Knowledge sharing and distributed cognition in industrial research

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1. Introduction

This paper describes results of extensive empirical research and theoretical reflections on knowledge-related communication in industrial research. Over the last decade the concept of knowledge has been given a central place in the field of organization studies. Among the processes studied are knowledge creation, knowledge transfer, knowledge application and knowledge integration (Coombs and Hull 1998). Although we are far from an integrated understanding of these processes, clear progress has been made toward that goal. Research has made progress in analyzing topics such as organizational learning (e.g., Huber 1991), knowledge management (e.g, Davenport and Prusak 1998) knowledge integration (e.g., Grant 1996b), core competencies (Prahalad and Hamel 1990), managerial cognition (e.g., Walsh 1995) and tacit knowledge (Nonaka 1994). A general claim underlying these views is that organizations should actively manage these processes and phenomena in order to stay competitive. Among the issues that are underexplored are the role of communication in knowledge processes and the relationship of knowledge processes to work processes.

In the literatures on knowledge in organizations, communication is first and foremost associated with knowledge transfer (e.g., Kogut and Zander 1992; Grant 1996a; 1996b; Moenaert and Caeldries 1996; Davenport and Prusak 1998; Hoopes and Postrel 1999; Hansen 1999; Gupta and Govindarajan 2000; Szulanski 2000; Hansen and Haas 2001). A telling indication is found in Fisher and Fisher (1998: 280), where the index states: "communication, *see* knowledge transfer". The phrases knowledge exchange, flow, dissemination, distribution and sharing are often used synonymously to knowledge transfer. The conceptualization of knowledge transfer predominantly follows general models of communication. Szulanski (2000:11) states that Shannon and Weaver's (1949) model of communication informs most of the actual research in knowledge transfer. In a similar vein, studies of information processing in research and development and other types of work settings has identified communication with the transfer of information (e.g, Allen 1977; Tushman 1978; Wegner 1987; Leckie et al. 1996; Moenaert et al. 2000). Synonyms used are the flow, transmission, distribution, exchange and routing of information. It should be noted that neither the information processing view, nor the knowledge transfer perspective has considered transferring an unproblematic process. The information processing perspective has emphasized the importance of shared coding schemes (March and Simon 1958; Tushman 1977). Knowledge based theories have argued that knowledge transfer is not comparable to an injection by a hypodermic needle, but requires interpretation, reconstruction and absorptive capacity (Cohen and Levinthal 1990; Szulanski 2000).

In this research I have focused on the 'work' done in research-related communication. The assumption that communication equals transferring has been put into question. I will show that several knowledge processes are involved in communication. In this article I will relate this to theories of distributed cognition (Hutchins 1991; 1995; Salomon 1993; Weick and Roberts 1993; Tsoukas 1996). The concept of distributed cognition is interesting since it focuses on the organization of knowledge processes in interaction. The studies of distributed cognition and correlated concepts enable to construct the concept of integration of cognitive labor. The degree of integration of cognitive work refers to the degree to which the cognitive labor of organization members is oriented toward the same problems. In this article I will confront this dimension with the degree of interdependence of tasks, a well-known dimension in the field of organization studies. This means that I confront the differentiation and integration of tasks and the differentiation and integration of cognitive labor. Communication is used as the vehicle for this confrontation. The information processing approach to organization studies (Galbraith 1973; 1977; Tushman and Nadler 1978) has viewed communication as the means to reduce uncertainty generated by interdependencies. On the other hand communication can also be shown to play a major role in the integration of cognitive work. By relating knowledge-related communication to a dimension of distributed cognition and task interdependencies, knowledge processes are linked to actual work practices. In many other studies knowledge processes are described in isolation. The value of knowledge creation and sharing is only stated in general terms, such as the gaining competitive advantage. Only in certain ethnographic studies have knowledge processes explicitly been linked with work practices (Orr 1990; Hutchins 1995; Tsoukas and Vladimirou 2000).

The contribution of this article is intended to be as follows. Whereas the information processing approach and the knowledge management literature have interpreted communication as the transfer of information or knowledge, I will show that several knowledge processes are combined in communication. This has only scarcely been acknowledged in the existing literature. Furthermore I link the knowledge processes in communication to work processes. I will argue that many interactions show integrated cognitive labor, even in the face of low task interdependence. This pleas for paying attention to the differentiation and integration of cognition as well as the differentiation and integration of tasks.

