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Knowledge networking: A conceptual framework and typology

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ABSTRACT

Knowledge networking is important for organizations in providing resources for learning and the generation of new knowledge; it refers to processes of interaction across epistemically defined boundaries between individuals, groups, or units. As such, it is an integral aspect of interdisciplinary collaboration. Building on a review and empirical work, we distinguish three modes of knowledge networking: modular, translational and pioneer. Managing the opportunities and challenges inherent in each form of knowledge networking demands attention and can produce positive results for organizational performance, increasing efficiency, creativity, or both; disregarding them can turn knowledge networking into the opposite of the original intention—*disadvantage*—because of the high costs generated by failure. We also propose an outline of a research agenda for additional understanding of structures and dynamics of knowledge networking in a variety of contexts.

KEYWORDS

Innovation, interdisciplinary, knowledge sharing, science networks, research organization, problem solving, management, coordination, collaboration

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INTRODUCTION

Recent research on organization has emphasized the role of knowledge and its management for performance in challenging environments. A particular difficulty involves the collaboration between people with different expertise, the acquisition of knowledge from new fields and the coordination of external with internal knowledge. All require interaction across knowledge-related boundaries, or, in our concept, *knowledge networking,* which is important in providing resources for interdisciplinary learning and the generation of new knowledge.

In this paper we develop a conceptual framework and typology for the study of knowledge networking in interdisciplinary organizational contexts, and use our empirical material to illustrate and explore it. There is a need for this, because most research on collaboration and its organization tends to neglect the *epistemic* dimension of communication across knowledge boundaries. It overlooks the impact of there being differences between the bodies of knowledge that are made to encounter each other, and therefore fails to address the processes through which such structural differences are overcome. One reason for this neglect is that most organizational research focuses on either the institutional or technological, or both, aspects of interaction—such as organizational structures, leadership, formal agreements and IT infrastructure—with the assumption that cognitive and epistemological boundaries, in themselves, do not possess any explanatory relevance. Yet evidence from existing research in organizational cognition suggests otherwise (e.g. Meindl, Stubbart, & Porac, 1996).

Epistemic differences constitute a unique challenge for the organization of interdisciplinary research; scholars need to address them in a more focused manner. Our starting point is the assumption that an individual's learning and knowledge production are guided by socially constructed frameworks of perception and reflection, or what we call *knowledge frameworks.* Such frameworks can in some cases be the result of the particularities of the specific task at hand and of the context for action. Often, however, they are the result of a broader social systematization of thinking within specific fields. In the latter case, we use the notion of knowledge regime, which refers to a system of practices, norms and rules through which a certain knowledge framework is consolidated and reproduced. We propose a set of basic parameters for specification of a knowledge framework, including: the characteristics of the world that is seen, within the framework, as its particular object of knowledge; the methods used in it for learning and generating knowledge; and the way it represents the purpose and role of learning and knowledge generation and of those who carry it out.

In organizations, knowledge is generally produced within collective practices. These practices can be distinct, ranging from local communities of practice (Wenger, 2002) to global networks of coordinated work (Hofstede, 1997; Archibugi & Lundvall, 2001). Common for many of these collective practices is that they include people who operate on the basis of different knowledge frameworks. Getting things done requires knowledge networking, that is, learning and knowledge production by interaction across epistemically defined boundaries between individuals, groups or units. We identify at least three common forms of knowledge networking—modular, translational and pioneer—each with their own challenges and opportunities.

Modular knowledge networking. This is a process where individuals, groups, or units, representing a number of knowledge regimes, interact by each making a clearly-defined knowledge-based contribution that is a component of the larger whole; the integration of their contributions is coordinated in a network by an overall coordinator and integrator. The activities within the components do not have appreciable direct effects on the other components; the knowledge frameworks do not need to interact with each other.

Translational knowledge networking. This process also consists of individuals, groups, or units, embodying different knowledge frameworks, and organized as a network to perform a particular part of the overall activity. In this process, however, the different parties interact with *each other* in generating and sharing knowledge. The communication between the frameworks is organized through a consolidated interfacing device, which can take on the form of, for example, a standardized language, a protocol for action, or a scientific ontology. Learning and knowledge generation is thus based on an iterative, translational activity between the levels of local practice and the global interfacing device.

Pioneer knowledge networking. Just as in translational knowledge networking, knowledge is integrated in processes of direct communication, but now *without* any consolidated interfacing device. There is marked interaction all across the network, with the original knowledge frameworks playing a less significant role. This is the least structured and most fluid of the three types of knowledge networking, placing the highest expectations on exploration and discovery. Being the most exploratory, there is no coordinator, as such; instead, since the networking is reliant on broad integration of knowledge, project managers ensure that communication across the network is maintained at the highest possible standard and that the participants receive the support they require to facilitate their interactions.

That said, we propose that the ability to distinguish between the opportunities and challenges inherent in each of the three forms of knowledge networking is important for performance in organizations characterized by interdisciplinary activity. We further propose that greater managerial attention to such opportunities and challenges will lead to positive results for organizational performance, through either increased efficiency or enhanced creativity, or both, whereas disregard can turn knowledge networking into the opposite of the original intention, i.e., *disadvantage,* because of the high costs generated by failure.

The novelty of our contribution lies in our having provided the typology for knowledge networking, including a "challenges and opportunities" analysis for each type of knowledge networking. A new research agenda has been developed on the basis of the typology. In order to achieve this, some preparatory conceptual work was needed: we have developed the concept of knowledge regime as a general notion for societal or organizational systems that produce coherence in learning and knowledge production, and we have refined the concept of knowledge framework as a reference to this coherence.

Our paper is structured as follows. In the next section, we argue for the topicality of studies of knowledge networking within and between organizations. In the section after that, we discuss the notions of knowledge regime and knowledge framework and the latter's three distinguishing elements. In the penultimate section, we distinguish between three forms of knowledge networking: modular, translational and pioneer. The final section is a presentation of the research agenda that can be derived from our conceptual work. Throughout the paper, wherever it has been deemed helpful, our empirical work is used to reinforce the discussion.

THE NEED FOR STUDIES OF KNOWLEDGE NETWORKING

The production, integration and diffusion of knowledge in and between organizations are all studied within a broad range of academic fields. Historically, two particularly influential traditions have shaped the study of organizational cognition: those of decision-making theory and the interpretive and inter-subjective perspective. The first of these focused on calculation and rational decision-making, which were conceptualized in terms of information processing. The relevant unit was the decision-maker, not the community or organization. Cognition was understood as a process in which values, norms and personal attitudes were linked with available information, with the outcome being a decision about behaviour.

During the last decades of the 20^{th} century, decision-making theory was challenged by a new, competing approach to organizational cognition—the second tradition mentioned above—that of the interpretive and inter-subjective perspective. In that tradition, the emphasis was on meaning and knowledge representation rather than information. Agency, action and practical reason replaced decision-making and behaviour as the main interest. Cognition was conceptualized in terms of classifications, scripts and schemata rather than in terms of information. Cognition was also seen as an inter-subjective process, either as a product of organizational scripts, such as routines and norms, or as a result of communication, collaboration and coordination. (For a more comprehensive analysis of the two approaches to organizational cognition, see Meindl et al., 1996; Lant & Shapira, 2001.)

