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Sharing Expertise: Challenges for Technical Support

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Introduction

Knowledge is an important resource in economy these days. It is typically distributed among different actors and embodied in various artefacts (cf. Saloman 1993; Hutchins 1995; Ackerman and Halverson 1998). So, on the level of national economies as well as on the level of an individual organizations, it is important to find innovative ways to stimulate learning by sharing knowledge among humans. There are mainly two - often intertwined - ways on how to share knowledge. On the direct way, human actors of different kinds of expertise can communicate and help each other to construct new knowledge. On the second, mediated way, the actors with a higher level of expertise can create artifacts, that may initiate and facilitate knowledge construction processes of others.

Humans in need for learning usually face the problem of either finding the appropriate material or the right expert. For tackling these problems, networked computer applications can play an important role. They can support the finding of and the communication with a dislocated expert as well as allow the creation of artefacts, which represent and give access to information with the aim of stimulating learning.

Within the field of CSCW, learning processes in organizations have been studied both empirically and also with regard to the design of information systems (cf. Lees 1997, Stahl and Herrmann 1999, Bierens de Haan et al. 1999, Fagrell et al. 1999). Looking at those design-oriented approaches, the answer garden approach by Ackerman (with Malone 1990, 1994, with McDonald 1996, 1998) is an early approach which tries to bridge the gap between the sharing of learning material and the search for experts.

In this chapter we challenge certain assumptions on which computer support in knowledge and expertise sharing is typically based. We look at two companies that represent opposite ends of the organizational spectrum and show how their work practices prevent the assembly and sharing of knowledge that is key to the company. Our first case study looks at a traditional industrial firm whose physical infrastructure has been maintained for a century. The division of labor involved in plant maintenance within this firm ensures that a comprehensive databank of maintenance documentation would be opposed to the individual interests of most of the involved employees. A second case study looks at a progressive network of high-powered consultants, collaborating virtually. There, a key knowledge domain involves the distribution of expertise, so that the right people can be connected with potential projects. However, here too the wide-spread documentation of such expertise as well as the open sharing of knowledge artifacts that these experts develop would be opposed to the interests of most members of the network, but particularly to that of the leaders. Personal control over artifacts like training materials and over knowledgeable ties to potential consulting partners is considered essential in this business, even within a network explicitly designed for sharing.

Computer support for work – whether in industrial or service domains – is generally conceptualized as a technical problem of collecting all the relevant information in an electronic repository and then making it available for systematic searching and browsing. However, our case studies indicate that such an approach is based on a number of implicit assumptions that are often not valid within the concrete social practices that exist in real work places. For instance:

- Much critical knowledge is never made explicit in materials that can be computerized: e.g., plant facilities are often changed without changing the corresponding blueprints so that only the workers who were involved can recall the changes.
- Data may exist in electronic form but be inaccessible for practical purposes because it was cataloged according to a system that has no relation to potential needs for that information.
- Knowledge of various kinds and local work practices play subtle social roles within the fabric of a company, not just the straight-forward purposes which are explicitly acknowledged.
- People are often only willing to share information based on interpersonal relationships, and with some guarantee that they will retain some ownership of that knowledge, if only in principle.

Such interactions between social and technical considerations present important challenges to the design of computer support for cooperative work. We will discuss these after first presenting our two case studies: a steel mill and a network of trainers and consultants.

Expertise Sharing in Maintenance Engineering

We have investigated knowledge and expertise sharing in maintenance engineering of a major German steel mill in the Ruhr area. The investigations took place in the context of the ORGTECH project (*Organizational and Technical Development in the Context of the Introduction of a Tele-cooperation System in Small and Medium-Sized Engineering Companies*) (Wulf et al. 1999). The project aimed at supporting the cooperative work processes within and between two engineering firms and the steel mill as one of their customers. The two engineering firms take on subcontractual work for the steel mill, e.g. the construction and documentation of steel furnace components. A construction department inside the steel mill coordinates the planning, construction and documentation processes, and manages the contacts with external offices at the steel mill. We have given special attention to a specific problem: finding out about the actual state of a certain part of the plant. Due to the complexity of the plant and its long history of over 100 years, this is a difficult problem. It requires extensive access to documents and drawings as well as to people.

Research methodology

The OrgTech project follows an intervenistic research approach: the Intergrated Organization and Technology Development (OTD) framework (Wulf and Rohde 1995). The OTD process is characterized by a parallel development of workplace, organizational and technical systems, the management of (existing) conflicts by discursive and negotiative means, and on immediate participation of the organization members affected. Within this change processes the question of how to support the sharing of knowledge among the different experts involved in the maintenance of the steel mill became a focus of concern. The results presented in this paper come from a variety of different sources:

- Analysis of the work situation: By means of numerous semi-structured interviews, workplace observations and further questioning about special problem areas, the field of application was examined in a comprehensive and detailed way.
- Analysis of the documents available: By looking at the given documents especially the drawings, system descriptions and literature about the topic, the relevant artifacts were investigated.
- System evaluation: On the basis of task-oriented examinations like usability tests and software-ergonomical reviews, the given systems were examined according to the criteria of ergonomical design, especially with regard to task adequacy.
- Project workshops: During various workshops with the application partners organizational and technological interventions were discussed to improve the maintenance engineering processes.