The empirical research on which this paper is based consisted of ethnographic studies of two industrial research groups. Both of them are engaged in quite fundamental research, exemplified by the fact that their researchers regularly publish in scientific and technical journals. Between April 1999 and December 1999 communication between researchers was studied in research group of a laboratory of an electronics company (ElCo).[1] At the

[1] The names of the companies and researchers have been changed to protect their anonymity.

time of study this group consisted of about 25 researchers. It is embedded in a much larger laboratory. Between March 2001 and September 2001 a similar study was done at a research group of an energy company (EnCo). At both groups interactions between researchers were observed, tape-recorded and discussed afterwards. These interactions comprised formal meetings, appointments, lunches and meetings at the corridor. In addition to face-to-face meetings some written exchanges were analyzed. In total, more than 250 interactions were observed or documented. Further, both formal and informal interviews were held. Field notes and the transcripts of interactions and interviews were analyzed in line with the grounded theory approach (Glaser and Strauss 1967; Glaser 1978; Strauss and Corbin 1990). This paper reports part of the results of these analyses. Two categories of codes that were developed take a central place in this article. One category of codes refers to the moves made in communication. A move is that what is done by communicating. Moves are single speech acts or combinations of speech acts (Searle 1969). Examples of moves are 'describing results', 'asking questions', 'agreeing' and 'hypothesizing'. Another important category of codes refers to the knowledge processes found in communication. In this paper these categories are related to two dimensions derived from existing literature. It should be noted that I use these dimensions only to refer to research tasks and research related communication. Since I focused in my study predominantly on research-related interactions between researchers, I will not discuss these dimensions with regard to interactions with development, marketing, product divisions or allied organizations.

This paper will proceed as follows. In the next paragraph the two dimensions that will be used to interpret research findings later on will be introduced. After that I will describe the different knowledge processes found in communication between researchers. In the fourth paragraph I will interpret these findings along the lines of two dimensions. In the final paragraph, I will relate these analyses to existing literature and draw conclusions.

2. Two dimensions

A problem that has since long taken up a central place in the field of organization studies is the differentiation and integration of tasks (March and Simon 1958; Thompson 1967; Galbraith 1973). As organizations grow, they differentiate. Sub-units are formed that have to perform distinct tasks. The way tasks are differentiated might yield various kinds of interdependencies that need to be coordinated. Thompson (1967:54) distinguishes three types of interdependence: pooled interdependence, sequential interdependence and reciprocal interdependence. Two organizational units are pooled interdependent when each part renders a contribution to the whole and each is supported by the whole. Units Y and Z are sequentially interdependent when unit Z can only perform its task after the

successful completion of the task of unit Y. Reciprocal interdependence refers to the situation in which the outputs of each unit becomes an input for others and vice versa. Van de Ven, Delbecq and Koenig (1976:325) add a fourth type of interdependence: team interdependence. This refers to situations where the work is undertaken jointly by unit personnel who simultaneously diagnose, problem-solve and collaborate in order to complete the work. According to Thompson (1967) and Van de Ven et al. (1976) team interdependence presupposes reciprocal interdependence, which in turn presupposes sequential interdependence, which in turn presupposes pooled interdependence. From pooled interdependence to team interdependence, these types consist of an increasing degree of interdependence. These interdependencies create a need for coordination. In the information processing approach coordination activities are interpreted in terms of information processing.

