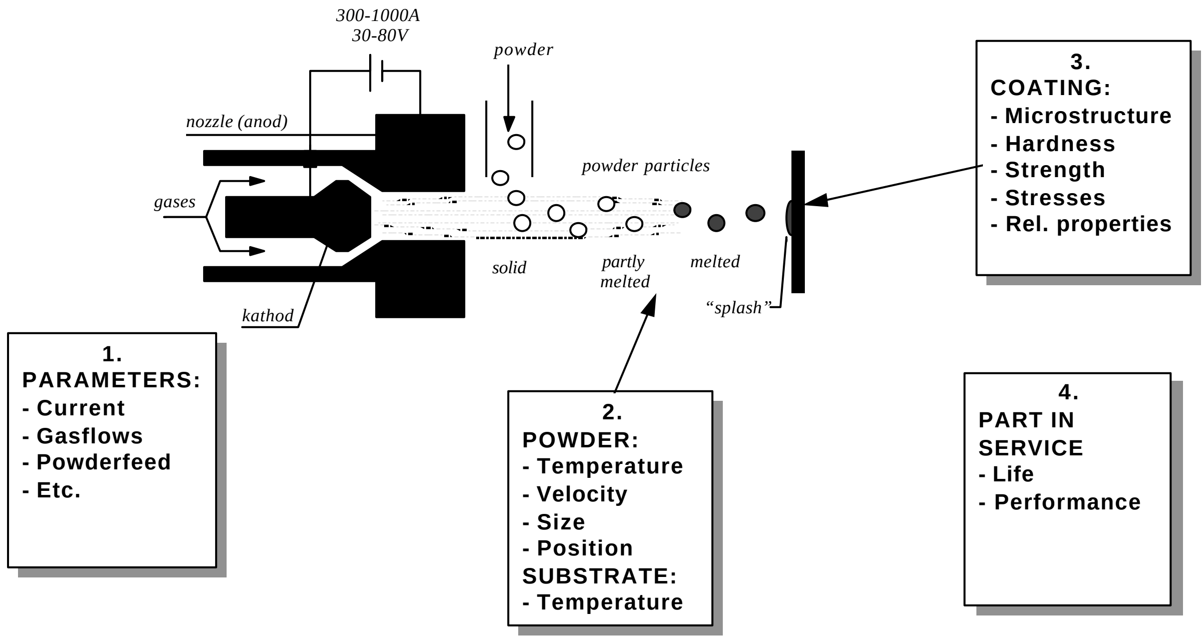
3. Two Cases of Knowledge Codification

The two exhibits presented here are both examples from manufacturing. Both concern the creation and sharing of technical knowledge for innovation with the purpose of improving organisational processes. The exhibits are drawn from two case studies applying qualitative interviewing, participant observation and document inspection as the three primary data collection methods (Patton, 1980; McCracken, 1988; Cash and Lawrence, 1989; Carstensen and Sørensen, 1994). Both studies, but in particular the first, contain elements of action based research (Braa and Vidgen, 1999). The data was not intentionally collected for this particular analysis. However, the focus of both studies was to focus upon relationships between everyday manufacturing processes and the use of ICT. For the purpose of this paper, we have critically re-analysed the findings. The two authors each conducted the original fieldwork in the two cases. The cases are represented as exhibits to highlight that the intention has not been to communicate the full contextual characteristics of the case studies. Instead it has been the purpose to focus on a few aspects pertinent for the discussion of knowledge management practices for technical process innovation. This bracketing off context represents what Monteiro (2000) denotes “unpacking complexity by zooming in”. Both exhibits focus on process improvement. Exhibit A within a particular, complex manufacturing process (Snis, 1997), and Exhibit B in engineering design and documentation specifications (Sørensen, 1994; Carstensen and Sørensen, 1996). The following two sections present and discuss the two exhibits in detail.

