
Cultivating Collective Expertise within Innovative Knowledge-Practice Networks (DRAFT)

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Abstract. The purpose of present paper is to examine the collective nature of human expertise from the perspective of three metaphors of learning, i.e., knowledge-acquisition, participation, and knowledge-creation metaphor. From the traditional cognitive perspective, expertise is an exceptional competence relying on mentally processing acquired knowledge structures. This knowledge acquisition (monological) perspective is challenged by sociocultural approaches, i.e., the participation (dialogical) perspective, examining expertise as a process of participating and growing up to a social community in which appropriation of cultural-historically evolved social practices and mediating material and epistemic artifacts play a central role. Rather than assimilation of already existing knowledge or growing up to a stable community, constant pursuit of novelty and innovation is a central characteristic of our time. The knowledge-creation perspective examines expertise in terms of sustained collective efforts of advancing shared objects of activity whether those are ideas, designs, plans, concrete products, or practices being reflected on. Such knowledge-creating practices involving interaction between individuals, communities, and objects appear to be irreducibly triadic relations ("trialogical") in nature, as will be explained. Two case studies of cultivating collective expertise of professional communities are provided which intermix dialogical and trialogical characteristics of expertise where individual, social, and material elements are intertwined in object-oriented and long-term activity. These investigations revealed that real-world expertise is usually defined relationally rather that individually and, frequently, involved hybridization or brokering across knowledge domains. The studies revealed various ways in which expertise is shared between the participants and cultivated by workplace communities' shared practices.

Introduction

The present paper examined human expertise from three perspectives, i.e., knowledge acquisition, participation, and knowledge creation (Hakkarainen, Palonen, & Paavola, 2002; Paavola, Lipponen, & Hakkarainen, 2004; Hakkarainen, Palonen, Paavola, & Lehtinen, 2004). Implications of these theoretical perspectives will be illustrated by reporting results of two on-going investigations of professional expertise. By relying on the two latter perspectives, it is argued that human expertise is collective in nature and cannot be understood as mere individual and mental process (knowledge-acquisition perspective).
We consider the metaphors as heuristic tools that assist in examining various aspects of learning. Following Davidson (2001), we propose that in learning there are always three aspects of human activity involved, i.e., subjective (individual learning and cognition), intersubjective (social communities and cultural interpretations), and objective (material culture and designed entities) represented by the three metaphors. While the first two have been extensively examined and investigated, the third aspect is mostly unknown territory. Yet, in order to have a holographic view of learning one needs to take all of the perspectives, simultaneously, into consideration.

Knowledge-acquisition perspective on expertise

Investigators have examined cognitive processes related to higher-level competencies since the 1970s. Expert studies revealed, contrary to researchers’ expectations, that domain-general reasoning processes or memory-skills did not substantially diverge between experts and novices. The knowledge-acquisition perspective on expertise assumes that experts exceptional performance is based on a large body of well-organized and usable crystallized knowing that assist them in separating essential from unessential aspects of problem solving (see Baltes, Staudinger, & Lindenberg, 1999; Krampe & Baltes, 2003; Bereiter & Scardamalia, 1993; and Feltovich, Ford, & Hoffman, 1997). Experts pursue challenging objectives by relying on limited resources of fluid knowing, develop new practices and procedures that transform novel activity into routines (crystallized knowing), thereby, releasing new resources for carrying out even more challenging projects. Activity becomes gradually easier as agents accumulate crystallized knowing embodying solutions to frequently encountered problems and develop routines for dealing with initially messy and problematic situations. Adaptive experts are ones who constantly invest resources released by accumulating experience for new learning (Hatano & Inagaki, 1992). Experts outperform novices because they have acquired across decade’s practice a rich body of crystallized patterns of solving problems that enable meaningful and effective functioning in familiar (both frequently and infrequently encountered) situations.