The new perspective on organizational cognition was developed at the crossroads of emerging approaches within several disciplines: the new institutionalism within organizational science; evolutionary economy and the resource-based theory of the firm in economics; ethno-methodology, phenomenology and constructionism within philosophy and the social sciences; cognitive science within psychology and a range of other disciplines; and artificial intelligence within computer science. When applied to organization science, the perspective addresses questions such as (in a modified version of Meindl et al., 1996):

- How do members of organizations conceptualize and make sense of their activities and their organizational worlds?
- What mechanisms are there for coordinating or integrating activities based on different cognitive frameworks?
- What is the relation between cognitive structure (for instance, the range of competences in an organization) and cognitive process?
- How do various forms of organizational cognition affect the performance of the organization?

The explorative nature of contemporary work on interpretive and inter-subjective cognition should be emphasized. Many basic methodological issues remain to be settled. How do we describe knowledge and the process of generating knowledge? What is the appropriate level of analysis? What are appropriate methods for different kinds of study? We see our work as a contribution to the search for answers to these questions.

At a more specific level, the disciplinary background for the present analysis is in the study of innovation. Our parallel, on-going empirical research focuses on innovation in various fields of science and technology. Since the mid-1990s, innovation research has attended increasingly to the role of knowledge and its generation. In contemporary economics this trend has led to the sub-field of knowledge management studies, where knowledge integration is claimed to be one of or perhaps even *the* main challenge in achieving innovation (Nonaka & Takeuchi, 1995; Davenport & Prusak, 1998; Nonaka & Teece, 2001). Integration has been called for in: collaborations between scientific disciplines and technologies (Hughes, 1998; Iansiti, 1998; Schienstock & Hämäläinen, 2001; Wolff, 2001); the achievement of functional coordination within firms (von Hippel, 1988; Dougherty, 1992; von Hippel & Tyre, 1995; Sapienza, 1997; Nonaka & Nishiguchi, 2001; Tidd, Bessant, & Pavitt, 2001; Carlile, 2002); and in inter-organizational collaboration (Powell, 1990; Freeman, 1991; Castells, 2000). As different forms of boundary crossing, they all require a specific aspect of integration, i.e., knowledge networking, and are thus highly analogous with each other.

Even though the question of knowledge generation in innovation is studied in several overlapping fields—the economics of innovation, evolutionary economics, organizational learning, knowledge management, competence-based theories of the firm and inter-organizational collaboration—and the importance of the issues of knowledge integration and networking are acknowledged by most, there are few studies that focus specifically on the *epistemic* dimension of interaction. Knowledge management studies, for instance, starts out in a promising way, posing questions such as, "What knowledge is there in the organization?" and, "How can knowledge be shared?" but then treats the knowledge-sharing mainly as an issue of access to information, rather than as the activity of crossing epistemic boundaries that it, in reality, so often is (Hansen, 1999; Cross, Parker, Prusak, & Borgatti, 2001; Gold, Malthora, & Segars, 2001).

The innovation literature, similarly to the other literature on organizations, tends to deal with knowledge integration as being a result of institutional and technological mechanisms (e.g., Tidd et al., 2001), rather than as an epistemic process to be analyzed in its own right. Only a few authors break this pattern (viz., Nonaka & Takeuchi, 1995; Iansiti, 1998; Miettinen, Lehenkari, Hasu, & Hyvönen, 1999; Cusmano, 2000; D'Adderio, 2001; Grant, 2001; Murray, 2001). Scholars of organizations would benefit from a greater acquaintance with social scientists' research on scientific disciplines and, particularly, on collaboration across disciplinary boundaries (Klein, 1996; Gibbons, Limoges, Nowotny, Schwartzman, Scott, Trow, 1994; Lenoir, 1997; Newell, 1998; Cunningham, 1999; Sommerville & Rapport, 2000; Becher & Trowler, 2001; Lattuca, 2001). Those authors have gone further than organization and innovation researchers in conceptualizing the processes of knowledge networking (Ben-David, 1960, 1966; Edlund, Hermerén, & Nilstun, 1986; Fujimura, 1987; Klein, 1990, 1996; Dahl & Sørensen, 1997; Langlais & Bruun, 1998; Boden, 1999; Knorr Cetina, 1999; Bruun, 2000;

Weingart & Stehr 2000). However, in contrast to researchers of organizations and innovation, social scientists studying collaboration and integration in science have paid little attention to issues of management, organizational capabilities and competitiveness. A comprehensive study of knowledge networking and innovation would draw from both traditions.

KNOWLEDGE REGIMES AND FRAMEWORKS

We define knowledge networking as learning and knowledge production by interaction across epistemically defined boundaries between individuals, groups, or units. This immediately raises questions about the nature of such boundaries and about the means with which they can be identified. At one level, all individuals embody different sets of knowledge, the implication being that all communication involves knowledge networking. At a different level, it is obvious that some groups of people share the same knowledge and that there is collective variation to be accounted for. Societies create systems for maintaining, reproducing, diffusing and developing bodies of knowledge. We call these systems knowledge regimes. Contemporary society is highly differentiated in this sense—it has shaped a large number of knowledge regimes. Although the study of knowledge regimes is only in its infancy, we already know that there is a significant variety of different kinds of knowledge regimes, including: communities of practice (Wenger, 2002), functional units in organizations (Dougherty, 1992; Carlile, 2002), scientific disciplines and sub-disciplines (Becher 2001), scientific and technological platforms (Keating & Cambrosio, 2003), scientific research programs (Fujimura, 1996) and professional systems (Abbott, 1988).

A knowledge regime is a system of individuals, organizations, institutions, intellectual and material resources, practices and values that consolidate and reproduce a certain way of learning and knowledge generation—a knowledge framework—which can be achieved through a range of mechanisms, for example the standardization of training, the implementation of exclusive certification systems, or the creation of a labour market for people with a certain competence (Turner, 2000). We adhere to a pragmatic notion of knowledge: knowledge is indicated by repeated success in the application of a certain type of information in action. However, whenever explicit reasoning is involved, there is a further requirement of proper justification and adherence to the rules of logic. In other words, repeated success in the application of a certain type of information is not considered to be a sign of knowledge if it is based on contradictory reasoning, or on beliefs that are poorly justified (as is the case when generalizations are based on very few examples).

Knowledge regimes generate scripts for behaviour—a nested system of scripts. Some scripts are fundamental, regulating the basic mode of learning and the type of knowledge that is sought, and cannot be changed without altering the regime. Others are more open for change, at least in the long term. They include the culture and organization of knowledge generation and its evaluation, as well as the basic concepts, methodologies and theories that are used. On the most dynamic level, there are particular methods, techniques and instruments, as well as concepts and theories, that are outside the epistemological core of the regime (as peripheral concepts and theories), and therefore relatively easy to change.