Field of Application

The Maintenance Engineering Department in the steel mill deals with repairing and improving the plant. It is a distributed process in which different organizational units of the steel mill and the external engineering offices are involved. Figure 1 gives a schematic overview over the maintenance engineering process.

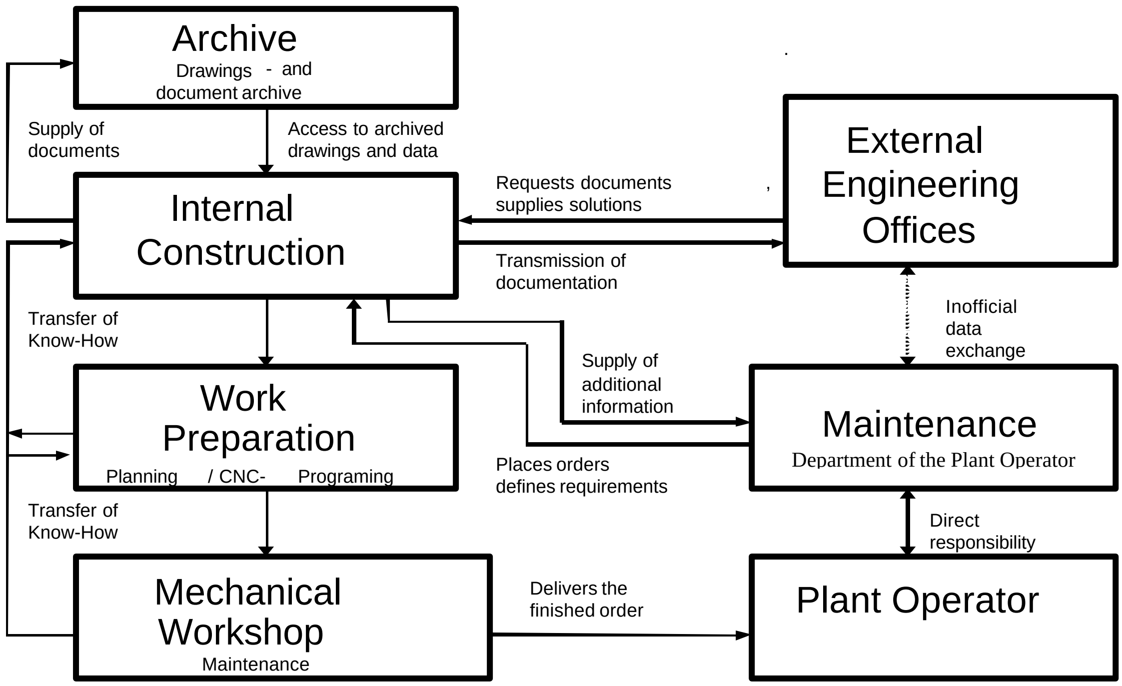

Fig. 1: Diagram of order processing

In general, the starting point for a maintenance order is the plant operator, who controls the production equipment and machinery in a plant and who has to supervise the steel production. When maintenance is necessary, the maintenance department of the plant operator asks the company-internal construction department for further processing. Depending on the type of order and the measures required, the transaction is handled internally or passed on to external engineering offices. An external order will be prepared and surveyed by the responsible contact person in the internal construction department. For this reason, the necessary drawings and documents are compiled and passed on to the engineering office for further processing. Usually, the order specifications contain errors and need further clarification right from the beginning. So, discussions and extensive re-ordering of drawings often become necessary. These have to be expressed in a comprehensive way and have to be returned to the construction department of the steel mill. Once again drawings and documents have to be found, coordination work has to be done and contacts to other departments have to be initiated. This process of reordering requires a high level of work and expenditure of time for all participants involved.

After the external offices finish the construction planning, the internal construction department has to check it, place the new construction plans into the archive and initiate the production process of the spare parts required. Finally the spare parts are assembled into the plant. While this is the general process scheme of maintenance engineering, various sorts of informal communication and self-organized variations of the process can be found and add to the complexity of the problems we will describe now.

In the following we will investigate the problem of knowledge and expertise sharing of one specific aspect of the process of maintenance engineering in detail. In this case, the problem to be solved is to find out the actual state of those parts of a plant which are relevant for a design problem. . For more than 100 years the different plants of the steel mill have been continuously modified, destroyed and replaced with other plants. The knowledge about this process is distributed among different actors in the plant and several archives containing drawings of the plant, which are stored on various media. The central drawing archive contains (cf. Hinrichs 2000):

- about 300,000 technical drawings,
- about 2,500 DIN A4 files with technical descriptions, part lists, statics information and calculations,
- about 500 DIN A3 files with plans of electronic and hydraulic devices.

A large part of these documents is filed in conventional paper form and saved on microfilm. The electronic drawing data consists of scanned drawings, which are saved in raster format (TIF) and CAD data (DWG). The electronically archived document stock contains:

- about 5,000 CAD-drawings,
- about 20,000 raster format drawings and 30,000 scanned drawings on microfilm files,
- about 90,000 documents describing the plant, maintenance processes and drawings.