3.1. Exhibit A: Codifying Thermal Spraying to Improve Process Quality

Exhibit A is located at a Swedish manufacturing organisation that developed, produced and maintained jet engines for military as well as civil use (Snis, 1997). The manufacturing process thermal spraying played an important role in ensuring the highest attainable quality in new jet engine designs and the organisation had consequently over the years in many jet engine projects developed considerable high-tech competence in this manufacturing process. Thermal spraying involves partly melting and throwing a material, usually a powder, onto a substrate where a coating is built up by the condensing particles. Figure 1. The application and the desired properties of the coating determine possible spraying methods and materials. Metals, alloys, carbides, plastics and composites can be applied by thermal spraying.

Figure 1: A schematic drawing of the thermal spraying process indicating the four main categories of variables affecting the process and product quality.



Thermal spraying had in this as in other settings a troubled history concerning quality assurance. The multitude of factors affecting the quality and the difficulties involved in measuring, estimating and testing process quality resulted in less than desirable ability to reproduce and manage a desired quality on a consistent basis. The quality of the coating was influenced by a complex set of parameters. For example, in plasma spraying about 50 macroscopic parameters needed to be adjusted. The set point determination of the process parameters was often a matter of trial and error and was time consuming. Moreover, the stress build-up in the coating, which was determined by the cooling conditions of the droplets on the surface, and of the successive deposited layers, varied as the coating grew due to changes in the local thermal field. In state-of-the-art thermal spraying, the set point parameters were determined for the entire duration of the praying process with no consideration to the changing conditions at the coating surface during spraying. These factors led to coatings with variable quality due to the lack of control of defects such as microscopic cracks, porosity The lack of quality and reproducibility limited the thermal spraying market share and increased manufacturing costs. At the time of study, rapid changes were being introduced across the world, applying advanced continuous measurement and data processing systems with the purpose of ensuring a higher quality of the thermal spraying process. The types of problems which thermal spraying employees faced stemmed from incomplete information about the state of the process and the inconsistency and uncertainty of what knowledge to collect, codify and apply.

In order to improve the quality of the thermal spraying process, the organisation initiated a research project with the purpose of investigating the main factors affecting process quality. Part of this project involved the critical appraisal of the management and co-ordination of tacit knowledge with the purpose of codifying this knowledge into an expert system (Snis, 1997). This effort complemented other research efforts (Nacsa and G.L., 1994; Nylén and Snis, 1996; Steffens et al., 1996). The expert system would intentionally allow dissemination and distributed application of the codified process knowledge through a technology driven interaction between a human operator (allegedly) without deep domain knowledge and a computer-based expert system on thermal spraying processes (Russel and Norwig, 1995; Turban, 1995). The project did not involve the task of automating existing explicit rules and principles previously codified. Rather, the task of the knowledge engineer was to carefully elicit complex and tacit process knowledge situated throughout the various professional groups involved, thus making it explicitly formulated as rules to be codified into a new expert system. As a result of the inquiries, more questions were raised than answered and the extremely complex nature of the tacit process knowledge was identified. One such example was the crucial local adjustments requiring both experience and skills made by operators monitoring and controlling the process. These were made as a direct result of observed process anomalies, such as a strangely shaped flame caused by too low power feed in the robot gun. The study showed how not only the technical factors affected the quality of the process, but also demonstrated the crucial role of human judgement influenced by the experience of the operator, personnel training and education, and collaborative efforts among the workgroup members, etc. Another example of the problems of codifying the tacit process knowledge was the internal inconsistency within the rule-base for quality. This inconsistency was premised on different sub-activities and roles within the major activity of thermal processing having pre-established different and conflicting rules. As a direct result of the substantial problems establishing a credible codification thermal spraying process knowledge, the expert system project was ultimately abandoned.

