
Draft of “The Strength of Network Ties: Cognitive Centrality and Team Interaction.”

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Abstract

The purpose of the study was to analyze networked expertise, i.e., expertise that arises from social interaction, knowledge sharing, and collective learning within a community of professionals. We examined patterns of knowledge sharing and distribution within and between teams of 120 workers at a Finnish telecommunication company by applying social network analysis and interviewing key actors. Networking practices between the participants were studied by examining to what extent persons provided pieces of advice and new information to each other or engaged in informal interaction or mutual collaboration. The perspective is enriched by interviews that are focused on key actors, e.g., frequently asked team members traced by social network techniques.

The results of the study indicated that the teams varied in terms of cognitive centrality (e.g., producing high versus low amount of knowledge for the other teams) and density of internal interaction (loosely coupled versus intensively interacting teams). The interviews of team leaders and key actors provided rich descriptions of collective learning and, simultaneously, indicated that there was a close association between networking practices of a team and the way the team members themselves understood their team's mission. Both strong and mutual links and a great number of (weak) exchange ties among the professionals indicate their complementary strengths as mediating knowledge in an organizational context.

Keywords: Social network analysis, knowledge sharing, networked expertise, strong and weak links.

Introduction

The problem addressed in our study is the role of networking practices of an organization and the mutual engagement of individuals and teams in these processes. Since utilization of experiences of others could be an important resource of learning, it is reasonable to examine how members of an organization share their experiences and knowledge, how knowledge flows, and innovation and ideas get distributed within the organization. The study focuses on analyzing networked expertise at multiple levels,
i.e., individual, communal (team), and organizational. These levels of analysis are in many ways dependent of each other, and the problems of knowledge management may not be productively solved without taking a broad perspective on the study of expertise.

**Individual Expertise and Socially Shared Knowledge**

In the cognitive sciences, the concept of expertise refers to a well-organized body of accessible and useful domain-specific knowledge which an agent draws upon and adds to, in effectively solving complex problems (Chi, Glaser, & Ress, 1982). Results of expert-novice comparisons have indicated that differences in perceptions, knowledge and knowledge organization are the basic sources of experts' capabilities rather than differences in reasoning skills (Chi, Feltovich, Ford, Hoffman, 1997; Glaser & Chi, 1988; Ericsson & Smith, 1991;). Further, the cognitive concept of expertise does not necessarily entail a special social status as a recognized expert. An actor may be an expert in his or her community even if he or she does not have a very important formal position in the organization in general (Krackhard, 1990, see Stein, 1997 on studying expertise as a social role in a community).

Experts' tacit knowledge cannot be easily explicated or elicited, and this topic is still in need of a great deal of research. According to Nonaka and Takeuchi (1995, 61-70), the key to understanding human knowledge is the social interaction between tacit knowledge and explicit knowledge. Through using metaphors, analogies, and figurative language, various personal hunches and insights may be articulated and new knowledge created. Tacit knowledge is, however, highly automatic and requires little or no time or thought: it is likely to be constrained by local circumstances, and putative knowledge is not always correct (Stewart, 1997). Tacit knowledge is represented in various social practices, methods, and tools. Such knowledge, in general, cannot be taught directly, but newcomers adopt it through participating in expert culture. From this fact arises as well a risk of unreflectiveness, mindlessness, rigidity, and oversimplification associated with the knowledge. Long-term and overlearned practices escape conscious control and may lead to mindless routines and reduction of cognitive flexibility (Feltovich, Spiro, & Coulson, 1997; Langer & Imber, 1979).

Sfard (1998) and Wenger (1998) argued that the development of expertise is not only related to the nature of an individual's knowledge structures but also to that person's access to relevant formal and informal cultural knowledge through participating in an expert community or network. The dynamic development of expertise is fundamentally dependent on participation in an expert culture ("community of practice", Lave & Wenger, 1991; Wenger, 1998) that carries cultural knowledge (formal and informal; non-codified, codified and embedded) of the domain and provides effective tools and practices of cognitive activity. As a consequence, the focus of cognitive research on expertise has moved from examining how individual experts process knowledge to investigating how collaborative activities within an expert community facilitate development of expertise (see Bereiter & Scardamalia, 1993; see also Ericsson & Lehmann, 1995; Ericsson, 1996). A relatively limited group of actors has, in addition, been a focus when studying the performance in situations requiring nearly continuous operational reliability. The concepts of "distributed cognition" (Hutchins, 1990,1991; 1995) or "collective mind" (Weick & Roberts, 1993) are essential, if one is to understand and explain interrelations of actions in a social system, such as navigation teams or flight operations. March (1999b) presented the same kind of vision concerning the
decision making in organizations: the structure of relationships among separate organization units has systemic properties that cannot be explained by relying on analysis at an individual level.

Taking the approach of learning in organizations, knowledge can be built by assimilating it from outside, or creating new knowledge through reinterpretation and reformulation of existing and recently acquired information. Learning does not occur simply because of obtaining additional data and information (Mason 1995, 220-223). Organizational learning does not merely take place through changing actions but also through changing internal structures and information processing procedures (Blanning & King 1995). Following Minch (1995, 80) the important functions of intelligent organizations can be named: 1) a learning function helping to acquire, structure, and integrate organizational knowledge; 2) a memory function helping to access and manage organizational knowledge; and 3) a communication function helping to share knowledge at the organizational level.

Unfortunately learning is often embedded in the repetition of the action itself rather than in consideration of the ultimate consequences (whether the previous decision was good or not). This presumably happens if outcome feedback is slow or unclear. March (1999) has written about how to learn from samples of one or fewer in companies. According to him, the experiences (failures, successes such as "it-almost-happened-situations") could be utilized better. There is not, however, always shared understanding about what distinguishes single informative cases from the others. As a consequence, very different stories may be told about the same events. We may also ask to what extent continuous use of collective or "organizational memory," for example, by repeating the "best practices," hinders knowledge creation. Collective knowledge can be used in various forms: databases, writings, stories, learning histories, and as memories in projects' participants' minds. It comprises the shared beliefs and norms, procedures, routines and scripts as well as the artefacts (Vartiainen, Simola & Kokko, forthcoming).

One of the key questions has become, in which proportions is the knowledge shared and distributed? Innovation and knowledge advancement rely on distributed cognitive resources, emerging through social interaction between the actors and collaborative efforts to advance shared understanding. In a shared problem-solving process, agents who have partial but different information about the problem in question appear to improve their understanding through social interaction. Many problems, which cannot be solved individually, can be addressed by combining limited knowledge and skills of several agents (Hutchins, 1991; 1995; Miyake, 1986; Norman, 1993; Oatley, 1991). However, if there is not enough shared knowledge, the distributed knowledge is not captured.