In order to be able to handle the large number of drawings and documents, in 1995 an electronic archiving system was implemented to archive and provide the technical documentation. This system allows finding drawings by numbers or keywords. Drawings are identified by numbers, which are specified by the filing clerk. For classification reasons these drawing numbers can be allocated to so called basic numbers. These basic numbers refer to plants and components existing within the company. They have been created for accounting and controlling reasons.

The electronic documentation is stored on a data jukebox, which is equipped with magneto-optical disks. Descriptions of the documents are stored on an Oracle data base and may be retrieved via the archiving system (called ADOS) programmed in Microsoft Access. At present, conventional and electronic archiving methods are being used in parallel, since the conversion from a conventional to an electronic archive takes a longer period of time to be implemented. A continuous conversion of all relevant data is aimed for.

Finding out about the actual state of a certain plant in the steel mill is a central problem in maintenance engineering. In our work with the plant operators, we investigated how these problems may be tackled.

Central Repository: The problem of completeness

The information stored in the central archive is incomplete for several reasons. First, there are information losses due to the physical properties of the storing media. Due to the hundred years of history, paper documents have turned out to be transitory. So, a large number of drawings is of bad quality or has to be reconstructed in order to provide the required information.

Second, drawings are stored on different media: paper, microfilms, and electronic storing devices. The drawings contained in the electronic storing device represent only a subset of all existing drawings. In case an information seeker does not find the relevant information in the electronic archive, he has to proceed with the paper and microfilm archives.

Third, the central archive does not contain all information on the actual state of the steel mill. Certain modifications of the state of the plant cannot be found in the drawings at all. When handling accidents, plants may be modified instantly without prior planning and without the creation of any drawing. At the end of a budget year, certain works are carried out instantly to use still available funds of the associated departments. These modifications are typically not documented in drawings either, although they are "known" by the staff members involved. Finally, even well planned and documented modifications of the plant may have been finally realized in a slightly different way than they are documented in the drawings. This can be caused by inadequate plans, which have to be adapted to the given environment. Sometimes the realization is carried out completely disregarding the given plans.

We have discussed different approaches to increase the completeness of the central repository. We suggested to improve the completeness of the electronic repository: all the drawings could be scanned and included into the database. Such an approach would require a high amount of time of human effort. Due to the high costs and the fact that the long-term future of the steel mill is unclear, this option is not viable from the point of view of the management. A more complete documentation of the actual modifications would be possible. However, it would require additional labor and the commitment of the different plan operators and construction firms. In certain cases the lacking documentation reflects missing permissions to do what has been done. In these cases the plant operators and the construction firms are very unlikely to document modifications even if the resources for that should be provided.

Central repository: The problem of categorization schemes

While the electronic drawing store suffers already from lacking completeness, additional problems are due to missing or problematic pattern of categorization. These facts make the retrieval of drawings difficult. The main way to retrieve documents in the database is via their basic number. This classification scheme divides the steel mill into cost centers. It was set up by the accounting department to allocate costs. However, it is not very intuitive to engineers because its concepts do not follow a technical perspective. The drawing numbers, another index, are rather arbitrarily given. They partly represent a temporal order for the creation of drawings. However this order can be pretty distorted because the drawing numbers are allocated to engineering offices when getting an order. Typically the engineers do not use up all the drawing numbers allocated to them for a certain order. In these cases they reuse the already allocated numbers for future orders.

While these categorization schemes by themselves are already problematic, they are not applied consistently. Approximately 20 % of the drawings stored in the central repository do not have any classification; a direct assignment to plants or their location is not stated. Their categorization can only be processed with in-depth system knowledge. Approximately 25 % of the drawings are not categorized according to the correct basic or drawing number or are stored without keywords. Such drawings can only be found by the description used in the ADOS system or are accessible by search via indirect paths (e.g. asking knowledgeable colleagues) only. These problems are mainly due to the fact that the transition from paper to electronic archive had been carried out by an external service provider. For cost reasons students were scanning and categorizing the drawings. These actors had lacking motivation and understanding for the complex categorization task.

Finally, the existing archive system does not offer extended search functions. Drawing numbers and basic numbers (both of which are not self-explanatory) are the main attributes to search for. Moreover, the interface to specify queries is not very intuitive (cf. Hinrichs 2000). So, retrieving documents in the archive database already requires quite some experience.

We have discussed different approaches to improve the retrieval of drawings. First, one could (re-)classify the documents in the electronic drawing archive. Such an approach would require a high amount of time of experts familiar with the particularities of the steel mill. Due to the high costs and the fact that the long-term future of the steel mill is unclear, this option is not viable from the point of view of the management. Considerations to save costs led already to the engagement of the external service provider who did not categorize the drawings appropriately. Another approach could make more attributes of the drawings available for retrieval. For instance, one could apply pattern recognition or optical character recognition (OCR) algorithms on the scanned drawings to make the legend on each of the drawings available for key word search. These extensions of the database scheme would require considerable labor input because it cannot be implemented automatically. Due to the high costs involved, it is not acceptable for the management.

Central Repository: the problem of competing decentralized stores

Due to the problems of the central archive there exist a couple of local archives maintained by the different actors involved in plant maintenance. Drawings are distributed among individuals in the maintenance departments of the local plants. These individuals often have built up their private paper-based archive of those aspects of the plant they are responsible for. These archives contain up to 500 sketches and often occupy several shelves in the offices. Often drawings within these private archives are annotated to document changes in the state of the plant. So these private archives are often more accurate than the central one.