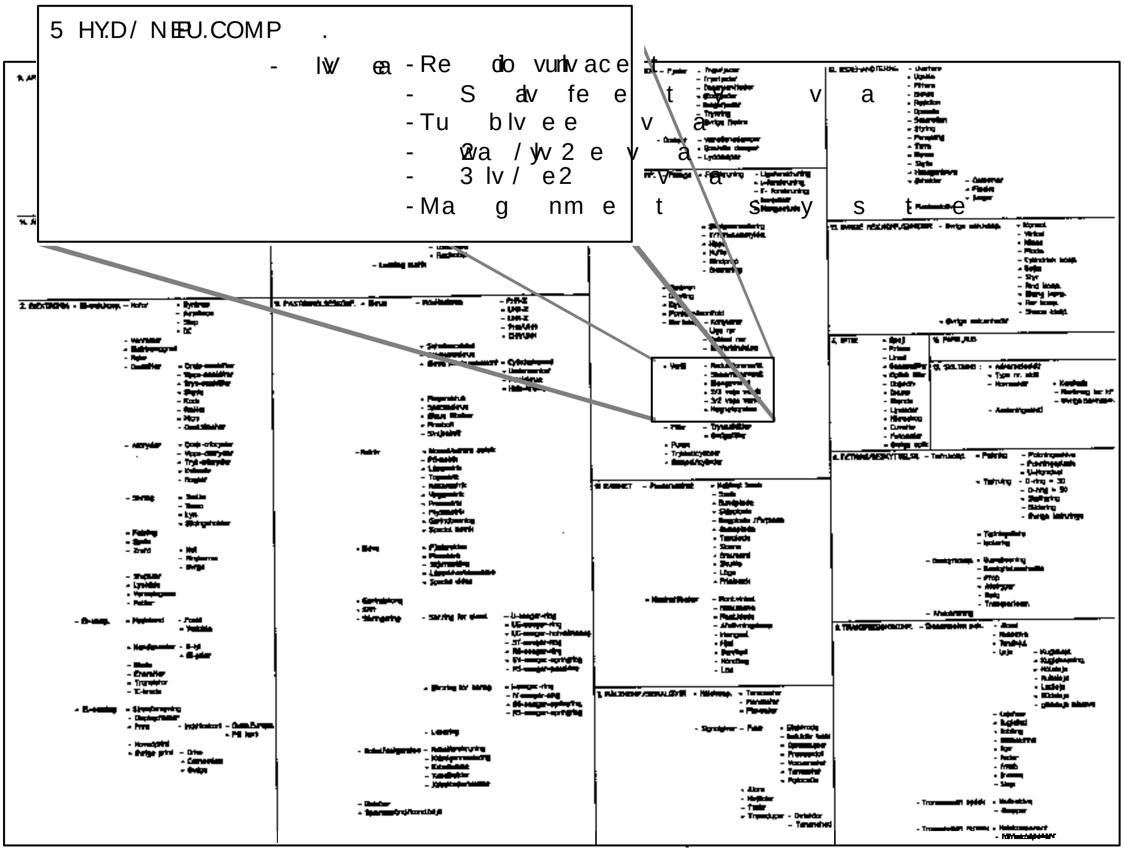
3.2. Exhibit B: Collaborating to Codify Engineering Design Models

Exhibit B is the case of a Danish manufacturing organisation that develops, manufactures and markets instruments for automatically measuring quality parameters of agricultural products, such as measuring the compositional quality of milk, composition and microbiological quality of food products and the quality of grain. The company was at the time of study world leader in this market segment. Designing these instruments involves a range of expertise from the disciplines of mechanical, chemical, electrical and software engineering. Other participants in the development efforts were individuals from production, the prototype shop, marketing, quality assurance and service departments. Once produced, the instruments were sold in relative small series of around 500 to laboratories around the world. Market leadership resulted in significant pressure on the organisation to innovate. It was in effect competing against its previous product ranges and could only survive through constant innovation. As a direct result of this situation, the organisation had implemented concurrent engineering methods in a matrix organisation. The development cycle involved extensive use of prototypes to test the engineering design principles against the manufacturing capabilities. This combined with the early involvement of people across functions, resulted in conflicting requirements being exposed and negotiated early in the manufacturing process, and thus ensuring a short lead time. The short lead-time was necessary because of the market leadership but came at a high co-ordination cost. Project participants spend a significant amount of their time both in meetings and engaged in informal co-ordination efforts.