Groups are often composed of members with heterogeneous expertise so that the group can benefit from a larger knowledge pool than any individual member possesses. Further, there is a growing body of evidence that cognitive diversity and distribution of expertise promote knowledge advancement and cognitive growth, especially in complex working environments. Kitcher (1989, 1993; Dunbar, 1995) showed that division of cognitive labour is an important prerequisite for advancement of science. Distribution of cognitive efforts allows the community to be more flexible and achieve better results than would otherwise be possible. Moreover, groups which consist of members having different but partially overlapping expertise, are more effec-
tive and innovative than groups with homogeneous expertise (Hutchins, 1995; Dunbar, 1995). In order to achieve high-level expertise, individuals in networks should complement each other's skills, yet there must be enough common ground to establish mutual understanding. Shared knowledge may help an organization or its sub-units to reuse knowledge, avoid duplication of efforts or provide them complementary expertise. Such a group advantage can be best capitalized upon if members understand how expertise is distributed within the group. It is essential both that diverse forms of expertise be represented and that members mutually recognize one another's complementary expertise.

Such a group advantage can be best capitalized upon if members understand how expertise is distributed within the group. It is essential both that diverse forms of expertise be represented and that members mutually recognize one another's complementary expertise. Wegner (1987) argued that groups function as more effective memory units when their members learn to know each other's domains of expertise. When new information is encountered, members presume that it will be processed and remembered by a participant who has special skills, interests, or knowledge in that domain. This kind of metaknowledge is an important determinant of effective problem solving. It is knowledge of local knowledge resources that helps members in their information search, storage, retrieval, and management. Consequently, it is typically situated and embedded in the working environment and, as such, not useful outside the organization.

With the metaknowledge or local information about who knows what, the overuse of shared information might be reduced. There is even an assumption that networks fill the gaps of unambiguous information. People use network structure as the best available information (Burt 2000). Even in teams, much of the work is done in non-group settings. Individual workers can, however call other members when needed, if the kind of group knowledge is openly expressed. Being aware of the limits of the team's expertise, group members can also seek it outside the team or organizational borders (Austin, 2000). Knowledge about structures of networks may replace knowledge as such by helping to find relevant information.

If knowledge is distributed, so is information. The unshared information cannot be socially validated if a contributing member is not able to convince others that recall is accurate. A member who communicates unique information may be perceived as more competent, as better prepared for the task, and as having access to valuable resources, e.g., connections with important people outside of the group (Wittenbaum & Stasser 1996). So, only part of the information is available to all members, or it is only partially shared (see Hutchins, 1991). Moreland (1999) argued that groups and teams might have the potential benefit of having diverse and heterogeneous knowledge even if the discussions are likely to be dominated by information that everyone already knows. Shared information thus dominates the discussions irrespective of whether it is the most significant or essential topic. Some groups primarily focus on exchanging member's knowledge and information so they can establish a shared representation of the task at hand (Kameda, Otshubo & Takezava, 1997).

The Nature of Network Connections

Network relations can be studied in several ways, ranging from investigation of overall network properties (like density) to dyad properties (such as symmetry and reci-
The essence of the matter is to see the importance of repeated exchange relations that form the basis of both dyadic (between individuals) and structural (in the company) embeddedness. In order to understand how knowledge is used in organizations, we look at the way interaction is patterned around (=among) the workers. One of the most consequential properties of repeated exchange relations is the strength of dyadic ties, that is, the intensity of exchange that reflects the degree to which a link is significant, stable and mutual.

The structure of knowledge exchange is often a nested one. An information use (missing words) to circulate within a work group more than between groups, within a division more than between divisions and so on (unclear). At the individual level knowledge production as well as innovation diffusion occurs among strongly and mutually linked team members within an organization. Thus, even if information would reach everyone, the fact that diffusion takes time means that individuals informed early or more broadly have an advantage (Burt 1999, 2000; Friedman & Podolny, 1992).

Informal communities of practice have an essential role in knowledge exchange. According to Gear, McIntosh, and Squires 1994), the development of new ways of acting is often connected with informal learning from three sources: i.e., learning from updating knowledge (incidental learning), dealing with unexpected or exceptional cases that do not fit in old views, or carrying out meaningful projects. In many cases, these projects involve many problems and issues that are related to pressures of change, and capture "everything that is in the air". However, it is not only a question of the strong, mutual, and long-standing relations between workers. The weak, occasional, and one-sided information links also matter. The relative importance of strong and weak links, however, is not yet well understood.

Hansen (1999) argued that efficient knowledge creation and sharing is characterized by tight coupling between people from different parts of an organization. Intensive interaction between experts working in different organizational sub-units facilitates productive collaboration because of timely integration of knowledge across organizational boundaries. Granovetter's theory (1973), older and well known, focuses on "strength of the weak ties". According to him, the distant or weak ties are efficient for knowledge sharing because they provide access to information by bridging otherwise disconnected groups and individuals in an organization. Weak links are the key for crossing boundaries between various otherwise separated knowledge cultures. Table 1 presents a summary of characteristics of knowledge exchange associated with weak and strong ties.
Table 1. Nature of Knowledge Exchange and the Strength of Ties

<table>
<thead>
<tr>
<th>CHARACTERISTIC OF KNOWLEDGE EXCHANGE</th>
<th>THE STRENGTH OF TIES</th>
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<tbody>
<tr>
<td></td>
<td>Strong</td>
</tr>
<tr>
<td>INFORMATION FLOW</td>
<td>Redundant and reciprocal</td>
</tr>
<tr>
<td>The nature of knowledge exchanged</td>
<td>Usually complex</td>
</tr>
<tr>
<td>Form of knowledge</td>
<td>Often noncodified or tacit</td>
</tr>
<tr>
<td>Relation to knowledge environment</td>
<td>Context-bound, i.e., a part of a larger knowledge structure</td>
</tr>
<tr>
<td>Type of communication</td>
<td>“Thick” and encapsulated, including chunks, expert terms, and scripts</td>
</tr>
<tr>
<td>Management of network connections</td>
<td>Usually takes up a lot of resources</td>
</tr>
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</table>

Links between team members that frequently meet each other are typically strong. Strong ties tend to mediate redundant information because they usually occur among small groups of actors in which everyone knows what the others know. According to our presumptions, the most essential knowledge in expert networks is mediated through the strong links. Strong links allow sharing of in-depth expertise within a work group but does not provide very much new information because a significant part of the interaction is redundant in nature. It is additive, more than overlapping. In contrast to strong links, weak links, on our view, support functioning of a knowledge organization by transmitting information to and from expert networks. An organization frequently receives new information through weak links, and these links may also mediate relations between different networks. Sparse networks usually have many weak links and nonredundant contacts. Networks with weak links are suitable for carrying out relatively simple, easily describable, and technical tasks. {the technical task would have to be described in some detail to be useful; hence a measure of redundancy. as in a manual from Xerox.} Weakly linked teams are also more likely to search for knowledge outside their existing contacts.