Seen from a central perspective, these paper artifacts are not easily retrievable as they are distributed among various locations of the steel mill. Their owners who also know best how to find the relevant documents regard them as „private“ property.

So the knowledge about the actual state of the steel mill is distributed between different drawing archives and human actors. The workers of the local maintenance departments of the mill typically best preserve the knowledge about the actual state of their plant.

Updating repositories: The problem of inappropriate division of labor

The maintenance of the drawing archive and especially of the database is the responsibility of the archive group. This group is like the maintenance construction department part of the central support division of the steel mill. Between this central division and the different plant operating divisions there is an ongoing rivalry for power and resources. The competition for resources has led to a strict division of labor between these organizational units. Only the archive group has the right to modify the central database. The construction department has to send the drawings to the archive group after their job is finished. Afterwards they have only read access to the central database. They cannot modify missing or incorrect classifications or update documents. The workers in the local maintenance departments, who have built up their own local archives based on paper drawings, do not use the electronic drawing database very much.

The restrictive access rights make it difficult to gain the benefits of a shared repository. Only the central archive group is allowed to reclassify or update the drawings. In case of a more flexible division of labor and corresponding access rights, the maintenance department of the plant operators and the internal maintenance engineers could both update the database. When discussing this issue with the workers of the different plants, they were not very eager to improve a database they have been neither responsible for nor using much. The given division of labor and the existing conflicts between the organizational units prevented activities which would have improved the quality of the central database.

Expertise Sharing in a Network of Trainers and Consultants

In the last section we have looked at an industrial setting where the documentation of the knowledge on the steel mill's state can draw on a long professional tradition of formalizations and categorizations. However, we have seen problems to share knowledge because parts of the data requested and even parts of the shared repository are not digitalized and are distributed among different actors. Now we will look at a setting from the service industry. SIGMA is a network organization of trainers and consultants. This field of application seems to be especially well suited for technical tools to support expertise sharing. The network is equipped with a technically well-working infrastructure. However, our study shows considerable problems when trying to supportthe sharing of expertise technically.

Research methodology

The primary goal of this study was to get to know the pattern and problems of knowledge sharing in SIGMA. In our research, SIGMA serves a prototype of a network organization in which autonomous entities form alliances to market complex services. For this study, we conducted 12 narrative interviews with network members of different kinds (hierarchical level, level of expertise, length of network affiliation). The interviews took between 45 and 120 minutes. Most of them have been recorded on tape. The interviews consisted of a free narrative part ("Please describe your work within SIGMA.") and more focused questions on knowledge acquisition and knowledge transfer in the second part.
The narrative interviews have been complemented by unstructured interviews with key role players (managing director, project manager). Additionally, several regional and administrative meetings as well as several annual meetings of the associates have been observed. The interviews were part in a long term research effort within this network organization (cf. Rittenbruch et al. 1998).
We analyzed the material along three lines of interest: Media used for information transfer and storage, problems seen regarding the organization of information flows within SIGMA, and how new members are successfully introduced into the network standards.

Field of Application

SIGMA is a training and consulting company distributed all over Germany. It is a network consisting of more than 200 entrepreneurs and freelancers which has the legal form of a Limited Liability Company. Apart from a few employees whose work contributes to the infrastructure of the network (e.g. administration and secretaries), the network does not employ members on the basis of traditional labor contracts. Instead, the individual members are freelancers with a variety of payment modes. The "network" offers several financial, infrastructure-related or administrative services to the associates, who in turn contribute 10% of their turnover to fund the network services. Another 20-25% of the turnover have to be given to the "client owner" who established a project for SIGMA. All of the members can offer their skills under the umbrella of the brand "SIGMA".

About two third of SIGMA's turnover (about 10 million US $) comes from trainings. The services cover a wide range of issues from teaching basic computer skills via specialized programming classes to leadership courses. SIGMA's clients range from the labor exchange administration to the upper management of Fortune 500 companies. Further business activities are in the fields consulting and software development (especially groupware configuration and Computer-Based Training applications).

Besides the four managing directors, SIGMA has no organizational hierarchy and understands itself as a self-organizing network. While, there are project managers and regular project members, a network member's position vary over time. The high level of self-organization and the flat formal hierarchy allows SIGMA to act flexibly within dynamically changing markets.

However, despite this value of free self-organization, SIGMA developed some structures within the network. Informal hierarchies are omnipresent and strongly structure the organization and the activities of its members. The four founders of SIGMA are managing directors and represent SIGMA in more general cases. They still have the client ownership of some of the biggest and most important customers of SIGMA. Because of their experience and their familiarity with the network and its members, they are also very important network nodes. Their work and status is usually confirmed by the annual meeting of all associates.

Around 40 network members are "managers", a status which normally can be gained when the turnover of the projects acquired reaches a certain level. The "manager forum" meets four times a year to discuss conflicts as well as more strategic issues within SIGMA.