Another dimension that can be distinguished is the integration of cognitive labor. This concept can be adapted from recent theories of distributed cognition. The concept of distributed cognition originated in the field of cognitive science (Hutchins 1991; 1995; Salomon 1993), but the concept has soon been taken up in the field of organization studies (Weick and Roberts 1993; Tsoukas 1996; Fisher and Fisher 1998; Faraj and Sproull 1999)). A number of concepts are corollaries of distributed cognition: transactive memory (Wegner 1987; Hollingshead 1998; Moreland 1999), organization mind (Sandelands and Stablein 1987), collective mind (Weick and Roberts 1993), distributed computation (Thagard 1993; 1994) and collaborative learning, problem solving and discovery (Cicourel 1990; Dillenbourg e.a. 1996; Okada en Simon 1997). The idea of distributed cognition refers to the division of cognitive labor (Hutchins 1991; 1995). Just like a particular organization of manual labor permits individuals to combine their efforts in ways that produce results that could not be produced by any individual alone, a particular organization of cognitive labor enables groups and organization to reach cognitive goals that would be more difficult or impossible to reach individually. Since knowledge within an organization is often dispersed over different members of that organization (Tsoukas 1996), the performance of the organization depends upon the way the cognitive work of organization members is integrated (Hutchins 1995; Grant 1996b). Distributed cognition refers to the cognitive side of task execution. A distributed cognitive system is characterized by a certain division of cognitive labor, which involves the use of distributed knowledge bases. A central hypothesis concerning distributed cognition is that the performance of groups is not only influenced by the knowledge of individuals, but also by the ongoing social organizing of those individual cognition's. This theoretical claim is in line with the central claims of the knowledge-based theory of the firm (Kogut and Zander 1992; Grant 1996a; 1996b). The functioning of a distributed cognitive system can be characterized by a degree of integration. The degree of integration of cognitive work refers to the degree in which cognitive work is oriented

toward the same tasks. This degree of integration is corresponds to Weick and Roberts' (1993:378) distinction between tightly and loosely coupled collective mind. It is related to the distinction between differentiated and integrated transactive memory systems (Wegner 1987). That distinction refers to the degree of overlap between knowledge possessed by individuals. The distinction I propose refers to the overlap between the cognitive work. It is a measure of redundancy (Nonaka 1994). This degree of integration of cognitive labor comprises might encompass coordination activities undertaken by organization members to deal with interdependencies, but does not necessarily do so.

Both dimensions can be dichotomized into a 'strong' and a 'weak' pole. If these two dimensions are combined, a two-by-two matrix can be constructed (see figure 1). It should be noted there is always some degree of dependency and some degree of integration of cognitive work. Thompson (1967) argues that individuals in an organization are always pooled interdependent, since they are dependent upon the performance of others for the continuing existence of resources in the organization. Likewise, there is always some degree of integration of knowledge work. Grant (1996b) explains that even the performance of tasks coordinated by rules and plans can be interpreted as a form of knowledge integration, since the resulting production is enabled by the isolated use of distinct knowledge bases.