Strong links appear to be essential, by contrast, for transmitting complex knowledge structures or tacit and noncodified knowledge (Hansen 1999; Uzzi, 1997). {yes} According to Nonaka and Takeuchi (1995), redundant connections are very important in the process of innovation because sharing of tacit and informal knowledge is only possible through extended and intensive communication. Knowledge that is not codified or fully documented, or that is dependent of its context, is often very difficult to transfer. {I think the issue is the degree of shared, tacit knowledge. If the sharing is
high, as between two theoretical physicists, then communication can be abbreviated, non-redundant, even with apparent gaps. If the shared area is low, as between me and a physicist, then s/he must explain everything in a highly redundant manner) Any shortcomings in the actors’ willingness and ability to share their knowledge may also cause problems in transfer. The bi-directional interaction characteristic of strong ties is important for assimilating noncodified knowledge because the recipient is not likely to acquire the knowledge completely during the first interaction, but needs multiple opportunities to assimilate it. Problems of assimilation can be overcome only through creating strong links between the actors in question.

The informal network is usually larger than the organization itself. Sparse networks that are characterized by weak links often have so-called structural holes, i.e., disconnections between actors that prevent flow of relevant and meaningful information (Burt 1992; 1999). Structural holes provide an opportunity for creating completely new links that can increase an organization's intellectual capital by bringing together actors from nearby parts of the hole and thereby helping people to become aware of the existence of knowledge and expertise relevant to their work. In such a process, "information gatekeepers," become important, having a crucial role both in intranetworks and internetworks. In many cases, they know how to find information that is relevant to solving problems (Brooking, 1999). Further, the gatekeepers mediate information coming to the organization from the surrounding environment. They provide an organization with access to an extended network (bridging a structural hole) that may be an important resource for learning and knowledge advancement.

Important workers usually hold many different roles or positions, being members of several teams. This kind of structural characteristic of the key persons' network membership is likely to facilitate intensive exchange of information between sub-units of the organization. The present project focuses on examining the role of these kinds of bridging ties between teams or within networks of communities of practice. A special consideration will be given to identify and examine the role of active and knowledgeable workers from whom other workers are getting new information or good pieces of advice and know-how needed in their work.

Hansen (1999) combines the concept of weak ties and the notion of complex knowledge to explain the role of weak ties in sharing knowledge across organizational sub-units. Shared knowledge may help an organization or its sub-units to re-use knowledge, avoid duplication of efforts or provide them complementary expertise. The strong ties that start as nonredundant and weak contacts are likely to become redundant over time. The ties can also break down and reorganize under another structure and new ties may form. Transformation of network ties is not, however, very well studied research area (see Keister 1999).

Strong ties also constrain action more than weak ties. They are associated with reciprocal activity and multi-directional flow of information. Although weak ties may sometimes be reciprocal in nature, they tend to require less effort or energy to take care of than strong ties. Hansen's (1999) findings revealed that weak interunit ties help teams to search for useful new knowledge but impede the transfer of complex knowledge, which tends to require a strong tie between the participants of knowledge exchange. Weak interunit ties appear to speed up the projects when knowledge in not complex but slow them down when the knowledge to be transferred is highly complex. On the other hand, Weick (1976) has argued that organizational entities that are
loosely coupled are more adaptive because they are less constrained by the organizational system of which they are part.

Yet results of many studies relying on social network analysis indicate that weak ties do not provide the same kind of socio-emotional support as the strong ties. Network linkages that are based more on trust and personal relationships (Uzzi's term, "embedded ties") than on exact contracts tell about "doing more than is said in the contract." The economic importance of socially embedded links is not, however, clear and may have both positive and negative effects (Frank & Yasumoto, 1998). The concept of embeddedness has also arisen concerning "thick" information flows with tacit know-how (Larson 1992), knowledge transfer and learning. Uzzi (1997) has described how information transfer in close ties is composed of "chunks" of information that are not only more specific but also more accurate than in other relations. Such transfer consists of composite chunks of information rather than as sequential pieces of dissimilar data (see Ericsson & Lehman 1996; Boshuizen et al. 1992).

Information exchange along embedded ties is more tacit and holistic than along impersonal ties (Uzzi's term of arm's length ties). The embedded ties facilitate effective problem solving by allowing the actors to engage in intensive negotiation and adjustments throughout the process (Uzzi 1997, Larson 1992). Embedded relations, however, may also be restrictive if they provide an access to resources but block activities outside the network. Overembeddedness is likely to reduce the flow of novel information into the network in the case where there are only a few links to actors outside of the network (Burt 1992, 2000).

The nature of knowledge exchanged and the strength of the ties among members of the network are very important considerations. The strong ties represent the reciprocal, redundant and specialized information flow whereas the weak ties guarantee an adequate number of ties with the result that new information also can be captured in the network. To conclude, neither weak or strong links alone lead to efficient networking and knowledge sharing. Both have their respective strengths and weaknesses in relation to knowledge advancement or transfer of knowledge across organization sub-units. The strong ties provide the best net effect in the case of complex knowledge whereas weak ties may more effectively transmit simple knowledge.

The present study relies on social network analysis to make visible the structure of the organization's communication and the nature of information flow. Social network analysis is a collection of techniques that are focused on uncovering the patterning of people's interaction. It provides relational information on participation; i.e., patterned sets of connections. It is especially designed to facilitate the analysis of structural data (Scott, 1991; Wasserman & Faust, 1995). Standard statistical methods, in contrast, provide information about attributes of individual actors rather than relationships among actors. As the relational aspect helps us to understand the social prerequisites of knowledge sharing and show the concrete information flow, the attributive data indicate the characteristics of individual workers.

**Research Aims**

We have simultaneously analyzed an individual's and group's networking practices. Studying the relations among participants appears to help better understand and explain collaborative processes that affect the individual participants as compared with
individual assessment. The questions addressed at the organizational level were, how intensively did employees of the company engage in certain kinds of interaction (density of interaction) and, whether the participants' interactive activities were dominated by some particular workers or teams (centralization of interaction). At the team level we asked how the knowledge is distributed within and between teams. We examined the role of each team within the organization by assessing its cognitive centrality, i.e., to what extent other teams relied on knowledge produced by the given team, i.e., What was its advice size? We expected that a cognitively central group would play a pivotal role in the organization more often than the cognitively peripheral one. We also assessed the relative importance of weak and strong ties within teams. Accordingly, we assessed how often knowledge is shared along strong (bi-directional links between workers in several questions asked) and weak (a great deal of asymmetric links only in some questions asked) ties. Further, team profiles were enriched by asking whether the teams were sharing diverse (non-overlapping) knowledge resources and work functions or if the action was based on homogeneous and shared (overlapping) expertise and work tasks. Team leaders are also asked to give some examples concerning joint learning in the team. Finally, we interviewed team leaders and certain key members (members who were in a central position of the participants' network of being asked advice) about their beliefs in the development of expertise and the importance of knowledge sharing.