Other structures developed along geographical and market-related aspects. In some cities members of SIGMA share office space (usually for representation and meetings, not as a workplace; only one office has a secretary), and members with similar business interests united in "business field groups" to coordinate their activities. Sometimes the latter have developed into limited liability companies which now also are nodes in the network. The structure of SIGMA is highly volatile.

Figure 2 illustrates this by trying to give a snapshot of the approximate structure of SIGMA. Germany has been divided into four business areas with one managing director providing as network node for each of them ("west" has been further divided). Member can build "regional nodes/offices", and members group in business fields to coordinate services, which again can also be one important customer or key account. On the right are the institutional members of SIGMA, which are in most cases limited liability companies themselves. The bottom represents the network itself, the members as well as the different service divisions. Some of them also exist in the legal form of a limited liability company. The picture is neither complete nor consistent (e.g. is the regional node in Dresden more associated with the "West2" area then with the "East" area where it geographically belongs to; the managing director of the "South" area decided to establish a Limited Liability Company for this area; there is also a business filed which insists on not belonging to an area), but this heterogeneity is possible and tolerated as long as they do not affect the sales.

From the very beginning, SIGMA tried to maintain the "spirit of SIGMA" as a cultural background of its members, and as a guiding line for newcomers. SIGMA regards itself as a business community open for everyone who complies with the business model and the standards and conventions of the network. The community acts as a network of cooperative entities, which are self-organizing according to market demand and concrete projects.

SIGMA always relied on a common technological infrastructure. In 1995, an "intranet" based on a Bulletin Board System (with a messaging system and file sharing areas) has been introduced, and replaced by a "Lotus Notes"-based Intranet in 2000. Only the intranet server service is included in the infrastructure service of the network, all other infrastructure cost have to be borne by the network members themselves, as are any costs related to training, software and communication (phone/internet). Almost every member of SIGMA possesses a personal computer (most of them with internet access) and a mobile phone.