Participation perspective on expertise

The above description of psychological research on expertise provides an individualist and mentalist picture of human expertise. From the participation (dialogical) perspective, in contrast, the development of expertise involves transforming participation from peripheral to central as a function of appropriating collective practices (Lave & Wenger 1991). Experts’ bodies of crystallized knowing do not emerge from depths of their mind but are internalized and appropriated from cultural-historically developed expert cultures. Expertise is a matter of growing up and participating in social communities and learning to function according to their shared practices, norms, and values, as Lave and Wenger (1991) have proposed. Expertise cannot adequately be understood as an individual mental process because it is mediated by complex knowledge artifacts and takes place within collective knowledge networks. Consequently, expertise is not only a mental, but a socially and materially distributed process (Salomon, 1993; Hutchins, 1995). Such position involves questioning the Cartesian separation between internal and external processes and encourages one to examine the human mind as a flexible, permeable, and extended system that can be integrated with external instruments and other agents, toward a higher-level intellectual system (Clark, 2003; Donald, 1991; Vygotsky, 1978). While expertise has been studied in psychology as an individual capacity to solve problems, we claim that
investigators have not sufficiently addressed cultural-historically mediated and socially distributed aspects of expertise.

Moreover, expertise relies on merging or fusing cognitive processes within various communities and networks (Hakkarainen, Lonka & Paavola, 2004). Collective fusion of cognitive efforts allows human beings to pursue projects and enterprises that go beyond an individual’s intellectual resources (e.g., Hughes, 1998). Human minds are not isolated entities, but merge and fuse so as to constitute collective cognitive systems. Workmates and colleagues function as an external memory that allows us to manage various daily activities, such as participating in meetings, returning calls, paying bills, remembering memorable days and all other non-routine events (Wegner, 1986; see also Engeström et al., 1990). This kind of collective memory system is called transactive memory (Wegner, Erber, & Raymond, 1991; Moreland, 1999). Transactive memory emerges spontaneously through even short joint practices and shared object-oriented working but breaks down if people switch groups. It provides an accurate metaknowledge concerning distribution of knowledge and competencies that helps to coordinate collective activities and achieve better results than would otherwise be possible. Socially distributed cognitive systems may represent expertise that is homogeneously (e.g., rowing team) or heterogeneously (baseball team) distributed (Johnson et al., 2000). People are more and more often working in multi-professional teams in which mere vertical development of expertise within one’s domain is not sufficient; rather, people need to engage in horizontal learning as well, relating and fusing their expertise to that of their fellow team members (Engeström, Engeström, & Kärkkäinen, 1995).

Toward knowledge-creating perspective on collective expertise

The acquisition and participation perspectives may be seen as two, diverging, fundamental approaches to expertise (Sfard, 1998). The present investigators have argued, together with Sami Paavola (Paavola, Lipponen, & Hakkarainen, 2004), that understanding learning and expertise in knowledge society may require a third perspective that addresses innovative processes of creating knowledge or transforming social practices. From the knowledge-creation perspective, expertise does not primarily involve acquiring already existing knowledge or growing up to a stable community, but making deliberate efforts to transform prevailing knowledge and practices. We call such processes ‘knowledge creation,’ to highlight their novelty and a shift from routine ways of understanding. As stated, our theory considers knowledge creation as a socially distributed process. Rather than mere dialogue between minds, collective expertise appears to be a trialogical process in terms of being focused on developing shared objects of activity. These mediating objects may, for instance, be ideas, theories, designs, concrete products or practices being reflected on. Collective expertise appears to coevolve in sustained and deliberate processes of working with trialogical objects of activity (Paavola et al., 2004).

Knowledge-intensive work takes place in a turbulent second-order environment

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1 In this paper trialogical activity is used as an umbrella concept that allows one to consider mediated aspects of knowledge practices as well as challenges of technology design. The concept of “trialogicality” (Paavola & Hakkarainen, 2004) indicates that one is dealing with an object with which various approaches can be related to, in order to foster shared effort to create knowledge and transform practices.
(Bereiter & Scardamalia, 1993) in which the criteria of success are dynamically tightening as a function of other players’ success. Such environments require expert communities to engage in constant innovation and social transformation in order to successfully meet challenges that are novel to all participants involved (cf., Ahonen, Engeström, & Virkkunen 2000). Knorr-Cetina (2001, p. 178) argued that the traditional conception of practices as being based on repeated routines, habitual procedures, or rigid rules does not accurately characterize epistemic communities that are engaged in deliberate and systematic “reinvention” of their knowledge practices so as to elicit novelty and innovation. Consequently, we propose that creative collective expertise typical for our times may be considered to be cultivated in innovative knowledge communities rather than traditional communities of practice (Hakkarainen et al., 2004; Paavola et al., 2004). Yet, the communities in question rely on social practices, knowledge practices tailored for promoting continuous innovation and change. Analogously with crystallized and fluid knowing, these practices allow communities to pursue novelty, and transform it to routines, in order to release resources for reaching again to work at the edge of the competence.