Method

Participants

The study took place in a large Finnish telecommunication company. Out of the company's 500 workers, 120 participated. About 27% (n=32) of them were females and 73% (n=88) males. The participants represented 10 teams that belonged to three departments and formed one process delivering a particular kind of client service. About 65% (n=78) of the participants represented commercial and technical custom work, 13% (n=16) management services (administrative), and 22% (n=26) technologies.

The study was carried out as a part of organizational development project on facilitating teamwork. The intervention focused on educating teams and team leaders on issues, such as knowledge sharing, team work, intra- and inter-organizational networking and so on. The intervention aimed at developing between- and within-team interaction as well as identifying various kinds of team competencies, increasing awareness of the competencies, as well as making them more well known for the other teams. In addition, we examined knowledge used by teams, and information flows within and outside the company. The data were mostly collected near the end of the project. One main goal has been to utilize the results as a part of the project, by discussing and asking about knowledge sharing together with the workers and team leaders especially and informing them of our findings.

Data Collection

The data were collected as follows: We presented a respondent a list of the names of all his or her fellow workers, and asked him or her to assess how intensively he or she is interacting with each of them. In other words, the questionnaire provided the participants a matrix to be filled. The left hand column of the matrix consisted of the list of
names of the participating workers ordered alphabetically, department by department. The participants were asked to assess a) to whom they go for advice; b) to whom they go for new information; c) with whom they have informal discussions and, d) with whom they carry out their most important collaboration (see appendix 1). The response rate of the study was 88%. The responses of the participants returning the questionnaire were, further, symmetrized, i.e., the networking connections of persons who did not, for one reason or another, return the questionnaire were assumed to correspond to the responses of participants who returned the questionnaire. Responses of a person who did not return the questionnaire were, in a sense, estimated by assuming that the responses would be symmetric to those of their fellow employees in networking connections with them. The response rate was high enough to allow this kind of operation. Due to the relational nature of the data, there really was not any other way of solving the problem of a few missing responses without losing a major part of the data (e.g., also the incoming links from the respondents to the missing persons). By following the present procedure, the missing links were mainly between the employees who did not respond to the questionnaire. In that way, the data still consisted of the responses of all the 120 workers.

**Social Network Analysis**

Social network analysis is a method of investigating the structure of organization's knowledge networks. We studied information and knowledge exchange for its density (how often information flows between actors) and centrality or centralization (whether there is an actor who is more important than the others or whether there is someone who does not get any information at all). So, the data consisted of the links between actors, indicating who engages in certain kinds of interaction with whom. The concepts of density and centralization refer to the various aspects of a networked environment. Density describes the general level of cohesion, whereas centralization describes the extent to which this cohesion is organized around particular actors (Scott 1991, 78-93).

We have mainly used Freeman's degree to measure the network activity of individual actors. With this measure it is also possible to use asymmetric data (such as addressed versus received connections). Further, the QAP -correlation was used to analyze whether the four matrixes/networks examined (providing advice, new information, informal interaction, collaboration) could be combined or summed up for further analysis of strong and weak ties. Social network analyses were performed with the Ucinet 5 program (Borgatti, Everett, & Freeman, 1999).

**Interviews**

All team leaders (10) were interviewed, as well as the most central members of each team, selected by relying on the results of social network analysis. In addition, long discussion sessions with the personnel manager was recorded on audiotape. Altogether, we conducted 21 interviews. The interviews focused on topics, such as collective learning, information seeking, and networking practices. However, the experts were also encouraged to describe the knowledge sharing practices of their teams outside the agenda. The tapes were afterwards transcribed and the material was jointly studied. For the article, the interviews provide practical examples, explanations and confirm the analysis carried out with the social network analysis.
Results

Relations between Teams at the Organizational Level

To begin the analysis, the density and centralization of the knowledge exchange network were measured in the entire client-based process formed by the participating teams. We analyzed the network regarding providing advice, sharing new information and informal communication as well as collaborating.

The simplest way to measure the density of a network is to compare the observed interaction (who is connected to whom) to the most intensive interaction. So, the density of the network is the total number of ties divided by the number of possible ties, and it can vary from 0 to 1. The more actors are connected to one another, the denser the graph will be (Borgatti et al. 1996b, 78; Scott 1991, 74). It is also possible to examine the extent to which a whole graph has a centralized structure (Scott 1991, 92-93). The results can be interpreted so that if there would be one extremely central worker to whom everyone else would be connected, the graph centralization would be 100%; or if all of the workers would equally have ties, the graph centralization would be 0%. Here the centralization values are calculated separately for outgoing ties reported by the workers themselves (outdegree) and incoming ties reported by their fellow workers (indegree). In Table 3 one can see the results of the density and centralization analyses.

<table>
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<tr>
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<th>Density (Sd.)</th>
<th>Centralization</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>In</td>
</tr>
<tr>
<td>Advice</td>
<td>0.24 (0.43)</td>
<td>34%</td>
</tr>
<tr>
<td>New information</td>
<td>0.18 (0.38)</td>
<td>33%</td>
</tr>
<tr>
<td>Collaboration</td>
<td>0.10 (0.30)</td>
<td>25%</td>
</tr>
<tr>
<td>Informal communication</td>
<td>0.24 (0.43)</td>
<td>25%</td>
</tr>
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</table>

The results indicate that giving advice is, together with the informal relations, the most common way to interact among workers. A somewhat less dense network is observed as new information is mediated. As expected, the collaboration network is the thinnest of all. It is understandable that a long-standing and mutual co-operation takes more resources than, e.g., an occasional advice giving. None of the networks of incoming ties (advice, new information, collaboration and informal relations) were especially centralized. Though, giving advice and telling new information was more centralized than maintaining collaboration and friendship (informal) networks. On the contrary, the outgoing links (outdegree) were somewhat more centralized. This result indicates first of all that workers have different criteria for reporting their ties. This
can be particularly seen in looking at the advice network: some workers reported considerably more connections than the other workers have done.

To examine whether the previous networks (advice, new information, informal relations and collaboration) can be seen as properties of the same dimension, the QAP-correlations were computed. The QAP correlation procedure is principally used to test the similarity of networks. The algorithm first computes Pearson's correlation coefficient between corresponding cells of the two data matrices. Then, it randomly permutes rows and columns of one matrix and recomputes the correlation. The latter step is carried out 500 times in order to compute the proportion of times that the correlation based on random permutations is equal to or larger than the observed correlation calculated at first. Table 4 presents the correlation calculated for every pair of matrices.