As a means of speeding up development further the company adopted Computer-Aided Design (CAD) workstations as a replacement for conventional paper-based design. This could, for example, facilitate less uncertainty regarding sub-assemblies and a more rapid transfer from engineering design via process planning into production. The introduction of CAD workstations also created the need for reuse of specifications (Sørensen, 1994; Carstensen and Sørensen, 1996). One of the advantages of using CAD instead of a traditional paper-based system was the improved opportunity of reusing old components in new products or at least reusing the specification of standard components. This could both save time and support standardisation. Standardisation of components and reuse of component specifications across projects was, however, crucially dependent upon distributed storage and retrieval of CAD specifications across temporal and spatial barriers. Categorising a CAD specification would enable one person to store it and another to subsequently find and reuse it. Hence, in relation to introducing CAD, the company developed the classification scheme shown in Figure 2 capturing components and units for all instruments produced. It was ordered in a tree-structure with classes, categories, sub-categories, and sub-sub-categories. There were 16 classes, and approximately 340 different categories, sub-categories, and sub-sub-categories. As an example, class number 5 was hydraulic and pneumatic components, which had 11 categories. One of these was "valves", which had 6 sub-categories and no sub-sub-categories (see Figure 2).

The product classification scheme provided a conceptual structure making it possible for draught-persons and engineering designers to perform distributed storing and retrieval of CAD models. It reflected a common standard for categorisation of the components and units in any instrument produced by the company and can be viewed as the negotiated order of how an instrument could formally be described. The classification scheme was partly paper-based represented on A3 size prints and partly computer supported by an alphabetically ordered list of categories in the CAD system. The classification process was not stipulated in any explicit organisational procedure. The draught-person performing the classification chose the appropriate category from on the printed scheme and subsequently entered it into the data management system by selecting the appropriate category from the list of categories in the CAD system.

Figure 2: The product classification scheme — the different sub-categories belonging to the category of valves, which are of the class hydraulic and pneumatic components. The small fraction of the product classification scheme illustrates the different sub-categories belonging to the category of valves, which are of the class hydraulic and pneumatic components.



Significantly, the initial scheme was designed by an ad hoc group of six people who spent a number of weeks designing it in their spare time outside of normal working hours. The work of determining the categories caused major discussions and even fierce arguments amongst the members of the group. As in the case of the International Classification of Diseases (Bowker and Star, 1991) re-interpreted by Schmidt (1994), use and management of the product classification scheme can be characterised as a struggle of carefully finding *"the appropriate level of ambiguity"*. It was not a primary requirement that *any* CAD specification stored by one person should be easily retrievable by another, rather the idea was to support retrieval of the most commonly used components and sub-assemblies. These components were most often characterised by a very well defined functionality, and therefore the classification scheme was primarily based on functionality. New components and units were constantly designed as a result of technological innovation in measurement technologies and manufacturing processes, at times making it difficult to perform the classification. This did however, not result in constant changes to the classification scheme. Because of the highly distributed use of the scheme, changes had to be negotiated. The categories were from time to time modified, and new categories were added in order for the scheme to represent the type and function of components specified. Changes to the scheme were results of negotiations between designers and draught-persons at designated meetings. The classes and categories in the scheme were based on a mix of functional and geometrical properties of components and units. Some of the categories reflected the practical problems of classifying components. There was, for example, a class named *"other mechanical components and units"* containing categories such as: "*console*", "*plate*", "*cylindrical component*", "*tube component*". This gave the draught-person a means of classifying non-standard irregular components, which otherwise would have been impossible to fit into the scheme. It was however reported by several interviewees, that the people who originally had designed the scheme found it much easier to use than people who had not been directly involved.

4. Codify or Collaborate?

Before exploring the theoretical implications for ICT supported knowledge management in greater depth, the immediate observations concerning the two exhibits are discussed.