Two theme issues of respected journals have recently focused on examining the transforming nature of the objects of modern professional activity (Engeström & Blackler, 2005; Kaptelinin & Miettinen, 2005). In knowledge intensive work, experts are not just working with more and more complex objects. These objects, further, are not usually pre-determined but tend to fluid and slippery in terms of being constantly transformed and repeatedly re-defined in the course of activity. As a consequence of the breaking down of intra- and inter-organizational boundaries, the objects appear, in many cases, to be hard to specify, fragmented or only partially mastered by an individual or team working with them. Following Rheinberger (1997), Miettinen and Virkkunen (2005) distinguished epistemic objects from technical ones. While the technical objects represent instruments connected with well-known, routine procedures, the epistemic ones prevail at the edge of their epistemic horizon and encompass what the investigators do not yet know. These dynamic objects function as originators of novel conceptualization and innovative solutions. The creative nature of knowledge work appears to be characterized by sustained work at the edge of the unknown.

The concept of “object” has philosophic roots in Marx’s and Hegel’s studies, and psychological roots in activity theory as developed by Vygotsky (1978) and elaborated by Engeström (1987). Activity theorists have recently started analyzing knowledge-intensive work taking place in inter-organization zones of inter-linked activity systems and focusing on objects transcending organizational boundaries. Doing new things is difficult both for individuals and their communities, but necessary when practices embedded in the interacting activity systems are not sufficient for solving and conceptualizing contradictions arising within the network or in relation to its broader environment. In similar vein, actor-network theory (ANT, Latour, 1999; Miettinen, 1999), grounded in a rich body of ethnographic science and technology studies, emphasizes how human activity takes place in heterogeneous networks of humans and artifacts. Actor networks represent temporary constellations of people, institutional agents, and artifacts that are mustered together to work with a shared object across organizations boundaries. Knowledge practices are deeply embedded in heterogeneous networks and various affordances provided by artifacts. Artifacts have a kind of agency – i.e., they exert effects –, which plays as vital a role in modern learning and working as do human agents.
In what follows, we will present two cases based on our work-in-progress in which collective expertise has been studied in complex workplace settings. The studies address both dialogical (participation perspective) and trialogical (knowledge creation) aspects of expertise. The first study addresses the role of mediating artifacts and technology-enhanced practices in design work, the second study concerns hybrid expertise as socially distributed and relative expertise in a ICT company. While we acknowledge importance of engaging in ethnographic workplace studies, the present investigations were carried out by mainly relying on interviews and social network analysis.

**Case 1. The role of knowledge artifacts in engineering design**

*Problem and focus of the study*

The study addresses knowledge networks of five mechanical engineering companies’ design processes (Björkstrand & Lallimo, 2005; Lallimo, Lipponen & Toikka, in preparation). The project addressed the transforming nature of objects and instruments of engineering design work. Due to introduction of new ICT tools in engineering design process, knowledge artifacts, such as product plans, digital models, development documents and so on, are easy to modify and reuse in future projects. Modifying already existing plans compared to starting the design from scratch saves considerable amounts of time and money and is preferred whenever possible. Although the distribution and modification of the artifacts is considered as a relatively easy task, the workers constantly face problems in effective reuse of the artifacts in new projects. They may have to work through multiple representations (designs on paper, designs produced by several generations of CAD), finding relevant pictures, identifying most recent versions). Modern engineering products may involve tens of thousands of components that are difficult to manage without advanced computer aided design (CAD) programs.

The study was conducted to chart the present practices and challenges of using ICT tools in creation, distribution, use and reuse of knowledge artifacts in product engineering companies. The companies manufactured quite different products, such as specific electronic lightning systems, industrial lifts, all-terrain military vehicles, and soapstone fireplaces. The companies represented small or medium size enterprises (250-700 employees) divided into many operational sections, and which operated mainly in international markets. Also, the companies were undergoing a transition from using 2D computer aided design software to more flexible 3D software promoting reuse and modification of design documents. 3D instruments are integrated with intelligent product data management system (PDM) and merge design and manufacturing in a novel way. To investigate the role of design and production systems in knowledge-creation the following questions were explored:

- What kind of knowledge artifacts engineers create and what kind of tools and knowledge is used to produce them?
- How does individual and collective expertise relate to production, use, and re-use of design artifacts in design processes?