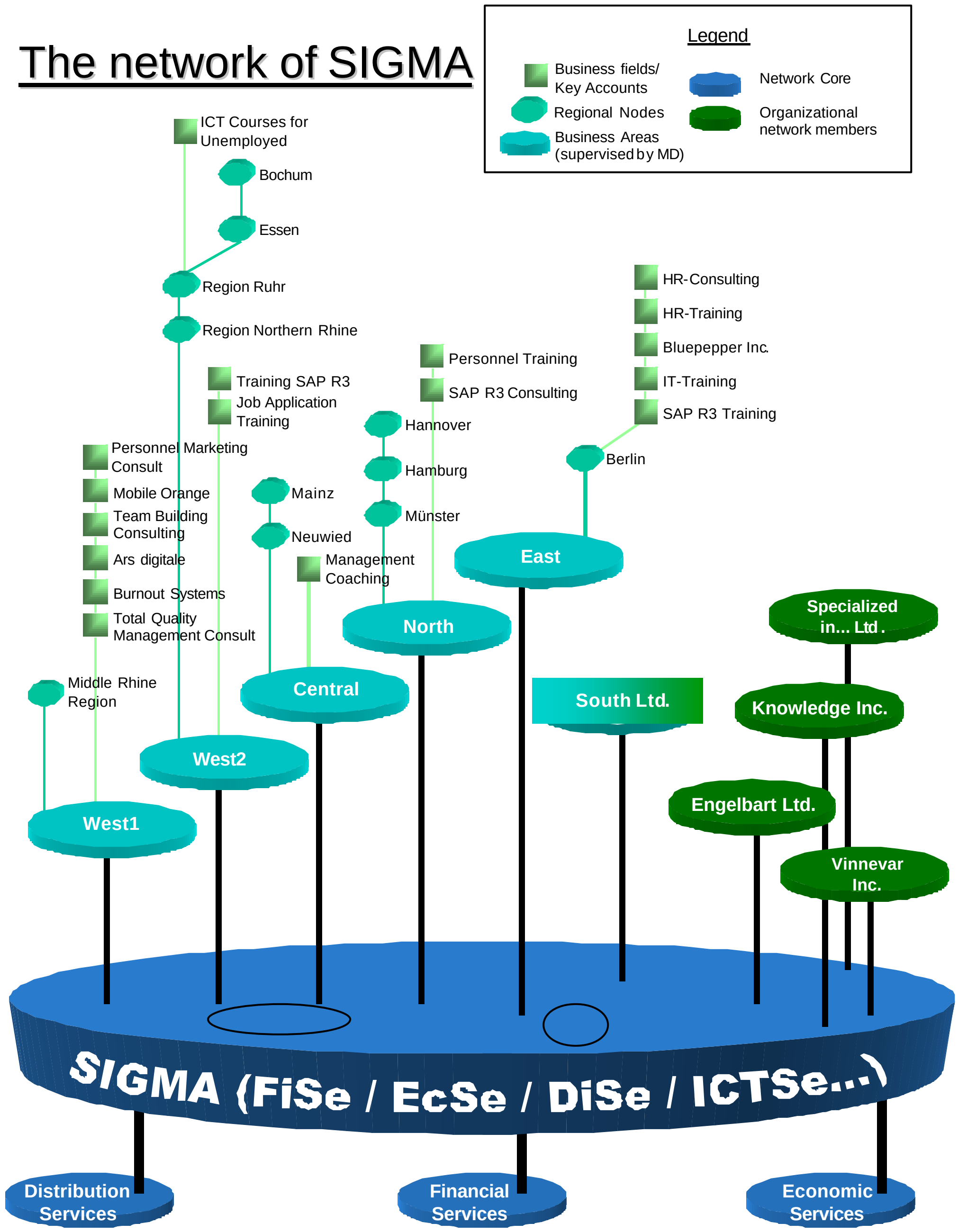

Figure 2: Regional and Organizational Structure of SIGMA

Working with Sigma means to provide one's own workplace, typically a home office with telephone, personal computer, internet access, a variety of software programs, fax and other technical equipment. The overwhelming majority of communication activities happen via (mobile) phones. Email (be it via SIGMA's intranet infrastructure or an external Internet Service Provider) is in most cases only used for document transfer. Fax and Mail communication usually only occurs if legally relevant documents are transmitted. Paper and Folders still are the most frequently used storage media, although personal computers and laptops are very common.

Electronic Repositories: The Problem of Organizational Awareness

When asked whether they would give away (e.g. teaching) material they had produced, almost all interviewees said they would give it to anybody in the network. But when asked for details, several expectations have been expressed concerning that knowledge transfer:

- "I want to know what the material is used for.": This is meant to informally control whether the material is used in the right context and whether some kind of financial compensation can be expected.
- "I want to have feedback on whether the material served its purpose.": This helps the creator of the material to improve the quality of the material or how it can be modified for different contexts.
- "If the material is being modified, I want the modified material to flow back.": This turns the information transfer into an act of collaboration.
- "I want a trustworthy handling of my material.": This especially addresses whether and how material should be forwarded to third parties. Material forwarding is socially controlled. In general, forwarding is tolerated if the author is notified.

Sometimes material is reused by its content, and sometimes only by its structure (e.g. training concepts). Some material becomes a "public good" within SIGMA after some time because it serves as a good example, some material is forwarded with the explicit condition that it is not used or cited literally (usually training concepts and material which have been developed for a client who now has the copyright). And, of course, all this is a matter of trust, personal recommendations and informal guarantees help as well to navigate through SIGMA when looking for material as well as for easily getting it. For all the material it is important that it circulates only within SIGMA. These are not generally "known" conventions. They are not explicit, and all of them have been described by different network members.

For most interviewees it was a conscious decision to be the "portal" of their own information and material. The request for material (usually via mobile phone, material is then provided by Email) was considered as a valuable act of communication and as an opportunity to get news on new projects, rumors and initiatives within SIGMA. The personwho is asked for material gains knowledge on new projects (or new clients) or new persons in SIGMA, since these are the typical situations in which material is being requested (to prepare for a new training). The requesting person can get additional information on how to approach the new project, where to find additional information or material in SIGMA and who can be valuable to talk at regarding further projects.

However, one interviewee thought a repository would be a good idea. This interviewee worked very close to a managing director (and important network node). So requests for material as an opportunity to communicate were not that important to him. Other interviewees clarified that the request for material not only serves this purpose, but also as a valuable opportunity to inform on current events in SIGMA. Additionally, an electronic repository approach would not allow for an access control pattern to teaching material as flexible as the "social control" described in the fourth of the conventions mentioned above.

Expertise Profiles: The problem of Updating

Those network members who are frequently acquiring new projects have problems to determine what competences are actually given in the network (important for not accidentally denying client requests that could be satisfied by means of the network), and who in the network has which competences (important for team composition). Approaches to tackle the problem technically failed.

A "profile database" (in form of an excel sheet) has been issued and re-issued several times. Even when a collaborative effort to produce a current version of the personal profiles succeeded (e.g. on manager meetings or the annual meeting of associates), it soon became outdated because almost nobody maintained his or her profile.

Different problems occurred in an approach to tackle the problem by means of internal home pages. Network members used those for "social communication" (anecdotes, cartoons, links to "fun pages"), although the management planned to make them available to clients, as well. Like the profiles, the homepages were not maintained very well and became outdated soon.
The basic conflict in our eyes is that the business model of SIGMA leaves all the infrastructure work to the individual, who is, on the other hand, forced to be as productive as possible. Maintaining one's profile is not directly productive. Profiles are usually updated when sending a proposal to clients, but the "update" is always very content-specific to meet the information requirements of the client. Together with the high degree of autonomy of SIGMA members, this leads to a low priority for the task of updating the expertise profiles.

Expertise Profiles: Hiding one's own corona

Another problem with explicating expertise profiles is the existence of "colleague ownership". Senior network members with own client ownerships have a corona of network members they conduct their projects with. Many of them have been introduced to SIGMA by the senior network member. They consider this corona to be "their" own human resources. (see paragraph on "mentorship" below). Though the senior member can claim a kind of informal "ownership" for his or her corona, any member of SIGMA can of course autonomously decide whom he or she is working with. However, senior members with bigger clients rely on their local infrastructure. Consequently, senior network members tend to hide the competences of their corona unless there is an explicit agreement on team building priorities.