Scripts should be seen as *paradigmatic exemplars* or *prototypes* rather than as tight determinants of behaviour (Nooteboom, 2001). This means that scripts do not affect people's behaviour in a direct, causal way, but through the mediation of interpretation. Scripts are always interpreted in some context, and people tend to modify them so as to fit the context better. Accordingly, people enter situations with a paradigmatic repertoire of different variants of a prototype script. The prototype works as a default on which one can fall back whenever one is unsure about how to behave. Consequently, with regard to knowledge regimes, we see that there can be variation in the knowledge frameworks they generate. The notion of knowledge framework is a key tool for the analysis of knowledge networking. In this we deviate from the usual practice of focusing on *specific* types of knowledge frameworks, such as those produced by scientific *disciplines,* and of talking about knowledge integration in terms of, for instance, multi*disciplinarity,* or inter*disciplinarity*.

By defining the knowledge regime and knowledge framework as general categories, we acknowledge that they occur in a variety of forms and that knowledge networking occurs in many distinct contexts. Common for all knowledge regimes is, in our definition of the term, that the knowledge frameworks that they consolidate and reproduce fulfil three criteria for identification: they 1) define a certain domain of objects and relations as the object of knowledge, 2) promote a distinct methodology (including methods and instruments) for learning and knowledge generation, and 3) embrace a particular interpretation of why learning and knowledge generation is important, and of the role that the knowledge-generating agents are supposed to play. That we use terms such as "domain of objects and relations" and "methodology" does not imply that we see all knowledge frameworks as scientific or academic. Both terms should be understood in a broad sense here, including, for instance, various types of knowledge (know-what, know-why, know-how, and know-who/when/where) and modes of learning (learning-by-doing, learning-by-interacting, learning-by-searching and learning-by-simulating).

Examples of knowledge frameworks

In this subsection we provide several examples of knowledge frameworks that we have identified in our own empirical research. There is of course a large body of literature that deals with different kinds of knowledge regimes and consolidated frameworks: communities of practice, functional units in organizations, scientific disciplines and sub-disciplines, scientific and technological platforms, scientific research programs and professional systems, among others. We do not discuss the similarities and differences between these categories here, since the role of the present section on knowledge regimes and frameworks is only to prepare for the analysis of knowledge networking in the next section. A few examples might nevertheless be useful to give the notion of knowledge framework a more concrete content.

In what follows we present three pairs of knowledge frameworks that we identified in three distinct studies. The characteristics of the knowledge frameworks are summarized in Tables 1-3, with the three quality dimensions of knowledge frameworks as the organizing principle. Due to space restrictions, we keep our commentary very brief.

The first study was conducted in an academic context, with a focus on two key knowledge frameworks in contemporary biomedical research: the functional genomics approach and the bioinformatics approach to biomedical research (Bruun, forthcoming). The underlying knowledge regimes of both of these frameworks are multidisciplinary, and therefore are better described as research programs organized around particular scientific platforms than as disciplines. The purpose of the study was to explain why many researchers felt that interaction between the two research programs was difficult, despite a general consensus about its necessity and desirability. The characteristics of the two knowledge frameworks are summarized in Table 1.

Bioinformatics researchers and functional genomics researchers focus on different objects of knowledge. While functional genomics researchers are interested in biochemical entities—their structures, interactions and biological functions—bioinformaticians see the world more in terms of abstract data, to be manipulated mathematically in software implementations. Accordingly, the two groups of researchers use different methods and instruments for learning and knowledge generation. On the basis of our interviews, they also seem to have different perceptions of their own roles as knowledge producers. While bioinformaticians tend to talk about the need for information management, and thus an optimization of genomics research, genomics researchers themselves talk more about the "real world" applications of their knowledge, for instance the development of new drugs and the struggle against problematic diseases.

Table 1: The characteristics of two knowledge frameworks (KF) involved in contemporary DNA, or oligonucleotide, microarray-based biomedical research: the bioinformatics KF and the functional genomics KF

	THE BIOINFORMATICS KF	THE FUNCTIONAL GENOMICS KF
OBJECT OF KNOWLEDGE	• Algorithms, data structures, analytic techniques, information retrieval, software design, databank design, relation between information in separate databanks	• Biochemical entities & reactions, cell structure, location of genes, structure & function of proteins, signalling pathways, regulatory networks, genetic background of diseases, model organisms
METHODOLOGY FOR LEARNING AND KNOWLEDGE GENERATION	• **Methods:** programming; data mining, string matching, structure matching, string-structure matching; data reduction and filtering; analytic techniques (such as SOMs, nearest neighbour analysis, dendograms, relevance networks) • **Instruments:** computers, programming languages (such as C, C++, PERL, FORTRAN); standardized formats (such as FASTA); specialised software; data visualization tools; the WWW	• **Methods:** expression analysis, study of DNA variation, genotyping of large sets of known DNA variants; microarray experiment; normalization, statistical analysis; data mining, analysis of biological significance; biological validation • **Instruments:** cDNA microarrays, oligonucleotide arrays; reagents, PCR & other laboratory equipment; scanner, computer; public databases, local database; specialised software, data visualization tools; the WWW, MIAME guidelines, MGED ontology, MAGE-ML documents
EPISTEMIC SELF-UNDERSTANDING	• **Purpose:** to optimize the management of biological and biomedical information • **Measures of success:** diffusion of new tools; diffusion of knowledge about how to use bioinformatics tools; publication in specialised computer science journals; increasing role in biomedical research (for instance as co-authors of articles) • **Image:** the analytic scientist who sees the logical (and therefore objective and eternal) connections between things	• **Purpose:** to understand the causal mechanisms of diseases; to contribute to the development of better drugs • **Measures of success:** publication of articles in high quality heroic scientist in the service of humankind (creating "advances in our understanding of life, and improvements in scientific journals (biology, biomedicine, etc.); a discovery; the development of a new, better drug • **Image:** the health of humans and other living things"); the entrepreneurial scientist

The second study took place in a small coffee company in Finland (Janasik, 2003). Despite its small size—approximately thirty employees—the company had a functionally diversified structure. Six functional knowledge frameworks were identified. A historical analysis of decision-making in the company revealed several instances of conflict between the different perspectives. Table 2 summarizes the characteristics of two of the six frameworks, named after the type of individual that embodied them: the Entrepreneur and the Accountant. In this case, the notion of knowledge framework is useful for posing questions: Do "entrepreneurs" and "accountants" in other small companies embody similar knowledge frameworks? If this is the case, can it be explained by some underlying knowledge regime that is external to the companies, or are the common perspectives simply a result of isomorphism in their working conditions?