*Methods*

Data collection was conducted by a series of semi-structured interviews in each company. First, the key persons to be interviewed were identified, together with company
representatives with respect to role and experience in the company. They covered different functions linked to product development from sales to design and manufacturing. Thirty one people were interviewed. Half of the interviewees were designers, the rest representing management, sales, production or research and development. The interviews were structured to address 3 main categories as follows.

1) Charting the professional background on the interviewee and his perspective on the historical development of design work. (*Education, working history, development of design work during that period, etc.*)

2) Charting the social network required for managing knowledge of the design process (*With whom do you work in design projects and how do you interact? Describe situations where you need to ask more information from others. When is interaction with others problematic or difficult?*)

3) How technological and social aspects of knowledge management were combined in the interviewee’s work. (*What knowledge management tools do you use in your work? What kind of knowledge is hard to record in the systems? What methods of knowledge sharing are used to support product development? Is there some useless knowledge you have to input to the system or is there something crucial missing that cannot be input to the system?*)

Total of 30 interviews were made. On average, the interviews took 74 minutes; altogether these were ca. 500 pages of transcribed data to be analyzed. Further, the interviewees were also asked to construct a sociogram map (ego-centric network) of the people and tools they interacted with during the design process. Audio-recorded interviews were transcribed and analyzed using qualitative content analysis with a special focus the accounts on producing, using, and sharing of knowledge artifacts, and in respect to instrument usage while producing artifacts. Interviews took place in a context of organizing workshop in each company for considering challenges of collective expertise while moving from 2D to 3D practices of CAD. Although the study addressed only discursive entities (participants’ beliefs) rather than their practices, their central position in the investigated companies’ knowledge networks allowed them to provide relevant and useful information for the present study.

Results

The finding of the study was that in contrary to the often used, linear waterfall model of design process where knowledge is processed and then passed on from one phase to the next, the people described the design system as a dynamic network of intertwined design practices and processes. The dynamic network contained several different expert practices connected through knowledge sharing tools and design-related artifacts. These networks were in constant state of fluctuation where some knowledge artifacts could be central in the network at a given time, to be “left out” after some time, then to be “re-invited” again.

The second finding was that the accounts on use of knowledge artifacts were to great extend inseparable from the specific network in which they were produced. For example, the correct interpretation of a design document could require knowledge of any or all of the following knowledge practices:
1. General expert practice (e.g., knowledge of engineering notation and design tools).

2. Company practice (e.g., historically formed practices in the company, such as internal quality management, the documentation practices in the company).

3. Knowledge-network practice (e.g., a deviation from the general company practice because of a specific need for individual practices arising from the network going beyond boundaries of the enterprise in question).

The below presented excerpt illustrates an interviewee’s description of different ways in which designers join a project network. Before an official (company practice) assignment to the designer is made the sales representative may negotiate details of documents with a designer but this requires that the sales representative is familiar with the designer and aware of the specific knowledge-network.

Researcher: In what phase do you come in to a project? If a deal is under negotiation when do they turn to you?

Designer: It’s very diverse situations like sometimes there might be a call from the sales manager calling from a customer meeting that if it’s possible to do this and this and I tell my own opinion if it is or not and sometimes it’s decisive if it can be done in our automation line and they know it best at the production and then what are resources for design and schedules that knows Tom (head of design team) best and depending on personal that what kind of relationships you have do people know each others’ expertise that for example we have a new sales guy that he has never asked me for any comments and then Mike (sales manager) calls very openly where we know each other

Further into the interview the designer describes how discussion around design documents is often broken to different expertise, like designers ability to identify past designs that can be exploited and how modifications to these designs relate to working with the raw material and applicability of the final product in the customers installation.

Designer: ... if a customer needs fast some model that you know is [similar to] an existing product then there’s no sense to use design resources when you first offer an existing product slightly modified and offer it as a express shipment that they get to concretely hold it in their hands because we have noticed that 3D image is not always true even if there are all figures and programs and other ... when you aluminum sheet this way or this way it bends differently and minimizing material loss has taught us that there are different tensions where a novice would think that it’s a bundle of 1mm aluminum it’s all the same stuff but you need to know in what alignment is it there.