Exhibit A characterises an organisation looking for a technical fix. It aimed at resolving the very complex issue of manufacturing process improvement through a fairly straightforward, although mentally complex, individual "knowledge elicitation" process. The process of codifying the complex, distributed and partly conflicting process knowledge was stifled by only being conducted by one person who was not an expert on thermal spraying but an expert systems expert. A hypothetical collaborative negotiation process would have had to take into consideration the different perspectives of people involved in various aspects of thermal spraying, such as robot operators, robot programmers, engineering designers, process planners, quality assurance experts, project managers, etc. As observed, the people in thermal spraying did not work as a community and they did not share a common view. Constructing an expert system would have been an effort associated with great risk, given that the high degree of complexity and the unfavourable environment (Mockler, 1992). The technological solution was attributed too high level of expectations. The knowledge which was to be codified was deeply rooted in human expertise, an expertise that would require significant collaboration and negotiation to even begin to formulate. Had they somehow succeeded in the endeavour, the solution would have constituted a fairly complex knowledge management technology accompanied by a relatively simple organisational solution, in terms of individual members of the process being able to consult the expert system. As far as the participants in Exhibit A were concerned, the problem was purely a technical one. This implied that the solution should be found in the technical domain. Attempts to persuade them that thermal spraying is a socio-technical process proved quite difficult. The attention of the organisation was closely focused on the technical parameters, and a closer inspection of the espoused theories on factors affecting the quality of the manufacturing process demonstrated a rich socially constructed picture of both conflicting and non-technical explanations. This exhibit aimed at codifying and packaging individual, conscious knowledge with the purpose of transforming it via an expert system into objectified knowledge through an objectification strategy for knowledge communication (Scarbrough, 1995; Spender, 1996). The exhibit renders itself relatively easy to be classified as an example of the cognitive model (Swan et al., 1999), as can be seen in Table 2, left column.

Exhibit B demonstrated to some extent radically different characteristics. The problem was relatively simple, i.e., co-ordination support for distributed storage and retrieval of CAD specifications with the purpose of reuse. The problem was addressed by a relatively more complex process of interaction between a group of six domain experts with deep knowldge. These individuals spent their spare time over several weeks arguing and negotiating until being able to present, in functional terms, a theory of what the company was all about. The solution was in technological terms stunningly simple. It consisted of a tree-structure to be used in association with implicit conventions for classifying, rendering the use of the technology reliant on tacit knowledge.

Knowledge is communicated through a combination of objectification through the classification structure and professionalism via the tacit conventions for using the scheme. However, the process that brought about the classification scheme was mainly driven by professionalism in the sense that constant negotiation and discussion were the primary means for bringing about or creating the “packaged” knowledge. In Spender’s (1996) terms, the individuals in the ad hoc group combined their conscious and automatic knowledge resulting in the development of collective knowledge necessary for producing objectified knowledge residing in the classification structure. Exhibit B fits the community model in the sense that the important aspects of the knowledge creation or innovation process were the establishment of a community negotiating the categories and the structure of the classification scheme. Information technology was of course a crucial element, but only in terms of recording the results of the group interaction and as an externally visible representation of the codification of tacit knowledge. Table 2, right column, illustrates Exhibit B according to the community model.

Carstensen and Sørensen (1996) argues that in situations where the complexity of co-ordinating co-operative work activities increase, there is a need for codifying co-ordination knowledge into co-ordination mechanisms thus reducing the complexity of co-ordinating distributed yet interdependent activities. Exhibit B is an example of this, in that it reduces the complexity of distributed storage and retrieval. The classification scheme used in Exhibit B was constantly subject to negotiation, critique and change. Due in part to externally driven changes that needed to be classified, but also because the collective negotiated understanding of the appropriate categories fundamentally changed through the use of the scheme. Without the classification structures and system that was developed, distributed storage and retrieval of CAD specifications, stipulating the co-ordination of work activities, would have relied to a far greater extent on “expensive”, time consuming, interaction amongst people across projects. It could be argued that without interaction and community building no system will successfully address the thermal spraying problem in Exhibit A. It was not a matter of finding the “technical fix” but rather of creating new situational and generic knowledge on the optimisation of multiple parameters. Eventually a system may be able to support the storage and use of the principles governing the quality of this manufacturing process. Initially, however, the most effective way of addressing the problem would be community building and negotiation. We therefore argue that the expert system should be replaced by a system of experts exchanging both explicit and tacit knowledge regarding the dynamics of the rule base for optimising quality. The organisational “blindness” inhibiting the view of thermal spraying as a social process could not be explained by a predominant engineering or technical culture, given Exhibit B also was from the manufacturing domain. However, the organisation in Exhibit A conceptualised the problem as related to improvements of the manufacturing processes, i.e., in terms of Schmidt (1996) co-operative work. Exhibit B, on the other hand, demonstrated improvements in the co-ordination of co-operative work activities (Carstensen and Sørensen, 1996; Schmidt and Simone, 1996). The focus on the technical manufacturing processes, which were deemed very difficult to control to the desired degree, could much easier render a technical solution viable in Exhibit A. The main problem arose when research clearly pointed out the importance of pertinent co-operative aspects of thermal spraying processes. It revealed itself, however, as a highly distributed collaborative effort with individual participants exercising tacit knowledge when engaging in thermal spraying. Exhibit B, however, explicitly concerned the co-ordination of distributed storage and retrieval activities. It was straightforward to conceptualise it in terms of supporting the co-ordination of who was doing what, when and why.