Table 2: The characteristics of two knowledge frameworks (KF) that were operative in a small coffee company in Helsinki, Finland, in 2002

	THE ENTREPRENEURIAL KF	THE ACCOUNTANT KF
OBJECT OF KNOWLEDGE	• Coffee brands; coffee machines; other coffee-related products; trends in the business; cultural trends • Coffee-related social network ("Who does what?" etc.)	• Changes in revenues, turn-over, debts, salaries, other costs, productivity • Changes in regulations, labour contracts, contracts with suppliers and customers
METHODOLOGY FOR LEARNING AND KNOWLEDGE GENERATION	• Methods: visioning, planning, scanning, building social networks; mobilizing people • Instruments: personal calendar for managing social contacts; car for moving around ("office time is often a waste"); papers, journals and the Internet for scanning; phone for communicating	• Methods: monthly financial reports, annual accounts, monetary transactions (salaries, invoices), communication with heads of outlets, communication with employer's association and labour union • Instruments: office, computer, book-keeping software, Internet, calculator, archives, branch journals
EPISTEMIC SELF-UNDERSTANDING	• Purpose: to create new business; to initiate new activity; to make good deals • Measures of success: mobilization of the board and employees around new initiatives; growth in turn-over; the stabilization of new activities • Image: enthusiastic project initiator	• Purpose: to keep the company on a healthy financial track; to make the financial processes transparent • Measures of success: the usage of economic instruments in company decision making; working cash flow practices; good solidity; salaries paid in time • Image: rational guardian of firm expenditure

In the company that was studied, the strain between the Entrepreneurial and the Accountant knowledge frameworks eventually led the accountant to leave the company. The entrepreneurial employee was mainly interested in the "substance" of the company's activity: the import of coffee and coffee machines, and the expansion of the business. The accountant, on the other hand, had concerns about the economic state of the company, particularly the cash flow. This led to conflicts about, for instance, the system of billing. The entrepreneur wanted a system that allowed him control and flexibility in pricing and other functions related to the billing, while the accountant insisted that billing should be decoupled from the entrepreneurial activity. For the entrepreneur, billing was a tool for negotiation, while for the accountant it was mainly a tool for maintaining a healthy cash flow. The two never found a solution to the conflict that would satisfy both parties. As a result of this, and other similar problems, the accountant left the company.

A third study was conducted in a large, Finnish dairy company, Valio, which entered the "functional food" market in the late 1980s. Since then, Valio has developed a number of functional food products, some of which are based on the use of a probiotic bacterial strain called *Lactobacillus* GG (LGG). As Valio developed its first LGG-based product, various epistemic boundaries had to be crossed, including disciplinary boundaries in research and cognitive and organizational boundaries in innovation. Janasik (Langlais, Janasik & Bruun, 2004) analyzed the manner in which a new way of thinking about the business of food developed within the company, eventually forming a process of internal networking (identifiable as the LGG network) that promoted a scientific basis for product development. Despite initial resistance from the rest of the company, which was still working within the confines of the traditional mode of food production and marketing, the LGG network gradually consolidated into an established knowledge regime with its own characteristic knowledge framework. The tension between those two lines of thinking in the company has persisted to the present day.

At Valio, the hardest part in the introduction of the new way of thinking was to align the use and practice of leading edge science with the more down-to-earth approach that characterized much of the work done in the company at the time. In order to understand the new way of thinking, the people within the traditional mode had to extend the very *notion* of food to include aspects that had previously belonged squarely to the sphere of drugs, such as, for example, the credibility of the science behind the new ingredient. On the basis of our interviews, this difficulty in extending the object of knowledge was the focal point of the communicative challenges between the two knowledge frameworks. The divergent understandings also had direct bearings on epistemic self-understanding: the dynamic, innovation-oriented entrepreneurs contrasted starkly with the reliable producers of high-quality bulk dairy products who were simultaneously trying to guarantee the subsistence of Finnish milk producers. Although today both knowledge frameworks still exist with a certain amount of tension within the firm, the first kind of self-understanding nevertheless occupies a prominent place there.

Table 3: The characteristics of two knowledge frameworks (KF) that competed with each other within Valio, a large Finnish dairy company, in the late 1980s and early1990s

	THE LGG KF	THE TRADITIONAL KF
OBJECT OF KNOWLEDGE	• Microbes, especially Lactobacilli; other milk ingredients (proteins, lipids etc.); specialized milk processing technology; trends in scientific research; trends in health-related behavior • Research and development in industrial and academic contexts	• Traditional dairy products; the processing, developing, marketing and selling of bulk dairy products • Changes in consumer preferences; changes in market trends • Logistics (own advanced distribution network)
METHODOLOGY FOR LEARNING AND KNOWLEDGE GENERATION	• Methods: visioning, planning; scanning research journals, magazines and Internet fora; conducting scientific research; attending scientific conferences; collaborating with spear-head research units • Instruments: research laboratories within and outside the firm; the company's technology licensing business unit; latest ICT technology	• Methods: collaborating with applied research units on improvement of process technology; organizing product tastings; surveying, analyzing and forecasting consumer and market changes • Instruments: milk processing technology; employees' taste organs; surveying and forecasting devices; latest ICT technology; devices for logistic analysis
EPISTEMIC SELF-UNDERSTANDING	• Purpose: bringing forth radically new innovations with high added value • Measures of success: successful completion of expensive and long-term research and development projects • Image: dynamic, commercially informed scientist	• Purpose: to produce high-quality bulk dairy products; to act as guarantor and developer of the livelihood of milk producers • Measures of success: growth in short-term sales figures • Image: reliable producer of high-quality dairy products

KNOWLEDGE NETWORKING

We have defined knowledge networking as learning and knowledge production by interaction across epistemically defined boundaries between knowledge agents, such as individuals, groups, or organizational units. Above, we argue that knowledge networking is becoming increasingly important for many organizations and particularly those involved in innovation. In this section we go deeper into this notion, utilizing the conceptual framework presented in the previous sections.

Knowledge networking is the activity of forming and maintaining an epistemically heterogeneous social structure, i.e., the knowledge network, as a part of some particular trajectory of learning and knowledge generation. The networking process thus links knowledge agents having different knowledge frameworks to each other, and to a particular focus and a shared effort. There are several possible forms for such collaboration. We present a typology of knowledge networking that is based on the set of criteria represented in Table 4.

Table 4: Three modes of knowledge networking and their characteristics

	MODULAR KNOWLEDGE NETWORKING	TRANSLATIONAL KNOWLEDGE NETWORKING	PIONEER KNOWLEDGE NETWORKING
EPISTEMIC OBJECTIVE	Combination	Alignment	Integration
DESIGN CONCEPT	Closed	Closed	Open
INTERACTION	Mediated	Direct	Direct
INTERFACE	Predefined	Predefined	To be built
COMMUNICATIVE SPACE	Narrow	Narrow	Broad
DECISION-MAKING	Centralized	Distributed	Distributed
MANAGERIAL CHALLENGE IN INNOVATION	Coordination, Recombination	Interface management	Communication management
POTENTIAL	Incremental learning	Incremental learning	Radical learning

On the basis of these criteria and the existing literature on knowledge generation in organizations, we identify three categories of knowledge networking: modular, translational and pioneer. Before discussing them, it is necessary to clarify briefly the relation between knowledge regime, knowledge framework and knowledge network. A knowledge framework can be created in two ways. It is either a result of the structure of a particular task, which means that it will be embodied by anyone with long enough experience of performing the task; or alternatively, a knowledge framework is created within a knowledge regime, and embodied by people who have been socialized to the standards of that regime. Collaboration between people with different knowledge frameworks (and most likely from different knowledge regimes) takes place in a knowledge network.