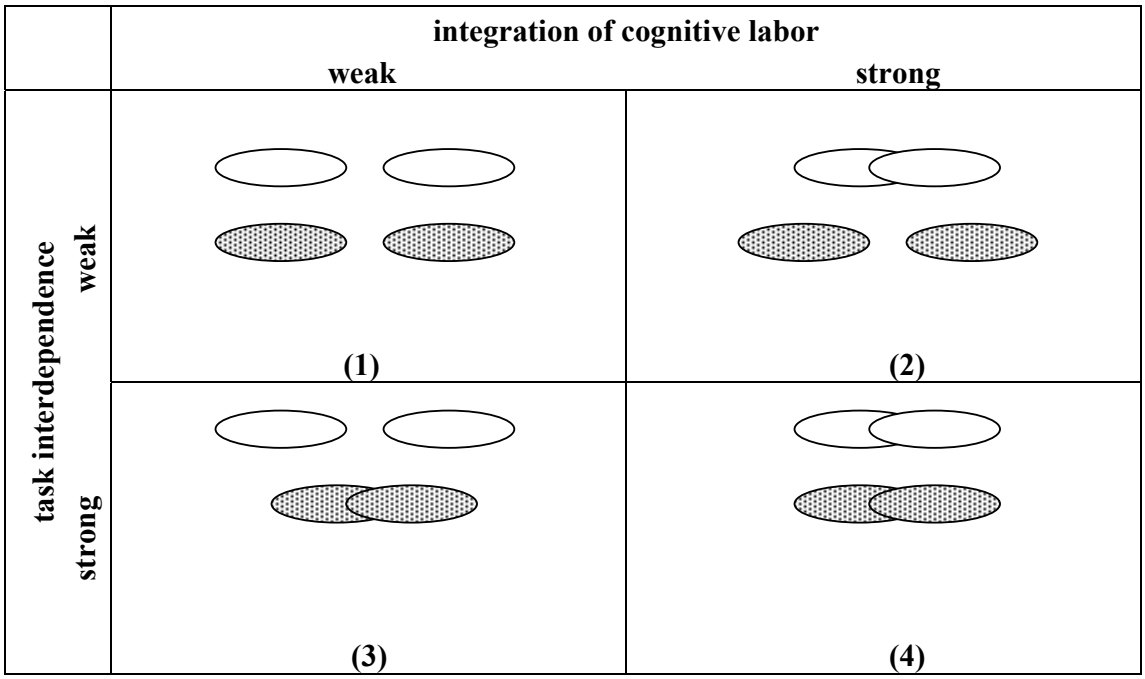

Figure 1: Combinations of degree of interdependence and integration of cognitive labor (white areas refer to the cognitive labor of researchers and dotted areas to their actual research tasks).

In this paper I want to explore the relation between these two dimensions. Some suggestions can be found in the literature. Weick and Roberts (1993) link two corresponding dimensions: the degree coupling of tasks and the coupling of collective mind. They studied tightly coupled technological systems and argued that such interdependent tasks should be accompanied by tightly coupled collective mind (quadrant (4)). Other studies presented in the literature on distributed cognition also focus on groups executing tightly coupled tasks, such as navigating, flying an airplane and software development (Hutchins 1995; Hutchins and Klausen 1996; Faraj and Sproull 1999). They show how such systems with interdependent tasks are often accompanied by an integrated system of distributed cognition. Weick and Roberts (1993) argue further that tightly coupled tasks executed without highly integrated cognitive labor, quadrant (3), are liable to failure.

Fewer theoretical hints can be found about the quadrant (1) and (2). A theory that might be useful is the information processing approach to organization design (Galbraith 1973; 1977; Tushman and Nadler 1978). This approach relates characteristics of work processes in organizations to information processing in order to explain the performance of organizations. On the one hand, the information processing approach states that work processes in organizations yield various degrees of work-related uncertainty. Tushman and Nadler (1978) distinguish three sources of uncertainty: task characteristics, the environment and interdependencies with other tasks. Since I have not focused on relationships with the organizational environment I will leave that out of consideration. The uncertainty stemming from task characteristics is high for all research projects (Tushman 1978). The main variable to explain differences in information processing is the existence of interdependencies. In cases of strong interdependence we may expect interactive information processing and problem solving, i.e. integrated cognitive work (quadrant (4)) (Tushman and Nadler 1978). However, when task characteristics are the only important source of uncertainty, the only claim of the information processing approach is that it is necessary for the organization members to gather, interpret and synthesize much information. This can be either done by strongly integrated cognitive work or less integrated cognitive work (such as gathering information from internal reports). The information processing approach does not express a favor for one of the two strategies.

From this short review of relevant literature we can conclude that existing literature has only clear predictions about the effect of the degree of integration of cognitive work in the face of strong task interdependencies. The information processing approach focuses on the difference between tightly coupled tasks and loosely coupled tasks, and argues that in the latter case their should be more information processing. The information processing approach claims that, due to the uncertain nature of research tasks themselves,

researchers should also gather, interpret and synthesize information in the absence of strong task interdependencies. However, this theory yields no expectations about the form that this information processing should take. Therefore it is interesting what we will see if we link observations about interactions between researchers to these two dimensions.

3. Communication and knowledge processes

In this paragraph I will show that communication may involve more cognitive processes than only transferring knowledge or information. Two additional processes stand out. First, knowledge may be applied in research related communication. Second, participants in communication may also be engaged in a process of knowledge creation. Different interactions may show different types and degree of knowledge application and knowledge development. Some of the types of knowledge use have already been acknowledged in existing literature. I will discuss the use of knowledge in communication first and the development of knowledge second.