Table 2: Summarising and categorising Exhibit A and B according to the cognitive and the community model (Swan et al., 1999).

Exhibit A: Codifying Thermal Spraying	Exhibit B: Classifying CAD Models
Thermal Spraying Quality Assurance Project. Project aims to overcome problems of quality control within the thermal spraying process	Collaborative development of classification scheme for CAD models. Scheme aims to support distributed storage, retrieval and reuse of CAD specifications.
In the main, the organisation viewed the effort as one of objectively defining and codifying the rules governing the process qualities.	The ad-hoc group emerged informally as a response to the need for reuse of Computer-Aided Design (CAD) specifications when the organisation migrated from paper-based to computer-aided design.
The rule-base specifying the qualitative rules affecting process quality was elicited by the expert interviewing different people in the organisation, reflecting the various roles involved in thermal spraying.	The classification scheme was constructed as collaborative after-hours "skunk works" over a period of several weeks characterised by many discussions and arguments.
Expert system at the centre of the development effort.	*System of experts* responsible for critical aspect of designing the codification of the manufacturing domain in the organisation.
The development of a computer-based expert system technology was a critical success factor	The CAD system support for the classification system was a minor but helpful feature. However, the printed classification scheme was considered crucial.
Project unsuccessful in providing a viable technological solution. It was concluded that due to the individual participants' different and conflicting opinions regarding the rules and the ranking of the rules affecting the quality of the thermal spraying process, an expert system would not solve the problem at that stage.	Project resulted in a classification scheme that was subject to constant debate in the organisation. Characteristically, most critique was voiced by people who had not participated in the design of the scheme and therefore had not had their perspective sufficiently represented.

Swan et al. (2000) highlight three primary concerns: problems of codification and the importance of tacit knowledge; exploitation versus exploration; and problems of supply and demand. Exhibit B clearly illustrates a demand approach especially in terms of the negotiation process, but also to some extent in terms of the use of the classification scheme. The ad hoc group codifying the theory of products produced by the company did so out of a perceived need. No manager told them to participate in these activities. However, it could be argued that the implicit pressure on members of the organisation to use the scheme is slightly biased towards being supply driven. For example, the additional time spent classifying a CAD model would perhaps benefit someone else and not necessarily the person classifying the components. The egalitarian culture in the organisation meant that this was not perceived as a problem. It is, however, still important to clearly distinguish between the development and use of the artefact. The classification scheme was a result of a negotiation process creating or exploring new knowledge. This was codified into the classification scheme which with its tacit conventions for use represented exploitation of the knowledge. As the classification scheme gradually became out of "sync" with the organisational manufacturing reality that it was created from, it was made subject to re-coding through further negotiation and exploration.