In all the investigated sites the main focus of deliberate transformation of design practices was on production and reuse of design documents. Most of the sales in the companies could be describes as mass-tailoring; selling existing designs that were “tailored” to fit the customer’s needs. Implementation of a new 3D design system forced the companies to reflect on their way of working. None of the five companies had detailed company-level instructions for how to conduct design work and the database of existing designs was the only common reference point among designers. However, the databases were arranged according to the end product and project description (date, customer, etc.), while designers were usually looking for existing documents that addressed a certain de-
design problem. To find the relevant document they had to rely on their own knowledge of past projects or to find someone who had this knowledge as the knowledge artifacts did not explicitly contain this information.

A designer with over 20 years of experience in the company described the challenges for a new worker as follows:

Researcher: ... if a new employer would come to the company what would be for her the most difficult things to learn?

Designer: Hardest for her would be learning those labelled products … the product repertoire is so wide that when an employer says that now I have this [product label] that she would identify what it is ... when products evolve that something that has been made ’83 and there is no proper documents but everyone who was working here then remembers what it is but someone new she sees a code and drawing and when she is asked what was old corner-light for NR railway carriages...

In many cases knowledge of the heterogeneous and diverse practices was required. For example, many designers stated that when examining a production drawing they could identify which one of their co-workers had made it just by the knowledge of different individual design practices. Also the range of different knowledge artifacts used was diverse, ranging from hand-written notes, paper copies and photos to computer-based 3D graphs and concrete prototypes with exact physical properties. Design practices were heterogeneous in terms of traditional drawing board design co-existing with 2D and 3D design practices.

Knowledge artifacts within a development process could serve multiple functions as objects of activity, as mediators or as boundary objects between different expert practices within the network. For example, all companies were implementing a Product Data Management–system (PDM) that linked the component data, prices and design drawings. This mediated the design activity by presenting the designers with clear constraints considering the production timetable and production costs. What the designers would consider as the best solution would often be impossible to produce within time or would cost significantly more than another solution that, for instance, the project manager would think as the best solution. The PDM was also the boundary object that subjects from both practices referred to in their accounts of design processes.

In one of the companies PDM was officially introduced as an answer to linking archived project documents to design processes. A young engineer was hired to the company as an expert of 3D-CAD and PDM systems. In the following excerpt he describes the rationale of introducing a design standards protocol:

Researcher: Does the design standard mean that there would be general guidelines of what knowledge is stored in the system when a product is designed?

Engineer: Yes and then that it could be found that all knowledge in principle or at least information about where you can find it ... in the old system it is a quite big problem that in the server there is a designated folder with subfolders and they don’t guide you at all you need to basically know that this was done this year if we want to find specific product models but of course PDM would now fix it if we will get it peoples minds that they would put data in PDM.
Next, the researcher asks how the implementation of the new system is advancing and the engineer identifies problems related to individual documentation practices, the varying company practices in different departments and general issues of “translating” old 2D design documents into 3D modelling documents.

Researcher: Yes, how much does there seem to be resistance for change it would be understandable that there would be?

Engineer: There is that quite a lot and then that you don’t really start to use it usually that is the only thing that well you don’t have time that then people forget what they have learned and suddenly you are back in where you started from... in the custom product department the big problem seemed to be that the design cycle is so fast that you just design a model that looks right and don’t design the interior parts and send it to the customer because the problem seems to be that the catch percentage [percentage of offers that lead to a contract] is so small then how much work do you put in the initial design that was fast in the old system while the new system is terribly good as it gives you straight away so much that you can create the drawings much easier than with the old one but the other side is that the old system has so much existing material and you should create new material for the new system.

Several distinctive differences in work practices between individual designers within a company could be identified. Young designers, fresh out of school, had in general better skills in new design tools, such as 3D-CAD, and often identified contradictions in the company practices. On the other hand, older workers stated that it took them years before they attained knowledge about the specific knowledge-networks. Such processes were e.g., developing transactional memory and learning the design ‘perks’ of other designers; something that could help them identify the creator of an old useful design document in case the original creator was not reported.

In the investigated companies the deliberate development of work was mainly twofold. First, it included the introduction and integration of new design and production tools, such as 3D-CAD and PDM systems to support knowledge management in design projects. Second, the companies had development teams that were closely working together with design teams. These development teams were a place where new ideas could be tested and quickly validated with designers, production, salespersons and management. Development work was described as both top-down and bottom-up process. Projects were initiated both by management to develop new product type for the marked and by shop floor level ideas. Development team manager for the company producing soapstone fireplaces described one instance of shop floor idea development as follows:

...I was thinking about another method for attaching together 1 inch thick stones ...we brainstormed how we could come up with a new method and in practice I drew a while with AutoCAD and then another [person] came from the production who has been [working] there for ten fifteen years ... we looked at it together and then we went to the Model Master [person who makes prototypes] and he thought about it ... then another designer came along to see that this would go here and that there and then we ordered the stones and in the next day we put it together and there was the whole group watching how it is possible to make so the shop floor was really crowded and everybody was commenting...