It has been observed frequently that receiving, interpreting and evaluating communicated messages, information or knowledge requires the application of knowledge (Cohen and Levinthal 1990; Weick 1995; Goldman 1999). More interestingly, knowledge should also be used to initiate a focused transfer of information. If its intended receiver initiates the transfer of information, for example by asking a question, we may speak of 'pulling'. Pulling is not unproblematic. In the first place, it requires having and being aware of an information need. To ask a question effectively, it is necessary to know what one does not know. One must have an idea of what it is that might fill the gap and be able to turn that into a question (see also Miyake and Norman 1979). This knowledge is not always present, which constrains asking questions. In a certain interaction John, who has started a new research project recently, visits Jack. Jack is an expert in dust particles. Although John's project involves managing dust particles, he has few specific questions for Jack. He does not know yet what he needs to know. Therefore he just wants to gain some background knowledge by talking to Jack. In that way he might learn what kinds of questions could be asked about particles. The development of a question is already a cognitive achievement. The development of research questions can be an important effect of communication. Effective pulling requires also knowing about the existence of knowledge and about persons possibly having that piece of knowledge. One of the researchers of ElCo stated: *"If I encounter a problem, I will first walk around in my group. I will go to Frasier, Henry or Pete, to the person of whom I think 'he is most knowledgeable about it'. You know what your colleagues do! If I want to measure the thickness of a layer, I go to Patrick or Mitchell. Microscopy, that's Peter. Image*

processing, Paul. You ought to know that!". Transactive memory studies have particularly stressed the importance of knowledge of the existence and whereabouts of knowledge (e.g., Wegner 1987; Hollingshead 1998). They called this knowledge about knowledge 'metaknowledge' (Wegner 1987). It is possible to extend one's own metaknowledge with the metaknowledge of others. At ElCo and EnCo it happened frequently that the person who was asked a question did not have an answer. However, he as able to refer the information-seeker to a third person, by using his metaknowledge in turn. ElCo's research laboratory had even installed an office specialized in aiding researchers in finding the right person.

In pulling one needs to apply knowledge of what information one needs and apply knowledge of who knows what. These uses of knowledge are typically oriented at one's own problem. They show little integration of cognitive work. More integration of cognitive work is visible in 'pushing'. In pushing, the sender chooses to transfer some existing information to somebody else. This may consist of information the recipient has never thought about. By pushing, the sender may take the cognitive burden associated with asking questions from the intended recipient. But to do this he needs to have and apply knowledge about the activities and problems of the other. Based on that knowledge and his relevant technical knowledge, he may conclude that something may be useful for the other. In one episode Pete proposes Richard to show him some printing techniques he had been working on. Pete knew that Richard had recently started as an assistant on a project studying a new kind of printing technique. Pete considered learning something about existing techniques useful for Richard. In this case Pete used his background knowledge of printing techniques and his knowledge about Richard's activities to induce that knowing about those techniques would be beneficiary to Richard. Pushing and pulling are often used complementary. Together they enable the fine-tuning of messages and addressing remaining questions. Frequently a researcher is not able to pose his questions in much detail. At a certain moment, Richard wanted to analyze pictures with a piece of software. He was sitting behind the computer, but did not know what to do. By chance Paul dropped in and Richard asked if he knew the software. Paul proved to be an expert. But Richard's question was not sufficient for Paul, since the software had many options. Therefore Paul named some of the possibilities and asked Richard in which he was interested. This resulted in more specific questions by Richard, questions that he would have been unable to ask beforehand. By both using their background knowledge, and their knowledge of Richard's problem, they were able to accomplish successful transfer of existing knowledge.

Communication does not only encompass the transfer of existing information. In many cases information is created within the interaction. In one episode Marc has a problem with the process of coating a certain object. During this process a pattern of irregularities