Table 4. QAP-correlations: The Similarity of Advice, New information, Friendship and Collaboration Networks

<table>
<thead>
<tr>
<th></th>
<th>Advice</th>
<th>New Information</th>
<th>Informal Relations</th>
<th>Collaboration</th>
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<tbody>
<tr>
<td>Advice</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New Information</td>
<td>.72***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Informal Relations</td>
<td>.60***</td>
<td>.67***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collaboration</td>
<td>.40***</td>
<td>.40***</td>
<td>.41***</td>
<td></td>
</tr>
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</table>

*** The percentage of random correlations that were as large or larger than the observed correlation was 0.0%.

The results indicated that the networks correlate very strongly, and thus, they can be seen as the properties of the same dimension. So, it is reasonable to add the matrices to examine the weak and strong ties among workers in later analyses. The mutuality and the value of the cell (how many times the relationship is confirmed in these 4 matrices) express the strength of the tie between two workers. So, this number varies between 0 and 4 in the asymmetric matrix and between 0 and 8 in the symmetrized (the sum of the both side of the asymmetric square matrix). If none of the workers reported the relationship, there is no tie, and the value of the cell is 0. If both of the workers reported the relationship every 4 times, the value is 4 in asymmetric matrix and 8 in the symmetrized matrix.

Using the density values inside each team and average centrality values of the team members, we get information concerning how often advice, new information and collaboration are provided to the rest of the organization (centrality) and how often the knowledge is divided inside the team (density) (see Figure 1.). The results indicate that the knowledge-exchange profiles of teams differ considerably from each other. Although some of the teams do not densely share knowledge (e.g., Teams 2 and 5), others share but do not so eagerly provide it to other teams, or the information is not greatly desired (e.g., Team 9). On the other hand, the knowledge exchange is at low
level measured with both of the aspects (sharing and providing, see Team 7) which indicates a weak team culture and at high overall level in the case of some teams (see Teams 6 and 10). The rest of the teams are situated at the middle of the figure and are not so much distinguished from the other teams.

Figure 1. The team profiles and knowledge exchange

We continued the results analysis by focusing on teams that diverged from each other in terms of cognitive centrality and density. These teams (Teams 5, 6, 7 and 9) represented the corners of Figure 1. Our aim was to examine more closely the team’s strategies of building either on shared (homogenous) or distributed (heterogeneous or multiple functional) expertise.

Further, MDS analysis was performed in order to examine whether members of the teams shared knowledge between one another. MDS examines relational data in terms of space and distance (Scott 1991, pp. 151-156). The intensity of connections was represented in the measure [degree] of closeness: the more networking connections there were between the participants, the closer they are situated in the MDS map (see Figures 5 and 6).

The analysis is calculated with a symmetric matrix in which one-directional (A-> B, B-> A) interactions are summed up. In addition, the MDS maps represent strong links between the members of the team, i.e., links that are bi-directional in nature (in a bi-directional link, both parties acknowledged the relation).

Figures 5 and 6 describe patterns of networking within teams 5 and 6. In the table, we show, for each member, his or her number of advice recipients (i.e., Freeman's degree or cognitive centrality) that represents the number of persons who acknowledge being
given a piece of advice. The maximum value of the number of advice recipients is the number of members of a community minus one (120-1).\(^1\) Participants of these teams are cognitively rather central and have rather high advice-size, being experts of their fields.

![Figure 5. Patterns of Knowledge Sharing in Teams 5 and 6 (based on multi-dimensional scaling)\(^2\)](image)

From the figures, one may infer that there were much more stronger links in Team 6 than Team 5. Also the group cohesion is higher for Team 6. One of the participants of Team 6 is a little bit separated from the others. It appears to be typical of Team 5 that the participants are functioning as individual experts who are providing a great many pieces of advice members of the organization but are only in very limited interactions with each other. They are technical experts that come from "the old school" and are not too motivated to work closely or share their knowledge with the other experts (who represent different fields). Team 6, in contrast, appears to represent a modern team in which people are asked to (and do) collaborate very closely, share knowledge and deliberately try to cross boundaries between their professional fields.

**Strategies of Sharing and Distributing Expertise at the Team Level**

The teams that are most different when one looks at team interaction and cognitive centrality were compared to see their profile of networking practices. The average centrality values in providing advice and new information as well as maintaining collaboration and informal ties are presented in the Table 5. Further, the centrality value of all incoming ties and all outgoing ties, and likewise the average value of strong ties are presented in the table. The differences between the teams were analyzed by using the one-way ANOVA test.

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\(^1\) It is assumed that one cannot advice him- or herself

\(^2\) Note: The relative location of participants is determined according intensity of their networking connections; in the figures are represented strong (i.e., bi-directional) links between participants by lines; the advice-size or cognitive centrality of each person is represented by a numeric value that tells how many member of the organization ha asked advice from an expert.
The average centrality values of the four selected teams are presented in Table 5. As expected, there are differences between the teams. The results indicate the characteristics of the teams with different profiles. Teams 5 and 6 are most different from Teams 7 and 9. The number of strong links is especially high in the case of Team 6; the number indicates the maximal team performance in terms of providing knowledge to the other teams. The "advice size" of it is high indicating that it provides lots of knowledge to the rest of workers. It also has cohesive team culture (compare Figure 1.) The differences are lowest in cases of informal ties and collaboration. The relative importance of providing advice and new information appears to distinguish Teams 5 and 6 from the others. Teams 9 and 7 remain at a considerably lower level. Team 9, however, provides more advice and new information throughout the organization than Team 7, whereas the Team 7 has more informal ties and collaboration partners than Team 9.

The results indicate that teams' own networking activities have a important role in the organization. Teams 5 and 6 that were often regarded as important partners in networking activity, were also themselves engaged in their own networking activities (out-degree values). They were not just popular and frequently mentioned by other teams (in-degree values). The results, thus, equally emphasize the role of the weak and strong ties, or, in other words, activity and popularity.