Mentorship: Participating in a legitimate peripheral way

SIGMA has a mentorship model which intends to familiarize new members with the network. Typically a mentor introduces a newcomer to the formal rules, conventions of the network and makes him meet other members. Although the mentorship model for SIGMA is an "official" model of responsibility of the mentor regarding the new member, its realization often has similarities with the process of legitimate peripheral participation as described by Lave and Wenger (1991). New members work in minor roles in projects together with experienced members. They acquire the knowledge and the skills necessary for working in SIGMA during their time in these projects. Other anchors of introduction are the intranet and – in most cases – different regional meetings, which usually have a formal part and an informal part. A brochure for new members has been produced in spring 2001, it is not yet clear, to what degree it increases the transparency of SIGMA for new members. It seems unclear how technical tools could replace or even augment the mentorship model which allows for legitimate peripheral participation in real projects.

Discussion

Looking at the two case studies there are quite some communalities: expertise shared among individuals plays a crucial role, access to shared repositories is important but insufficient for knowledge (co-)construction, and organizational micro-politics can hamper knowledge and expertise sharing. However, the particularities of the two fields of applications lead to quite some differences in the process of expertise sharing.

Shared repositories

For centuries, engineering has developed conventions on how to represent complex technical facts. Within their professional education engineers profoundly learn about techniques how to document their knowledge in a mutually understandable way. Building on these professional conventions, it is much easier for an organization to build up repositories of shared documents. By contrary in the domain of consultancy there is much less of such (common) formalisms and conventions for documentation purposes. These differences influences the ability of the actors to document and access knowledge in shared artifacts.

We also see differences between repositories in organizations which have a long history and whose history is relevant to current problem solving. Within SIGMA we have an organization which has a rather short history. Many problems of central repositories can be best observed in organizations which have a long history of document-related knowledge sharing. We assume that young organizations may face similar problems at a later stage of their history.

Another difference comes from the infrastructure support the organization offers for the production and maintenance of shared repositories. While the steel mill has created a specific organizational group which documents the knowledge on the state of the plants, in SIGMA there is no central organizational unit to support the documentation and sharing of know-how. In the case of SIGMA this fact is due to the rather low percentage each associate pays for the common infrastructure. As there is no central repository, sharing of knowledge-related artifacts has to happen decentralized between peers. The artifacts are still contextualized by the reference to their producer, and by the interaction which precedes their exchange. In the steel mill, organizational procedures are established which regulate how to modify and to access the information in the central repository. However, the central repository leads to a decontextualization of the knowledge-related artifacts. This phenomenon is increased by the problematic categorization schemes. However, two facts ease the recontextualization of the drawings in the steel mill. The professional conventions ease the reinterpretation of the drawings. Moreover, there is a stable mapping between specific plants of the mill, the drawings documenting the current state, and the maintenance workers who have additional and up-to-date information.

With regard to the problems of classifying and retrieving artifacts in a large shared repository, the steel mill gives an account the of the complexity of the task. The long history of changing classification schemes and the different professional perspectives of engineers and accountants add to the complexity of the problem. The graphical nature of the drawings and the different electronic formats of the drawing let search algorithms to be difficult to specify.

Clearly, the steel mill is a case where not all the relevant material is accurately digitalized. But both cases indicate, that this is not just a legacy issue, but also a matter of work and communication practice within the organizations. Although in both cases evidence exists that improvements are possible (an external engineering office maintains a *complete* archive of its projects done for the steel mill, one business group in SIGMA has built up a repository with restricted access), it also became clear that because of certain aspects of the organizational culture (spontaneity of building in the steel mill, side-benefit of communication among the autonomous actors of SIGMA) there never will be a complete and accurate repository of all drawings or all teaching material.

Expertise Locator Software

The location of expertise is very different in the two cases. In case of the steel mill we look at rather stable tasks and clearly defined responsibilities. Finding the appropriate expert to find out about the current state of a plant does not pose a big problem to the members of the organization. Exception from this rule are newly employed stuff and apprentices who do not know yet the structure of the organization well. So the algorithms and the data necessary to allocate experts in the steel mill can be found rather straight forward. The efforts to maintain the profiles are rather limited, one has to follow mainly job changes within the steel mill. Moreover such a traditional organization is equipped with means to maintain these data. So technical support for expertise location is rather easy to build but its utility is rather limited, as well.

By contrary, SIGMA has a high need for expertise location support. SIGMA's tasks change dynamically, so does the relevant expertise of its members. The mutual understanding of each others expertise is obviously much lower in SIGMA than it is in the mid-size software development organization described by Ackerman et al. (2002, in this volume). We assume that this fact is mainly due to the decentralized nature of the network organization and its bigger size.

(Re-)defining the scheme to describe the expertise profiles is as big a task as updating the individual members' profiles. It is difficult to create a common understanding of the scheme as well as of the individual attributes. Moreover the ongoing modifications require efforts which are not directly productive. Additionally, any explicit model would not only show competence, but also show lack of competence, especially when it would be coupled with a locator system. Both types of information are sensitive and not everybody within SIGMA would like them being published within the whole network.

Shipman and Marshall (1999) described other examples where users do not consider the necessary standardization for ontology building as helpful, Rice et al. 2000 showed in their study of a virtual organization how even simple keyword usage in a collaborative tool of a virtual team degenerated over time.