is formed. He introduces this problem to Jason, who in turn asks for some details. Based on this he forms a hypothesis on the cause of the problem. In this particular conversation, which lasted only for about five minutes, another thing happened too. Marc exclaims at a certain moment: *"I don't understand it, for it is the same liquid as I am normally using, and then there is no problem. Only now I am using it in black."* A couple of seconds later he goes on: *"But maybe ... the pattern is there all the time, but you don't see it. I might be seeing it now because of the dark color."* Marc comes up with a supplementary explanation for his own problem, explaining the fact that he has not noticed the irregularities before. Among the things that were found to be newly developed in communication between researchers are suggestions for experiments and technical solutions, ideas for future research, hypotheses, questions, doubts, arguments, evaluations (agreements, rejections) and conclusions. In few cases it is complete knowledge that is created. What is created are predominantly contributions to a knowledge development process. For example, coming up with new questions may be an important contribution to a knowledge development process. In a certain meeting Jason presents a model of fluid dynamics. One of the other researchers present asks: *"Does gravity have any effect here?"* Because Jason had not thought of that possibility it raised a new problem for him: finding out if gravity has an effect. Subsequent analyses showed that it indeed had an effect. Further it should be noted that active thinking within an interaction is not only tied to face-to-face communication. The cases involving the creation of new content, do also involve the use of other media, such as telephone, e-mail and other written exchanges. For example, a review procedure followed at ElCo is largely based on written communication. Nevertheless, new evaluations and suggestions are formed in the process.

It can be concluded that communication does not only involve transferring, but knowledge use and knowledge creation as well. This means that these processes are intertwined in practice. While thinking about one of the processes, one should think of the others as well. A complete analytical separation might result in partial analyses of each of the processes. Analyzing the transfer of information without analyzing the knowledge use and knowledge creation that established that transfer, leaves it underexplored.

4. Interdependence and the integration of cognitive labor

In the last paragraph I showed how different knowledge processes are intertwined in communication. In this paragraph I will interpret the interactions in terms of the dimensions earlier in this paper. I will show that the processes associated with the quadrants (1) and (4) were indeed found in my research. However, many other interactions seem to be located in quadrant (2). They exhibit a fair amount of integration of cognitive work in the absence of strong interdependence. I will argue that such integrations of knowledge and cognitive labor are valuable for the functioning of industrial research.

In my study of researchers at ElCo and EnCo I found both highly dependent research tasks and quite independent research tasks. Highly interdependent (parts of) research tasks were labeled shared problems. In my empirical research I found interactions related to such interdependent research tasks, that show a strong integration of cognitive work. Moves associated with working on a shared problem are suggesting a technical solution, suggesting experiments, describing findings and theory, describing own results, describing technology, hypothesizing, giving arguments and asking questions. These relate to working out solutions together. The interactive constructing of answers is even more visible when researchers observe together and describe their observation, or calculate or try something on the spot. Take for example an interaction between Jason and Rick. Three days before this interaction Jason and Rick have thought up a series of spin-coating experiments that they would like to carry out in a clean room. In this interaction they are executing these experiments, together with two technicians. They inspect coated discs by the bare eye and under a microscope. They tell each other what they see and draw conclusions. They perform scratch tests and look at the resulting scratches under a very strong microscope, again telling what they observe. Other moves associated with working on a shared problem are suggesting research activities and instructing. Instructing occurs when a researcher orders an assistant to do something. Typically for these moves oriented at a shared problem is that they lead relatively frequent to changing the problems the researchers are working on and to undertaking specific actions. This can be interpreted as the coordination of actions that is necessitated by interdependent tasks.

Quadrant (3) refers to tightly coupled tasks executed with a low degree of integration of cognitive labor. That situation is called ‘heedless interrelating’ by Weick and Roberts (1993) and is expected to be liable to failure. In my research I have not stumbled upon such cases, but that also be caused by the fact that I have studied interactions and not the absence of interactions.

Many research tasks are quite independent. This can be derived from the fact that both at the research groups of ElCo and EnCo, the average number of project members was less than two. This might be due to the fact that the researchers studied were engaged in quite fundamental research. Product and process development projects involve much stronger interdependencies. Quadrant (1) refers to researchers who work on quite independent research problems and show a low degree of integrated cognitive work. This quadrant refers to researchers working on their own problems. Researchers engage in problem solving activities with regard to their own problems. They individually analyze, experiment, design and interpret. Further, researchers gather information from literature, company reports, and other internal sources. The gathering of such existing information represents a bit more integration of cognitive work, since researchers make use of previous cognitive work of others. But if this information gathering is merely restricted to pulling, it involves little current cognitive work of others. However, such isolated researchers proved to be scarce at both EnCo and ElCo.