<table>
<thead>
<tr>
<th>Team (n)</th>
<th>Average value among team members in the selected teams (Mean /SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Advice (in)</td>
</tr>
<tr>
<td>Team 7 (11)</td>
<td>12/4,8</td>
</tr>
<tr>
<td>Team 5 (7)</td>
<td>32/14,1</td>
</tr>
<tr>
<td>Team 9 (7)</td>
<td>21/7,5</td>
</tr>
<tr>
<td>Team 6 (9)</td>
<td>34/14,1</td>
</tr>
<tr>
<td>F values²</td>
<td>F(3,30)=</td>
</tr>
<tr>
<td>1) The in-degree values are calculated by using a symmetrized matrix (n= 39) whereas the out-degrees and strong links are calculated based upon the original matrix where the number of cases is lower (n=25). This procedure was selected because symmetrization would have provided a biased description of the role of strong links.</td>
<td></td>
</tr>
<tr>
<td>2) *** p&lt;0.001, * p&lt;0.05</td>
<td></td>
</tr>
<tr>
<td>3) Concerning post hoc tests (LSD), the p values are only reported at the 0.05 level. In the networking relations concerning advice (in) and new information (in), Team 5 differs from Team 7 and Team 6 differs from Teams 9 and 7. In the case of informal (in) relations Team 5 differs from Teams 9 and 7, and Team 6 differs from Team 9. In collaboration network, Team 6 differs from Teams 7 and 9. Measured with all out- and all in-relations, Team 5 and Team 6 differ from Teams 7 and 9. Concerning the network of the strong links, Team 6 differs from Teams 7 and 9.</td>
<td></td>
</tr>
</tbody>
</table>
Participants' Beliefs in Teamwork and Knowledge Sharing

The above results indicate that there were substantial differences between the teams that were selected for further analyses. The interviews of team leaders provided evidence that supported the above results regarding the nature of differences between the teams. The leader of Team 6 (with much shared and distributed knowledge) described the knowledge sharing (not knowing about the results reported here):

"Our team is a very collaborative one, and everyone is, by and large, able to do a share of each other's work, so that if needed ... everyone should be able to do everything ... Is everyone able to master all kind of things? ... ...I don't think there is any who wouldn't do it. The other can do it better than the others. This is not so difficult. We are using only two technical environments ... it is not at all too difficult to learn them both ... it is more a question of the time -- that we have not had an opportunity to teach more. This has been the most important thing."

The leader of Team 5 (with little shared and much distributed expertise), in contrast, saw the situation in a different light. He explained why the work was distributed rather than shared in the following way:

It would be a pretty amazing person who would be able, truthfully, to tell us he can master anything ... I say that here, one is confused [at a loss] all the time, so you need to educate yourself all the time just so you could keep up [in your own field], and know where we are going. We have quite a strict division of labour because in our team there are professionals of certain fields; so, in principle, work tasks cannot be shared. If one person represents a certain field, another does not have mastery of these issues and cannot deal with them. Only this customer service [has less strict division], in that we can be a little bit flexible so that one can take care of another person's work.

...we have so many workers who have come into the 'house' in the 1970s. They are so fixated on the routines that it is very difficult to make it [the work process] different, to change direction. If they have told you that they are going to do certain kinds of things [work activity or tasks] or that it is not their business to do something, then it is so [in their view, and one can't argue with them]. Why do you think that it is so? It is an attitude, old habits ... They just cannot be flexible because previously they did only that [routine] sort of thing and did not have to do anything else.

Can you see this [rigidity] clearly in your team? Yes, you can see it clearly. Of course it may vary from one case to another, so that it is not always too much. ... Sometimes it is all right. Sometimes it is not ... If we had that sort of common task, that every-body would be packing up some box and working with the same task, it would be easy to make certain type of [coherent/uniform] team ... However, we are involved so much in different activities that it is very difficult to create such an interchangeable role. I do not have much to ask from members of the team because I know that they do not know anything whatsoever about the particular thing I would ask. In contrast, I do not have any knowledge of things the others might ask me. We do not have such communi-
cation between us. We are communicating with people from production, we have much more to do with them than with each other.

The multiple functions and distributed tasks of the team were described in the same way by another professional of the team who was frequently asked for pieces of advice:

We don't really explore anything together in the team. I am a lone wolf and work with my own tasks. The other members of the team are not aware of what I am doing ... This does not bother me and it is not going to. I work and do things alone, so that we are not really working together as a team. Otherwise it [the team] is working well, but I don't understand what they mean by the concept of team! We have always had one ... I guess that they know me mostly by my own name rather than as a member of this team.

There were efforts to share the technical knowledge but as one professional told us:

"The structure of the technical equipment is so complex that we always come back to this situation [of division of knowledge]. The work environment is determined because of the division into parts. It is always there."

Team 9 (with much shared knowledge) informed us, as one might expect, that expertise is very strongly shared within the team: the only exception is a specialist in a certain technical environment. The goal of the team, however, has been to divide even this part of their activity equally among the members. A member said,

“Actually a major part of our work [is shared]. Then there are some things that only some one or two people are responsible for. It was formerly the case that Mary, alone, had a lot of this kind of competence, related to the technology we are using. But now we have been trying to acquire it; now she teaches those things piece by piece ..., the things that the others have not mastered, she has gradually been teaching these to the others.

As the previous discussions focused on kind of practices of team culture either shared or distributed, the last team with low information flows and obviously weak team culture differs from the others regarding words, too. The leader of Team 7 reported on his work as a foreman. He could not see the difference between collaborative teams and the old idea of working together. Yet, he saw it as a problem that his team does not meet often enough:

I have, I have ... a great deal of experience as a foreman. I have been a foreman more than 30 years. I have only worked in this position ... It is not a new idea to ... that people work together in a group and be jointly responsible of the work. We [members of my team] have the problem that, [in general], we do not see each other very often; as a consequence our communication takes mostly place via email. In spite that, I myself see everybody [in person] because I am there every day. I have tried to visit; rather frequently, I visit the place [the front-line place in which their work takes place], so that I actually, that my work takes place in face-to-face discussions; so I use email relatively little, but I do use it.
All of the teams were also asked to tell about their workplace communities, whether they have joint habits, a special kind of language or other cultural practices of their own. One of the team leaders recounted:

*Yep, we have shared ways of speaking and our own special terms. Many customers are so-called regulars, and we have certain nicknames for them, so that only we know about whom or what we are talking.*

For most of the workers, the team culture was taken for granted: One person said, "I suppose that every team has its special characteristics, its own sense of humour and system. What [team] would not have it?" But all of the participants did not understand the question [about team culture]. One of the less interacting team leaders asked:

*"No, I don't understand what it [team culture] could be, a hug for everyone on the morning, or what?"*

The other expert commented, "There is nothing peculiar or special in the way we talk to each other. Just normal talk." Nevertheless, team culture was mentioned several times during the interviews. Having team spirit was, for example, said to be shown in providing help and correcting mistakes without someone having to ask you whether you would mind doing it: "It is self-initiative, providing help when needed."