Swan et al. (2000) paint a very clear picture of the choices involved in supporting the management of knowledge the strategic choice is between codifying or collaborating. This is both the strength and weakness of the distinction between the cognitive and the community model. Taken at face value, both the cognitive and the community model can provide undesired results. Simply providing elaborate, so called “knowledge bases”, containing vast amounts of information inherently leads to information overload (Hiltz and Turoff, 1985) Supporting the management of knowledge by providing support for networking and interaction communication can similarly lead to interaction overload (Ljungberg and Sørensen, 1998; Ljungberg and Sørensen, 2000).

Clearly the weakness of Exhibit A, the lack of negotiation and socially situated interaction, was exactly the strength of Exhibit B. Had the latter process entailed one person without deep domain knowledge defining a classification scheme, chances are that this would never have been adopted. The cognitive, community dichotomy, however easily alienate the process of codification in itself, rendering the theoretical position in danger of re-enacting the, to a large extent, polemic debate within the Computer Supported Collaborative Work (CSCW) field primarily between Suchman (1994) and Winograd (1994). The debate was centred around the deep contextual nature of human activities and how the mere act of categorising has political implications. Given the increasing geographical and temporal distribution of work activities, and the emergence of information and communication technologies in most walks of organisational life, *there is and will be* an increasing need for computer supported codified automatic and collective knowledge. In addition, there will also increasingly be a need for applying computers in the process of codification. The process of co-ordinating, negotiating and planning work applies recursively to the co-ordination of work (Schmidt and Simone, 1996). Therefore, to the extent that we can reduce the complexity of negotiating where CAD models are located on a computer network, we will perhaps also soon use the computers to negotiate the categories we use when classifying. Communities that only exist virtually and interact through computer-based networks have little other choice. They establish principles and systems for categorising and codifying the world they inhabit (Sørensen, 1999). A process of on-line negotiation has for many years governed the emergence of new Usenet News Groups. By focusing exclusively on the community model, we may overlook opportunities for technology supported implicit codification by observed behavioural patterns. In the case of Exhibit B, categories rarely used could be drawn to the background with occasional votes as to which of the infrequent ones should remain, what new categories could be suggested and which ones no longer were relevant. We could argue that the notion of classification structures as rigidly codified aspects of the world partly could be de-emphasised through the use of ICTs. In terms of Grannovetters (1973) theory on strong ties within small well-defined groups and weak ties between groups, it could be argued that the strength of the classification scheme precisely was the design rationale to enabling a weakening of the ties between people in relation to work around the re-use of CAD models. It reduced the need for establishing strong ties between design teams.

The question is perhaps not as much whether to codify or collaborate, but rather when codifying, accepting the real issues of creating knowledge through translations to and from implicit and explicit knowledge (Nonaka and Takeuchi, 1995). The constant reproduction of the inscriptions in the networks of people and technology never ends, and “for technology, every day is a working day” (Latour, 1996). The careful negotiated balance between human actors and technology in Exhibit B only persists if supported by frequent negotiations and development. Conversely, the complex task of co-ordinating distributed storage and retrieval of CAD models is carefully supported by the classification scheme. Now that it has served its purpose of creating awareness, we may begin deconstructing the good-bad dichotomy of the cognitive and the community model, perhaps by exclusively focusing on establishing a viable position for computer-supported management of knowledge within the community model.

5. Conclusion

People and ICT are increasingly interwoven. Addressing the relationships between people creating and managing knowledge, and systems supporting, facilitating and enabling them to do so, involves complex considerations and difficult design choices. Decisions need to be made with regard to the configuration of manual and computer-based systems as well as careful consideration being given to the balance required for the support for codification and storage with the support for communication, co-ordination and collaboration. Faced with difficult design decisions regarding the support for managing knowledge, simple contingencies and classifications of possible solutions will not suffice. It is not a question of codify or communicate, but of how to provide the appropriate balance. What is needed is a theoretical vocabulary that can assist us in bridging the gap between technical and social discourses. We argue, in an attempt to balance concerns for social and technical issues, that ICT can serve a major role as support technology for the management of knowledge, but that firm conclusions must be based on careful consideration of issues of organising and issues related to: (1) the emergent properties of different technologies; (2) the allocation of functionality between humans and systems and; (3) the design of both manual and computer-based technologies.

6. References

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