The knowledge regime and the knowledge network should be seen as ideal types at opposite ends of a continuum. In the real world, structures of knowledge generation move along that continuum. What might first be a knowledge network can consolidate into a knowledge regime with a shared knowledge framework. Conversely, a knowledge regime undergoing fragmentation can successively acquire the heterogeneous characteristics of a knowledge network. The distinction between them is also a question of analytical level. A more detailed analysis of a knowledge regime generally reveals that it consists of interacting sub-level knowledge regimes, and that it can be seen as a knowledge network if analyzed at a lower level. Correspondingly, seen from a higher analytical level, a knowledge network can appear to be a knowledge regime. The ideal and relative nature of these notions needs to be recalled; they are tools for analysis, not ontological categories.

The typology of knowledge networking can be used for distinguishing between different forms of interaction in learning and knowledge generation. We propose that the three forms of networking, which of course occur in many variations, incarnate problems that are specific to each of them, that is, problems that characterize the knowledge network independently of categories of industry, sector, etc. The proper solution to such general problems will depend on the local context of knowledge networking. However, if our hypothesis that people working in different industries, sectors, etc., share similar network-specific problems is true, then learning across organizational sectors is motivated. Empirical research would then enquire as to how common problems have been solved in different contexts.

Modular knowledge networking

The potential benefits of division of labour and hierarchical organization are well known for scholars of organization. *Modular knowledge networking* (MKN; see Table 4 and Figure 1), in its simplest form, organizes learning and knowledge generation through two levels, consisting of separate, independent modules of learning and knowledge generation at Level 1, and an integrating function at Level 2 (Simon 1962).

Modular knowledge networking is common in industrial manufacturing and innovation. The notion of "product architecture" has been used to refer to the components of the manufactured product and the way in which these are linked. Henderson and Clark (1990) argue that multi-component products embody two types of knowledge, component and architectural. Component knowledge is about the core design concepts of the components, combined with a) mastery of their production and b) a value set that underpins this activity ("b" is our addition.) Architectural knowledge, on the other hand, is an understanding of how components are integrated into coherent wholes, combined with the skills and desire to perform such an integrative task. In other words, MKN combines knowledge frameworks for the production of component output with a knowledge framework for the integration of such output. This is the modular division of labour. Each component of a product, say a car, can be manufactured independently, for instance by different firms. However, decisions about *changes* in components cannot be made without regard to the product as a whole and the interaction of its components. Architectural knowledge is thus needed for the coordination of component development within distinct knowledge frameworks. Modular knowledge networking allows different combinations of exploration and exploitation.

We can imagine a situation in which the core design of one of the components is changed without affecting the core designs of the other components. For instance, to continue with the car example above, the engine could be changed from running on gasoline, to diesel, without dramatically affecting the rest of the car. In this case, exploration in engine design is compatible with more exploitative modes of operation in the production of other components, and even in their integration. A more radical alternative is "architectural innovation," which implies that the way in which the components of a product are linked together is changed, but the underlying knowledge frameworks remain unaltered (Henderson & Clark, 1990, p. 10). In Henderson and Clark's example, a change from the production of large ceiling-mounted fans to portable fans would require the introduction of a new architecture, although the core concepts of the components would still be the same; the fan would still be composed of a blade, a motor, a control system and a mechanical housing.

MKN can be found anywhere where knowledge generation is organized through component production and integration. For instance, multidisciplinary scientific projects are often implemented as MKN, with each disciplinary representative focusing on his own field of expertise and a project coordinator combining the knowledge produced as project reports, anthologies, or seminars. What makes such products modular is that the focus is on *combining* knowledge frameworks, not on effecting direct communication between them; metaphorically, it leaves each framework as a black box, but seeks to combine the various black boxes.

Such division of labour in scientific activities has been called "indiscriminate interdisciplinarity" (Heckhausen, 1972), "encyclopaedic interdisciplinarity" (Boden, 1999) and "encyclopaedic multidisciplinarity" (Bruun, 2000).

Academic MKN, as exemplified by the development of a multidisciplinary project, seminar, or anthology, can be explorative in the sense that it combines perspectives in new ways, and thereby provokes in its audiences a broader or otherwise different grasp of the problem at hand than is customary. However, the scope of exploration is usually limited, because of the restricted degree of interaction between perspectives. Similarly, architectural innovation in product development is limited to the refinement and extension of established designs. More radical steps, such as, to continue with our car example, moving from production of fossil fuel- to solar-powered cars would require the establishment of a new architecture based on new design concepts. During the period of transition, the latter would have to be far less closed, with less-centralized decision-making and more direct communication between the specialized component producers (Henderson & Clark, 1990, p. 11).

The coordinators and integrators play a crucial role in MKN, since they are the obligatory point of passage for all communication within the network. The efficiency of such networking is partly a result of the selective powers that the coordinator, or coordinating group, has. On the negative side, such centralized selection restricts the communicative space of the network and thereby also its potential as a source of more radically oriented learning.

Translational knowledge networking

To explain translational knowledge networking, we first reiterate that modular knowledge networking resolves the conflict between strategies of exploitation and exploration by giving priority to exploitation; people can continue to work within their own knowledge framework in MKN at the same time as their activities are indirectly connected to people with other frameworks. In other words, perspectives are sustained in MKN. Communication is usually mediated, filtered and modified by the coordinator. In the second type of knowledge networking, *translational knowledge networking* (TKN; see Table 1 and Figure 1), communication between knowledge frameworks is more direct and, in consequence, knowledge generation more distributed. Still, these networking processes demonstrate many of the characteristics of exploitation (in contrast to exploration). The reason is that they organize communication through a standardized, mediating code that translates the languages of particular knowledge frameworks into a language that can be understood by all. Metaphorically speaking, the coordinator is replaced by a standardized tool for codification, or interfacing device. Examples are the Digital Model (D'Adderio, 2001), the Delphi Method (Munier, 2001), the laboratory protocol (Fujimura, 1996) and the scientific ontology (Stoeckert, Causaton, & Ball, 2002).

Industrial design requires intense interaction between different functions, or sub-level knowledge regimes, in the firm. This interaction can be organized through TKN. To use one example, the Digital Model is a software-based method for development of products such as cars, providing a "virtual prototype," that is, a single, updated source of product data that is available to all development functions and that can be displayed according to the specific requirements of each. Once the engineering function has generated it, for instance, the Digital Model is used as a common reference point by all other organizational functions: the toolmaker, for direct input to the tooling machines, the analyst, for input in simulations and the marketer, for obtaining feedback from customers or executives (D'Adderio, 2001, p. 1411). The Digital Model is generally not static, but can be manipulated in an iterative fashion by the different functions. Each specialized unit may modify the Digital Model as development advances, each providing input based on its particular expertise. In this way, knowledge can be shared without carrying the costs of non-standardized communication. Specialized knowledge is the backbone of the process.