Most interesting with regard to my present purposes are interactions that can be located in quadrant (2). There are many interactions that express a relatively high degree of integration of cognitive work with regard to tasks that are quite independent. Although the integration of cognitive work is normally not as strong as between researchers working on interdependent problems, it is still considerable. Many of the communications studied involved researchers working on separate and quite independent tasks. Integrated cognitive work between them may take the form of pushing and thinking along with each other. The notion of thinking along with someone refers to coming up with new information with regard to somebody else's problem. This may include: suggesting a technical solution, hypothesizing, suggesting an experiment, agreeing, rejecting, giving arguments, asking questions, questioning, concluding, redescribing and summarizing. What is accomplished by these moves is not the creation of a complete piece of knowledge. It is constructing and deconstructing bits and pieces that may eventually become part of a complete answer to a research question. Thinking along with someone involves applying one's knowledge to somebody else's problem. This encompasses both applying technical knowledge and applying knowledge about the problem and activities of the other. As described in the previous paragraph, the transfer of existing information might also involve cognitive work in relation to somebody else's problem. In pushing the sender considers something (potentially) useful for the receiver's work. This may involve findings or theory, information about technologies, experiments, and other researchers and information about other researchers and literature. In pushing an important share of the cognitive work associated with transferring is executed by the sender.

Thinking along with someone and pushing are often not isolated activities. First, the researcher whose problem is discussed is regulary contributing actively too. In interactive communication, that person may also come up with new ideas, questions and arguments. Second, thinking along and pushing may be preceded by other moves. It can be preceded by someone telling about his problem or telling about a solution that he is considering. Third, thinking along and pushing are often not limited to single moments. In the course of time, several such supporting cognitive activities may be undertaken. At a certain moment Henry became worried that a young colleague, John, who was working at the same corridor on very different project, was postponing experimenting too long. Henry mentioned this to John and started interfering more with his work. In later interactions he suggested possible ways to execute the experiments that he considered necessary, showed some existing facilities and introduced him to other persons who might be helpful. At the research group of ElCo clustering researchers creates more continuous relationships. Though it should be granted that some aspects of the interactions in clusters consists of dealing with interdependencies, in many cases it establishes the integration of cognitive work in the absence of strong interdependencies. A prolonged application one knowledge to another one's work may eventually turn into taking over a part of the work of the other. In such a case a research problem has turned into a shared problem, into interrelated subproblems. This means that this collaboration moved from quadrant (2) to quadrant (4).

Such integrated applications of knowledge do not represent a structure that is fixed once and for all. The distributed cognitive aspect of industrial research is inherently dynamic. What knowledge can be applied to what task differs over time. Furthermore, thinking along with someone and pushing need to be continuously enabled by communicating about activities, problems and knowledge. The predominant effect of interactions is learning about the activities, problems and knowledge of others (104 out of 227 episodes analyzed yielded that result; only 59 resulted in a contribution to a solution). Many interactions seem to have learning about others as their prime goal. Researchers purposefully tell about their problems and activities and ask others about their problems and activities. This is hard to understand for those who consider information primarily as a means to solve one's own problems (e.g., Allen 1977; Leckie et al. 1996). But this learning about others typically enables asking for help and helping others in the future (see also Faraj and Sproull 1999). What is accomplished is a continually evolving system of distributed cognition. Integrated cognitive work is a collective accomplishment that should be enabled over an over again.

A typical feature of thinking along with someone and pushing is that most of the knowledge that is used is not transferred. In thinking along and pushing researchers apply their knowledge, which results in suggestions, questions etc. or the selection of

information that is considered useful. It is this information that is transferred, not all the knowledge that is used. The knowledge that is used includes tacit knowledge. Polanyi (1958) explains that all explicit knowing involves the use of a tacit foundation. To transfer all knowledge used would be very costly. The value of thinking along and pushing derives from the knowledge that is used but not transferred. In the knowledge management literature the value of intensive interpersonal communication is often explained in terms of the transfer of tacit knowledge (Nonaka 1994). I hypothesize that it is not so much the transfer of tacit knowledge that is at stake in interpersonal communication between researchers, but the application of that tacit knowledge in integrated cognitive work.