A densely or tightly connected team is, however, not always a good team. Neither does the "spirit of the team" necessarily facilitate learning: strict norms and control may also cause anxiety for some members. Being outside of the in-group is harder in a densely-connected team than in a loosely coupled team. One professional who felt herself to be an outsider in spite of her strong expertise, said:

*Our team's sense of belonging together is not the best possible. Sometimes a picture is presented [by someone] that we have always been a team and it goes well, but it is not so. People are given that sort of impression, and many persons in our workplace believe so, but it is not true. How do you know that? For example, people are not taking responsibly for work where there is the pile of unfinished tasks. When you try to guide, there is no willingness to learn. Even if we are organizing some kinds of recreational activities, not all members of the team are always informed. Sometimes if you happen to be on a lunch break, and they chat about something together, agree about something, you might be completely left outside when you come back. Ou what, See what we've decided we're going to do, they say. This has [already] been agreed ... we suffer, we others in there. It is not personal, it is only the team. It is not workplace teasing or anything like that.*

The loud and noisy way of talking between team members was not experienced negatively by team members. About the good spirit of Team 1, one of the members said, "It is so that if an outsider listens to us [conversing], there is terrible screaming and noise, commotion, and it may sound like we are barking at each other. But everything is like that, it [noise] is a part of it [our work process]. Maybe our way of using language may sound hard to a woman's ear. Everyone knows, however, that it is never at the personal or individual level, it is just general way of mouthing off."
A special characteristic of Finnish culture is to have joint "sauna" (bath) evenings among the team members. As soon as a person has participated in a sauna evening, then he is accepted/admitted to the group, as often stated in the participants' interviews. The participants proposed a "sauna indicator" of team spirit according to which a team was working well when 75% of members participated in sauna evenings.

The material provided some useful descriptions concerning joint learning. Team 9's leader (with much shared knowledge) described their activities with the following words, everyday and familiar in many working places:

_Sometimes it happens that someone calls out: "Hey, come and look, it [the task] can be carried out in this way." Then we go to the computer [to look at some new thing]. When we study these computer runs, we realize someone is able to do it, and we may say: "Hi, let me see it! Oh, that's the way you do it ... So, the practice itself seems to be our main teacher ..._

The team with only low team cohesion had the same kind of perspective on joint learning:

_Our whole work process relies on joint reflection. ... Someone takes a course and the information is distributed or spreads; or we study together. We might have a piece of new equipment, a manual; and we may know the principles and start [exploring] from there. We are looking into the things that you cannot learn from training. You have to call to those producers... To study is to test in practice. You can't just listen...._

...You always have to go and look at the screen ... what the others are doing ...

The teams with multiple functions and distributed technical environments had also experienced situations of joint problem solving:

_We learn through the problems ... When there are problems, if someone informs us that something is not running OK, or something like that, we put our heads together and reflect among our group why it is not working ... then we try to explore, measure, --- ponder and examine all those pieces of equipment that appear to matter ... and read the standards and all kinds of documents..._

To enrich our perspective with some more questions we examined the individual level.

**The individual level**

By interviewing key members of the teams we sought to deepen our understanding of the nature of the participants' expertise. We selected for interview 10 most frequently chosen (i.e., the highest number of in-degree values in social network analysis) employees, one from each team. They were asked about the skills and competencies that are needed to become an expert, the practices of teamwork and knowledge sharing in their own teams. They were also asked about the education and work experience they had, and requested to give an assessment whether it had turned out to be adequate. The participants were not told why they were selected to the interview.
The qualities needed in expert work were frequently said to be cognitive characteristics like the memory and somewhat broader learning skills:

First of all, I have that sort of head ... it is easier [to learn] when I am shown things, and see how it is done. That way I remember it best. But if I had to read it from paper, it would not be so easy. You see, I can get the things just by remembering them.

memory skills ...the work is often based on good memory and good learning skills, active ... ... interested in matters and things, willing to learn to understand the new things...

Cognitive memory load pressures frequently reported by the participants appeared at least partially to arise from the high proportion of noncodified information. The employees explained that because of manifold information and variations, it is difficult to create any procedures and the work is "just to play with the lots of paper slips hanging all around."

Social skills were mentioned frequently, too. An expert stated that it is important that "an employee ... is able to co-operate and willingly works well with the other workers ... is a person who does not seclude themselves from others...." Moreover, he or she should be "eager to inquire after information, it is just the interaction ..." Concerning the other personal qualities, being alert or eager to catch always the newest information and self-help were on hand. The following characteristics of a good expert were also emphasized: "Good tempered (does not get angry or frustrated too easily), cooperative and willing to collaborate. "In our team, a good expert is who masters all of the things that there are [to master]. Nobody is able to do it [completely] just now."

When we asked further about situations closer to those of working life, in which learning is advancing, new information, exceptions, and problems were highlighted. Functioning in rapidly changing areas and working with very raw and not properly tested products, were often reported to be very challenging.

"there is so much inaccurate information and [so many] mistakes that it makes the whole stuff [work, tasks] difficult."

There is a lot of that we have to fight all day long ... even if manufacturers claim that this works; a piece of equipment may only work in certain environments. So when we implement or insert it, it does not function properly. We go back and inform them that it is not working even if they promised that it would ...This is not happening every day but, let's say, weekly ...It seems to be because pieces of equipment are, in many cases, introduced too early, too raw to the market; they have not been well tested.

The relation between education and work was seen by the participants as an intricate question. It was not a meaningless one, even though "the technology has changed in the data sector about 120%. There are not even memories left about how it was done [before]."

The experts thought the social skills and personal qualities to be only little or not at all developed during education. Knowledge sharing was seen to be akin to such skills: if
you don't have the personal characteristics that support social skills and cooperation, then there is not much that can be done to facilitate knowledge sharing. There is always someone who has "the knowledge in a drawer" or "the files on locked shelves."

Concerning knowledge exchange from a technical point of view, some practical solutions were proposed to codify the information, such as to prepare technical aids (self-guiding systems) in the working environment.

The producers and other corresponding companies were often mentioned as an essential information source. The importance of the Internet and the certain web pages there were emphasized as well as the informal long-standing contacts to other experts, inside and outside of the company. "The information seeking or mining has become as a daily routine," they told us. One of the experts characterized the way he himself finds the newest relevant information needed and the learning process connected to the problem-solving situations in joint work situations:

"You just have to look for information ... the Net is a pretty good information source and the producers ... if you have something to do with them so you just keep on asking about matters and things. It is the activity that is needed... There is only one place inside the house that provides information for me. There is very little that we need or can get inside the house. We communicate more with the producers ... of course, every team member has their own links along which the information flows ... they are calling, discussing things with people, with the ones who make these things ... you know the certain fellows and then you just call them and talk this and that. I also have certain passwords to load the stuff directly from the net. If you cannot get it there, then you just have to find something else. I also have other kinds of channels ... informal contacts. You have to use your own links. I take the information direct where it is. I want to have it fresh. Others use my contacts as well. I know to whom to turn to. It is the interaction... you speak informally about this and that to make it work.