For TKN, the challenge is to design interfacing devices that work well, and to organize and manage their use. We call this *interface management*. TKN arranges knowledge networking on two levels, the *global level*, represented by the interfacing device, and the *local level*, consisting of people with specialized knowledge who are working in some particular context. While local level inputs often are characterized by epistemic *homogeneity*, in the sense that they are produced within some consolidated knowledge framework, the global level is *hybrid*, a combination of inputs from different frameworks. The requirement for producing such hybrids is that one develops a language or other form of codification that can mediate between knowledge frameworks. This can only be done by forming yet another, new knowledge framework for the production and maintenance of the interfacing device. Digital Models, Delphi questionnaires, laboratory protocols, standardized scientific ontologies and other interfacing devices do not exist in some epistemic vacuum, but are implemented by people who have been assigned because they have specialized knowledge about the interfacing device as such. In contrast to the coordinator in MKN, they do not merely combine the performances of different specialists or groups. Instead, they plan, design, develop and maintain the instrument that allows translation and communication, and thereby more self-organized integration, between knowledge frameworks. The challenge for managers of TKN is to stimulate effective communication between the global and the local levels.

D'Adderio (2001) suggests that communication between the levels needs to be supported by the construction of local appropriation routines. This is confirmed by Munier and Rondé (2001), who studied the application of the Delphi Method in a technological foresight carried out in France in 1994. Delphi-based foresights are based on the translational knowledge networking of experts. The process has several phases. First, a questionnaire is prepared. The questionnaire formalizes the future possibilities that are considered to exist for the topic at hand. It is then distributed to the panel of experts. The panellists answer the questions in the survey on the basis of their expertise. Answers are analyzed statistically and the outcome—such as the median value of the opinions of other experts—is in turn fed back to the experts, who then get a chance to revise their first estimations. The panellists are, in other words, not supposed to communicate freely with each other. Interaction is instead organized through the use of the interfacing device, the statistical feedback.

Munier and Rondé (2001) show that panellists responded to global information in different ways, despite its having been standardized; responses were based on local "translations." Note that the interpretive work in the early stages of such a process tends to be *explorative* in nature, because for most parties the interfacing device will be a *new* instrument, requiring knowledge that falls outside their domestic knowledge framework. Consequently, we are not surprised that D'Adderio (2001), writing about the use of virtual prototypes (Digital Model) in the car industry, reports that engineers who interacted with analysts via the Digital Model *learned* to perform simple forms of analysis themselves, thus changing the nature of the exchange between the two functions: "Engineers are able now . . . to prepare their 3D model in a way that is most useful to analysts. This, again, improves coordination in the opposite direction and promotes an inverse translation flow, this time from Engineering to Analysis. Meanwhile Analysis, as a development function, retains its fundamental role by 'specializing' on higher-order, complex analysis problems" (D'Adderio, 2001, p. 1420).

To summarize, the challenge for TKN concerns interface management; to design interfacing devices that can be appropriated by the different knowledge agents involved, and to develop routines for initiating, maintaining and developing the appropriation activities themselves. This in turn raises the question about best practices for the design of interfacing devices: Is it best that the devices be developed centrally, by professional designers of a particular interfacing device, or should the process of their development involve many, or even all, TKN parties? Munier and Rondé

(2001, p. 1539), in discussing the Delphi Method, argue that *multidisciplinary collaboration* by all the experts, not just the interface design specialists, is needed in the first stage, when the questionnaire that codifies future possibilities is being created: "... knowledge should be shared by the experts *via* knowledge conversion processes, in order to obtain clear topics, understandable by the whole community of experts . . ." (Munier & Rondé, 2001, p. 1539). Collaboration on the design of the interfacing device can then be quite explorative in orientation and involve direct rather than interface-mediated communication. Thus, there is no watertight boundary between TKN and the third form of knowledge networking, *pioneer* knowledge networking.

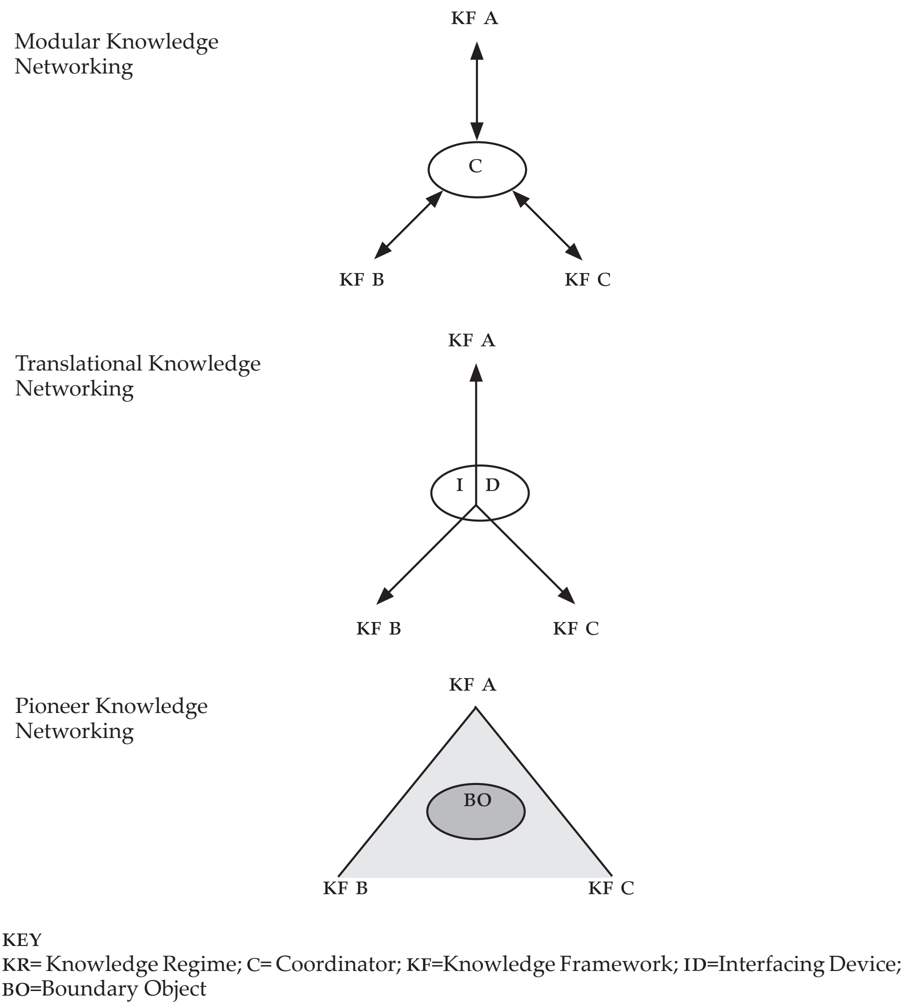

Figure 1. The communicative structure of three models of knowledge networking: modular, translational and pioneer knowledge networking.