Right now expertise localization is in most cases a task of social navigation. Asking the colleagues is a desired access control mechanism working in both directions: For the expertise seeker it is important to get informed recommendation where to look further, and for the experts it is ensured, that it is not an arbitrary request, but it comes through selective channels. Another benefit is that this system of expertise location inherently uses up-to-date information. While these mechanisms help contextualizing requests for expertise, they do not satisfy the needs for efficiently building project teams. So software support for expertise location are needed (cf. Ehrlich , in this volume). However, networked organizations pose high demands on expertise locator.

The role of micro-politics

The sharing of expertise is hindered in both fields of application by micro-political considerations. Competition for human or financial resources reduces in both organizations the flow of knowledge. In the steel mill this fact is manifested by the problematic state of the central repository and the non-integrated local stores for drawings. In SIGMA the phenomenon of "colleague ownership" reduces the organizational visibility of certain actors' expertise. The lacking visibility of expertise can be seen as a partial substitute for boundaries derived from formal organizational structures. The coexistence of competition and cooperation ("coopetition", cf. Brandenburger and Nalebuff 1996) may also play an important role in explaining why members of SIGMA prefer to be the portal to their sharable material. In this case they can control the reciprocity of mutual favors much better than by placing all their material into a central repository.

While it is well known that micro-political considerations hinder the flow of knowledge-related artifacts within an organization (cf. Argyris & Schön 1996, Senge 1991), the study of SIGMA indicates that these considerations can also affect the visibility of expertise. The design of expertise locator systems has to take this fact into consideration.

Creating knowledge work support: Awareness for implicit assumptions

The descriptions we gave from our application fields also stress that designers should be cautious when applying an idea to support knowledge work to an application field. Often implicit assumptions of approaches to support knowledge work do not hold:

- Not all of the knowledge artifacts are digitalized (e.g. drawings in the steel mill).
- Not all of the knowledge artifacts can be digitalized (e.g. economic reasons in the steel mill).

- Not all digitalized knowledge artifacts are public goods in an organization (e.g. teaching material in SIGMA).
- Knowledge artifacts which are supposed to represent the current state of a real object or situation (e.g. drawings of plants in the steel mill) do not always do that.
- Work practice and documentation processes (as a process of knowledge artifact creation) are not always coordinated appropriately (e.g. the documentation process in the steel mill does not cover the spontaneous building processes).
- Individually created "private" knowledge artifacts are – though extremely helpful sometimes - not always known and easily accessible (e.g. "private" artifacts in both fields: "local" construction drawings in the steel mill and teaching material in SIGMA).
- Not all of the digitalized knowledge artifacts can be stored in a public repository - even when they are somehow accessible for everyone in an organization (e.g. cultural obstacles in SIGMA).
- Accessing knowledge artifacts via social navigation is not always replaceable by an automatic query-based approach since the "social" aspect of social navigation may be considered too valuable to lose (e.g. communication culture in SIGMA).
- Explicating expertise is not always appreciated in an organization (e.g. in SIGMA, because of organizational and cultural reasons).

We believe that the creation of computer support for knowledge work and expertise sharing is as much a task of organization and work design as we know it already from research in computer supported cooperative work. The discussion of the case studies helps us to find and validate design requirements for tools supporting expertise sharing.

Conclusion

In this paper we discussed the results of two studies of knowledge artifacts and their handling in very different fields of application. On the one hand we had a steel mill with its conservative organizational structures, where we looked at the handling of construction drawings for plant maintenance processes. On the other hand we had SIGMA as a networked community of trainers and consultants, and as an extremely decentralized type of virtual organization, where we observed expertise sharing regarding teaching materials. Our studies address repository-based approaches to support knowledge work as well as "locating-expertise"-oriented approaches and document the obstacles found.

Repositories are not always complete. Economical and cultural reasons may even hinder their creation and maintenance. Examples have been the cost of digitalization in the steel mill, the history of drawing categorization in the steel mill, or the desire for "social" access control in SIGMA.

While, regarding its organizational structure, the importance of "private" knowledge artifacts and archives was no surprise in SIGMA, the importance of the local "private" archives of plant operators and other staff members for the maintenance process in the steel mill was interesting to note. Knowledge workers tend to create their own "memory system", and this can be a valuable (in our case even indispensable) complement to any organizational memory.

This also shows where social navigation is superior to "formal" query-oriented navigation to find expertise. Social navigation also explores those private archives, and it adds context to a request for expertise. This can be advantageous for the knowledge seeker, since he may get help in applying the knowledge to the problem context, and it can be advantageous for the knowledge provider, since he gets information on the context the knowledge is being applied in, and on how the knowledge develops into different contexts. Additionally, the act of communication itself can be considered valuable especially in distributed organizational contexts, since it helps maintaining a picture of the current state of the organization.

For “locating-expertise” approaches we learned, that expertise explication and/or its maintenance is not always welcomed. Individual and organization-wide aspects of work organization complicated approaches to expertise explication in SIGMA.
The results of our studies gave valuable insight on how tightly the functioning of an organization’s knowledge infrastructure and its work culture (practice, tradition and communication) are connected. It teaches us as designers again, that the design of software tools to support knowledge-intensive organizations is always also a process of designing knowledge work.

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