The participants mentioned often the informal communication channels though no one described the issue in a very detailed way. The two useful places for employees to hear informal news that was "pretty often correct," became familiar to the researcher, too. People mentioned that "the social hatch area, of the equipment storage room is the best place to get news." If you do not get it from there, you have to "read it from local newspaper." Someone said that "news often has wings on its back"; thus, the working persons do not need to get news from the official channels.

Managing in the midst of rapid change is difficult. There were comments with a negative tone towards change; many of the participants interpret "change" to mean very demanding "challenges". A positive and dynamic attitude was not always present. A worker told us that he had waited 40 years in his work situation so that the change period would be over and it would be time to utilize what you really can do; but the time never came, and the system has never been completed.
Discussion

The results of the study indicate that social network analysis can productively be applied to analyze interaction among the workers. The methods of SNA helped us to examine relations between weak and strong links in various teams. By providing explicit information on the networking practices of the organization, we guided the company to examine its’ formal and informal network structures. The study indicated that knowledge within the company is still centralized in certain critical experts rather than distributed among a large group of employees. This situation holds, especially, for certain kinds of technical, expert knowledge that represents the core competence in the field. The experts on these fields cannot go for advice to other members of the organization because those persons do not have sufficiently deep expertise. They have their own expert cultures, but these networks appear to extend beyond the boundaries of the company, in this case among the producers and, perhaps, to some competitor companies, either directly or indirectly via some third actor, such as clients. There appeared to be a need for the experts to keep up their own personal network, a phenomenon that fits closely with the idea of intentional networks (Nardi 2000). These experts appeared to function as information gatekeepers, the actors who capitalize intellectual resources that arise from bridging structural holes (Burt 2000, 1999, 1992).

We also examined the extent to which knowledge sharing occurred in the teams and how the knowledge of the teams was distributed across the organization. The strong ties were examined in relation to all incoming and all outgoing connections in order to assess the importance of redundant and mutual knowledge-sharing versus non-overlapping information resources. The actual performance measures (such as earnings, bonuses, goals achieved, and so on) were not available to us. These measures may not, however, have been meaningful because some of the teams only supported the functions inside the company while the others were responsible for functions outside the company (such as client work). However, the issue of "advice size" -- the amount of information and knowledge that a team provides for the other teams -- could be treated as a rough estimate of their relative importance or cognitive centrality. Previous studies that often focused on social capital, for instance, showed a clear association between team performance and the average social capital of individuals on the team as well as the importance of non-redundant sources of networks of advice and information (for a review of this issue, see Burt 2000).

The results of the study appear to be consistent with Austin's study (2000) indicating that the density of within-team ties alone does not determine a team's cognitive centrality. The frequency of diversified connections -- such as multiple weak links -- is a better indicator of a good team performance. The weak links appear, so to speak, to feed the strong links by updating the knowledge base. Presumably, the absence of weak links makes the working environment suffer deficiencies in information and knowledge updating, and perhaps even encourages biased "groupthink" where the action only depends upon information inside a cohesive group (see e.g., Kameda & Sugimori, 1993).

Although expertise cannot be directly taught in education, formal and codified knowledge has an important role in working-life contexts. The participants' interviews suggested that collective learning took place through interactive processes, such as shared inquiry and negotiations, as well as developing a collective repertoire of be-
behavioral routines—appropriate ways of thinking and acting. Teams' collective cognition appears to facilitate and guide team members' learning and open up new perspectives (Wong & Sitkin 2000). It was noticeable that cohesive teams reported practices and experiences of collective learning. Yet the quality or rigidity of the routines and practices was not asked about by the investigators.

We hypothesize that the most distributed practices are not necessarily the best ones. The relative importance of shared and distributed knowledge, however, should be studied further. Several characteristics of discourse were observed in these communities of practice, i.e., e.g. joint words and metaphors. Yet, a knowledge-intensive and technical environment cannot be based on bare rituals and noncodified knowledge. There were strong demands to get more assistance provided by written codes (‘helps’) to facilitate practical work. Similar results have been reported by some other studies. For deeper collaborative knowledge to be produced, explicit but uncodified knowledge would have to be more widely shared, not merely held by a few ‘gatekeepers’.

Tacit knowledge cannot replace the codified conceptual and factual knowledge, rather both of them are needed, especially in complex environments based on co-operation of several actors with distributed, work tasks and diversified expertise. If codified information is not available, routines appear to serve as memory units as they are repeated sufficiently ("new things become routines"). However, knowledge is more easily transferable and changeable if it can be explicated. The highly centralized communication structure is certainly familiar to many working places acting in a field of rapid change: conventional tasks can be handled by most of the workers as the newest techniques and know-how are in the hands of only a few workers. In this kind of situation expertise is not sufficiently shared so as to obtain the best collaborative results}. It takes up a great deal of resources to codify or distribute even the most urgent pieces of the core knowledge. For all that, it appears that the individuals who possess superior analytical skills, task specific knowledge, or social skills (e.g., narrative techniques) are likely to enhance the collective learning processes. They are likely to become central actors notwithstanding how knowledge is otherwise organized in the company.

Knowledge sharing is extremely important in coping with complex environments and creating new solutions, and in dealing with other affairs that one human being would not be able to do alone. To have appropriate relationship between shared and distributed human resources is the key to optimal collaborative outcomes although quite difficult to assess. The teams with adequate and non-redundant contacts have the advantage of access to a broad diversity of perspectives, skills, and resources in the situation where the knowledge is shared among the team members {this line a bit obscure}.

The relation between expertise and experience is often highlighted. Comparing novices and newcomers with expert workers having long work careers has been a common way of examining the nature of expertise. Long experience does not, however, necessarily make one an expert; there are many people who may be characterized as experienced non-experts (Bereiter & Scardamalia, 1993). It appears that, while dealing with a rapidly changing field, the versatility of experience is more important than the duration of experience as such, although a certain minimum length of practical experience is needed. The employees are typically working for several years in the same
company (sometimes even 30 or 40 years). The youngest may, however, in some areas provide the knowledge concerning the newest technique. That {what??} could also be the reason for an employee to work only short periods on one task. Not knowing anything about the previous history of the workers, a new person might be misled by information on previous events [practices] in the company. However, a relatively long and the rich experience of working life appeared to be characteristic of almost every person invited to the interview on the basis of cognitive centrality among the social network of the company. Yet, we do not know, why only some of the workers with long experience achieved an exceptional level of expertise.

References:


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Appendix 1.
Networking questions

Please make a note in column in the case of every worker asking the following questions:

1) Who do you go for to ask some advice?
2) Who do you go to ask for new information?
3) Who is the worker you are having discussions outside the work-related matters, who do you have trust on?
4) Who is a collaboration partner of yours?

<table>
<thead>
<tr>
<th>Names</th>
<th>Advice</th>
<th>New information</th>
<th>Informal contacts, support</th>
<th>Collaboration</th>
</tr>
</thead>
</table>

…names to be listed…