Pioneer knowledge networking

In spite of the occasional fluid character of the boundaries between the different forms of knowledge networking, a particular form of it, *pioneer knowledge networking* (PKN; see Table 4 and Figure 1), as an ideal type, is clearly distinguishable from MKN and TKN. PKN is based on the participants' *transcending* their domestic knowledge frameworks, generating and integrating knowledge through direct communication across framework boundaries, without any mediators, such as third parties (coordinators, integrators), or established codes for translation purposes (interfacing devices). The initial lack of common ground often occurs among new cooperation partners, who may find themselves talking about completely different or only partly overlapping objects of knowledge, applying completely or partly different methodologies, or even having different interpretations of the purpose of their knowledge generation activity and of the role of the knowledge agent.

As an example of what we mean by PKN, we present our own collaboration with computer scientists in designing a computer simulation of knowledge networking. When we began that work, the two parties—our own group and the computer scientist group—embodied quite distinct knowledge frameworks. Our group knew much about social theories of learning, knowledge generation and collaboration, while the computer scientists had programming and simulation design as their main skills. Our methods were primarily qualitatively oriented, while they operated with algorithms. For us, computers were instruments for writing, communicating and accessing the Internet; for them, computers were the object of, and medium for, research and design. Nevertheless, we were able to develop a shared project. In order to make ourselves understood, our group had to start thinking in terms of programming specifications. In practice, this meant that concepts had to be translated into an abstract language, which in principle could then be further translated by the computer scientists into more technical specifications and, finally, algorithms and Java commands. On the other hand, the computer scientists have seen the project as an opportunity to rethink their earlier (natural language learning) simulations in the light of social science concepts and theories. If the result is to be successful (from the perspective of our group), they have to design the simulation in a way that allows us to generate theoretically significant hypotheses about the nature of knowledge networking. They will not be able to do that unless they understand what we are trying to achieve and why. Both groups have to transcend their original perspectives and a shared language has to be created at the level of programming specifications.

In PKN, interfaces and translations are neither pre-designed nor standardized, but emerge as a part of communication and collaborative knowledge generation. A breakdown in the need for going beyond knowledge framework scripts does not necessarily leave people numbed, as might be expected; they can take recourse in what Shank and Abelson (1995) call *storytelling*. Just as scripts do, stories connect events and actions. However, while scripts offer a relatively ready-made recipe, in storytelling these connections must be invented (see also Brown & Duguid, 1991). This is precisely what we have been doing in the computer simulation project: we invent the programming specifications for our social science concepts; we tell new stories. *Analogy* is an important tool in this activity; new connections are created through analogy with previous experiences that have some structural similarity to the novel situation (Nooteboom, 2001). A path for pioneering emerges from this rudimentary structure.

The notion of *boundary objects* (Star & Griesemer, 1989; see also Bruun & Toppinen 2004), as tools for interacting in a particular time and place, becomes useful here. A boundary object supports communication between distinct knowledge frameworks by creating a focus for common attention, but without requiring interpretation in the same way by all knowledge agents. The object has to be ". . . plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. . ." (Star & Griesemer, 1989, p. 393). They differ from the interfacing devices of TKN by being more loosely defined, experimental and changing; boundary objects, as we define them, are *non-standardized* devices for anchoring epistemically heterogenous discourse. In the project described above, the computer simulation as such constitutes the boundary object. It gives a common focus to the efforts of the two groups, despite being interpreted differently by them: for our group the simulation is an instrument for developing the theory of knowledge networking; for our collaborators, the group of computer scientists, it is a context for developing new program architecture and design. There are different types of boundary objects: repositories, such as new databases and libraries; hybrid forms and methods, providing shared problem-solving formats across functional settings; representations, such as sketches or computer simulations, which provide a tangible focus that can be shared; and "maps" (such as Gantt charts, workflow matrices and process charts), which "represent the dependencies and boundaries which exist between different groups or functions at a more systematic level" (Carlile, 2002, p. 451).

An important, both defining and determining characteristic of PKN is the need for synthetic knowledge. This is well illustrated by the contemporary attempts to integrate computer science with bioscience, or bioinformatics, in order to develop new tools for large-scale DNA, RNA, and protein projects (Fields, 2003, p. *ix*). While much biomedical research and innovation can be organized in a modular manner (Gambardella, 1995), the use of bioinformatics in biomedical research often seems to require pioneering and synthesis. The biologist needs help with the statistical analysis of the enormous amounts of data that modern experiments generate; such tasks, however, cannot be "externalized" to the computer scientist, or the bioinformatician (as one would do in MKN); because there are many ways of discovering relations between data; and only the biologist can distinguish the biologically relevant outcomes. Thus, active and close collaboration is needed (Kohane, Kho, & Butte, 2003). Many of the problems predicted by the PKN model occur in the actual attempts to collaborate, most notably in the difficulty of building bridges between specialized knowledge frameworks. To continue our example, bioinformaticians attempt to facilitate communication by using various boundary objects, for example sketches that they have made, because they function as an "external scaffold" (Bruun & Langlais, 2002; Clark, 1997) for individual thinking, creating a tangible tool for interactive communication (Henderson, 1991).

Boundary objects alone do not suffice for integration at a more global level, such as that of the creation of a stabilized interfacing device. More permanent integration requires, as Fujimura (1992, 1996) points out, that a system or "package" of standardized boundary objects and routines for using them is constructed. Here, "construction" refers to the social embeddedness of knowledge, ideas, perceptions, and so on (Berger & Luckmann, 1966/1987; Bloor, 1976/1991; Pinch & Bijker, 1984). In the present context, "constructive" designates that not only knowledge, but also the means for communication and mutual knowledge generation need to be constructed and embedded in the particular knowledge network in which they are used. The process of doing this is the actual pioneering, and the form for it is the PKN. As a result, a new territory of knowledge is constructed (Deleuze & Guattari, 1986; Klein, 1996; Becher & Trowler, 2001).