A higher degree of integration of cognitive work, even when tasks are quite independent, can have several advantages. These advantages are related to the use of the knowledge of more persons. By the integration of cognitive work a researcher can use the knowledge of his colleagues too. Among the advantages found in my research were the following. In the first place, applying one's knowledge to somebody else's problem may yield more possible solutions, hypotheses, explanations and questions. Researchers with different backgrounds have different knowledge bases to draw upon. But even persons with a relatively comparable knowledge base may come up with additional hypotheses (Okada and Simon 1997). Coming up with new ideas and questions is a creative process that has unpredictable properties. Existing knowledge might even hinder creative processes. During a lunch meeting, two researchers discussed a new research problem with colleagues and asked for possible solutions. The colleagues came up with two options that raised their enthusiasm. Afterwards they told that they did not tell about the solutions they were already considering in order to prevent narrowing their colleagues' focus. In the second place, the integration of cognitive work can yield higher degrees of reliability. As Thagard (1997) notes, it is often easier to identify mistakes in the work of others than in one's own work. An example of the increase of the reliability of research outputs is a review procedure at ElCo. Manuscripts that will be presented in an external forum have to be checked by two other researchers, not involved in the project. Researchers at ElCo explained that this was meant to ensure that the content meets certain standards of quality. I hypothesize that these advantages are reached in a time-efficient way. Compared to the time a researcher himself spends on a research problem, others can come up with additional ideas, questions, arguments or evaluations in a relatively short period of time. By letting people think along occasionally, the knowledge of more persons can be applied to one's problem, without necessarily loading those others with other activities involved in the research. Einstein is sometimes quoted as having said that scientific research is ten percent inspiration and ninety percent transpiration. Thinking along with someone enables using the inspiration of others without bothering them with the transpiring work. A different type of advantage of thinking along with someone is the

following. In the knowledge management literature we often find the warning that professionals are reluctant to share their knowledge, since their knowledge is their most valuable resource (Davenport et al. 1992). Thinking along is less threatening in that respect. In thinking along much knowledge is used, but only a fraction of it is given away.

5. Discussion

Based on observations of interactions between industrial researchers I have argued that communication involves several knowledge processes. Transfer of information or knowledge is often intertwined with the use and development of knowledge. Moreover, the use of and development of knowledge are often oriented toward research problems independent from one's own problem. This indicates that there can exist a relatively high degree of integration of cognitive work, even in the absence of strong interdependence between tasks. This integration of cognitive work is probably not as strong as in well-developed interdependent teams, but it goes beyond that what might be expected from considering tasks and their interdependencies alone. The value of integrated cognitive labor in face of weak interdependence becomes understandable from the perspective of knowledge integration (Grant 1996b). In integrated cognitive work researchers make use of other's knowledge, without having to learn everything the other knows. This may increase reliability and creativity in a time-efficient way.

These findings are in line with the general claim found in the knowledge management literature that organizations should pay attention to knowledge processes. But in the knowledge management literature the kind of fairly integrated cognitive work discussed in this paper, is underexplored. The creation, use and transfer of knowledge have often been discussed as distinct processes. Many studies focus on the transfer, flow or distribution of knowledge without taking the other processes and tasks into consideration (e.g., Szulanski 1996; Hansen 1999; Gupta and Govindarajan 2000). Likewise, in the literature on organizational learning the focus lies on learning by individuals who subsequently transfer what has been learned to others (Shrivastava 1983; Huber 1991; Kim 1993). Strong integration of cognitive work is only studied in team processes (e.g., Faraj and Sproull 1999). In the literature on distributed cognition to focus is also on highly interdependent teams with tightly coupled cognitive work. Further, from the information processing approach it follows that researchers should engage in information processing, but this perspective does not discuss the form this information processing should take. Therefore I conclude that my analysis in a valuable contribution to the existing literature.

The analysis presented in this paper suggests that the study of organizing should not only focus on the integration of tasks, but also on the integration of knowledge and cognitive work. The integration of cognitive labor may have a value beyond the integration of interdependent tasks. This analysis supports Nonaka's plea for redundancy as a factor supporting knowledge creation (Nonaka 1994). A drawback of this study is that it is predominantly based on qualitative analyses. In future research its conclusions should be tested more rigorously. Future research should also focus on settings different from industrial research. In general, the relationship between the differentiation and integration of tasks and the differentiation and integration of knowledge seems to be an interesting field of inquiry.

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