PKN is therefore, per definition, an explorative activity. There is, however, no guarantee for success in such joint exploration across knowledge-related boundaries. A review (Bruun, 2000, 2002) reveals three major challenges. First, it requires a high degree of methodological self-awareness and self-reflection, because there are no fixed rules—no predetermined scripts—for how to solve the epistemological problems that are bound to emerge. PKN is therefore, as already mentioned, narrative in nature, based on an interactive storytelling rather than a process of enacting of scripts. Not only the details of the story, but the storyline itself, have to be invented. Abductive thinking and the use of analogy play an important role (Merrell, 1995). This brings us to the second challenge: effective PKN requires certain predispositions and competencies, such as openness for new impressions, fearlessness in the face of the unknown, sufficient awareness of the knowledge frameworks of one's collaborators, the ability to codify one's own knowledge framework and communicate that information to collaborators from other knowledge regimes (Klein, 1996). Such individual dispositions are imported to the network by each of its members, so the selection of participants is important. On the other hand, network activities also affect the participants, and can contribute to bringing forth constructive attitudes. The third challenge is to effectively bridge the social and cultural differences between knowledge regimes. These are related to the particular practices that constitute knowledge frameworks and thus enable knowledge generation. What is new in this is to see the interaction between these practices as a distinct type of networking activity, in contrast to that posed by the MKN and TKN typology. Although the need for more studies of these differences remains apparent, a number of key characteristics, most of them surprisingly pragmatic and dependent on the social dynamics of the workplace, in all of its local, extended and even virtual respects, have been postulated. It is often striking how, at the level of the workplace, where individual scientists, designers, managers and so on, daily gather to create new products, whether those products are for example knowledge itself, consumer goods, drugs, processes, or whole new industries, the factors that can influence the success of pioneering efforts can be so seemingly primitive, banal, even mundane, and as a result easy to neglect. Such factors include the inter-personal dynamics of the workplace, the physical quarters of the project, the "chemistry" between the leadership (or what constitutes it) and the led; the financial incentives for productivity; and the questions of motivation, loyalty and belonging. Everything and everyone, even the eccentrics, must somehow be induced to function for the good of the project, the enterprise, and the organization. At the same time as all these can be daunting, there are enough successes that their common features are becoming more clear (Sapienza, 1995; Klein, 1996; Mey, 2000). For example, the need for respect for the characteristics of other professions and academic disciplines is paramount, no matter how odd they might seem from the outsider's perspective; just as there needs to be sensitivity to the different interpretations of boundary objects that representatives from other fields may entertain. No less necessary is that projects have leadership that is aware of the extra challenges and pressures that pioneering work presents (Kidder, 1981; Hughes, 1998; Vaughan, 1996; Hollingsworth & Hollingsworth, 2000).

PKN displays a strong tendency toward distributed learning and knowledge generation, which itself becomes one of the most difficult managerial challenges, both as a mode of operation, and as an innovation itself. Some PKN not only expresses this as an emergent quality, but as an explicit goal: discovering a new method of innovation is itself one of the innovation objectives.

CONCLUSION

The black box of knowledge networking has been opened and at least partially illuminated. We have developed several concepts within the idea of knowledge networking that are helpful in managing the processes of generation and integration of knowledge in and between organizations. When managed well, we propose, knowledge networking can make all the difference between successful and unsuccessful performance; managed poorly, it can become a burden, a disadvantage that makes organizations inefficient and uncreative. We agree with Sapienza and Stork (2001) that ". . . if leaders are unable to harness the benefits of diversity, discipline differences can compromise the outcome."

Recapitulating, we see that organizations continually need to learn, absorb, generate and integrate new knowledge, at many different levels. This process is made up of variously relating degrees of knowledge exploitation and exploration, which fluctuate continuously between, respectively, consolidation as knowledge regimes, and coordination or reconfiguration in knowledge networking.

We have identified three *ideal types* of knowledge networking: modular, translational and pioneer. In reality, two, or even all three types can occur in parallel or intermixed in one and the same organizational process. Our typology is useful for distinguishing between the opportunities and challenges of the different forms of knowledge networking. For managers, this can imply a deeper understanding of the needs of individuals and their organization. When different knowledge networking processes overlap, our conceptual tools can contribute to a better insight into the contradictions that complicate the work process.

For theorists of management and organization, the distinction between the different types of knowledge networking presents a range of research questions that are worth pursuing. At the level of general theory, the properties of the three types of knowledge networking need be further investigated. The descriptions of properties in the previous section, condensed in Table 4, are based on reasoning on the basis of available research, but lack sufficient theoretical and empirical backing. More articulated theory, based on focused and systematic empirical research, should explain why these three forms of knowledge networking have different properties and what those properties are.

Our conceptual framework gives rise to a whole set of research questions with a relevance for both theory and the concrete task of building and managing organizations: What problems are typical for each form of collaboration? What kinds of solutions are there for those problems? When is one kind of knowledge networking more efficient than others? What factors determine the choice of collaborative form? The research that we have conducted indicates that there is a relation between the type of problem and the way in which knowledge networking is organized. In a software team studied by Bruun and Seppo Sierla (not yet published), well-defined problems were solved by decomposing the problem into sub-problems, and by working on them in a modular fashion. Ambiguous and poorly defined problems, on the other hand, were dealt with through pioneer knowledge networking (see also Langlais, Janasik & Bruun, 2004). The same study showed that the software engineers tended to use translational knowledge networking—in this case, a formal software standard for communication in testing—for well-defined problems only. Other problem characteristics may also have an influence on knowledge networking. At the same time, it is quite possible that the relation goes in the other direction as well: a certain form of knowledge networking affects the way in which problems are defined.

Both the Langlais, Janasik and Bruun (2004) study and the Bruun-Sierla study suggest that collective projects do not fall into just one or the other of the knowledge networking categories, but instead use several of them, either serially, in parallel, or nested within each other. Thus the software project mentioned in the previous paragraph moved from pioneer knowledge networking to modular knowledge networking as initially ambiguous problems were solved and the overall tasks of the project became more defined. Conversely, in phases of modular or translational knowledge networking, the engineers would change to pioneer knowledge networking whenever they stumbled upon difficulties that seemed to need broader consultation. What problems are posed by the transformation from one type of knowledge networking to another? Are certain transformations—for instance, from pioneering to modular—more difficult than others—let us say, from modular to pioneering? To what extent do the knowledge networking types co-exist in organizations? Do they ever occur alone? Can the different types be intermixed in a way that overcomes the problem of contradiction?

We can also ask how the knowledge frameworks affect knowledge networking decisions. How can we define and operationalize knowledge frameworks in a way that allows us to make systematic comparisons? In other words, how can the differences between knowledge frameworks A and

B be compared with the differences between knowledge frameworks A and C? Such comparison is necessary if we want to be able to say anything more general about how knowledge networking is affected by the characteristics of the participating knowledge frameworks. An as yet unpublished study by Henrik Bruun, Timo Honkela, Ann Russell, Nina Janasik and Matti Pöllä suggests that a clustering method called the self-organizing map (SOM) could be used for the identification of knowledge frameworks and for a quantitative measurement of the distances between them. The idea is to cluster electronic material on the basis of the SOM's contents, and to use the resulting map for an analysis of the determinants of clustering and for measuring distances between the clusters. It is an open question, however, as to whether such distances could have any relevance for knowledge networking.

In addition to structurally-oriented research, more empirical research is needed on the mechanisms, social as well as cognitive, of bridging the distance between different knowledge frameworks in the various forms of knowledge networking. What kinds of strategies, techniques and tools are used? Will attending to such questions and implementing their answers actually lead to positive results for organizational performance, through either increased efficiency or enhanced creativity, or both? If they are disregarded in practice, does knowledge networking become the opposite of the original intention, i.e., *disadvantage*, because of the high costs generated by failure? Inquiring into the issues of transformation and mechanisms marks a step from our current starting point in the more *structural* aspects of knowledge networking (i.e., a focus on the structural characteristics of knowledge frameworks and knowledge networking), to a more *processual* one, with the emphasis on knowledge networking as cognition, action and interaction. We feel that the conceptual framework presented here has both descriptive and explanatory relevance and, as we hope our further work will confirm, a certain degree of prescriptive power. The patterns and processes of networking never cease.

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