The above excerpt describes how an idea of a new production method transformed
Excerpt also describes the different expertise required to produce the artifacts. The study of expertise in the context of design projects could not be separated from the cultural-historical development of the company practices or from the development of practices within the knowledge networks. Furthermore, the construction of a common object between the different practices was often mediated by software that allowed users to present different representations of the “object-in-progress”. The design documents, plans and drawings are trialogical in nature; in the subjects’ accounts the design activity was organized around deliberate collective transformation of the object in which the knowledge artifacts played a significant role.

Case 2. Combining individual and collective expertise in design intensive work - Knowledge brokering and hybrid expertise within ICT company

Problem and focus of the study

The second study addressed collective knowledge networks in a company developing collaborative technology for national and international markets. The purpose of the present study was to gain understanding of knowledge flow and knowledge creation in multi-professional, knowledge intensive work, which takes place in increasingly flatter organizations. The ICT company under study had faced problems of combining the product-related technical knowledge, which was possessed in technical development function, and the customer-related knowledge possessed by sales function. The researchers were invited to the company in a situation where the company had launched initiatives to develop ways of knowledge sharing and creating new knowledge and products. This is a typical case in the field of knowledge intensive work, where the existing information gets out-of-date quickly, and creating new products and knowledge are dependent on how the knowledge is shared and developed in heterogeneous expertise settings. Thus, the question of the organization of knowledge creation bounced back to exploring how the vertical, oftentimes dispersed expertise and multiprofessional work settings were interrelated and how their co-development takes place. With other words, in the company the horizontal learning and expertise (Engeström et al., 1995) was needed to cross boundaries of expertise domains. The framework of the study relies on notions of how individual expertise and collective knowledge networks are tightly intertwined. In multi-professional work particularly, the respective expertise of various individuals constitute distributed, however interlocked, participation frameworks, by which differing domain knowledge and working practices are linked together.

Together with their colleagues, the present investigators conducted a study focusing to organizational communication structures and practices of sharing the existing crystallized knowledge and enabling fluid knowing around new products. In the reported study particularly, we explored central actors’ interaction network, and their knowledge brokering practices (Lallimo, Muukkonen, Lipponen & Hakkarainen, in preparation). Knowledge brokering supports the knowledge flow between otherwise separated organizational functions and people. Knowledge brokers are entrepreneurs, who are capable to combine existing resources in new ways. As we try to illustrate in this study, their special kind of expertise may be represented as a form of hybrid expertise through which an expert culture’s knowledge is “translated” and transformed into a form that participants of another expert domain can understand (Howells, 1998; Sverrisson, 2001). For example,
in the field of ICT development, an individual representing profound technical, sales & marketing expertise, and knowledge about customers represents hybrid expertise. To this end, in order to understand collective knowledge networks from the point of knowledge sharing and creating new products and knowledge, we particularly explored the following questions:

- What are the knowledge brokers’ positions in the communication network, and
- What elements of expertise and working practices are linked to brokerage activity?

Methods

The company under study produces business-to-business groupware, internet, and intranet solutions to organizational and public sector. It has sales offices, development centers, and partner companies employing about 1000 workers worldwide. Particularly, the research was carried out with a unit consisting of 119 people. The study presented in this paper belongs to series of studies conducted during three years research period, focusing to management and facilitation of knowledge in multiprofessional settings.

The data were collected and analyzed by two methods. Firstly, by using social network analysis (SNA) (Wasserman & Faust, 1994) and a suitable questionnaire format, each worker of the company evaluated his/her communication links related to all other workers in the company. They were asked from whom they receive information concerning different products or customers and to whom they turn for advice in different questions. By this manner, the structures of interaction network and epistemic network positions of individual people of the company could be explored. For the particular purposes of this study, nine central actors who had an above average betweenness centrality value in all aspects of the questionnaire, were identified as knowledge brokers. The betweenness centrality value indicates the extent to which an actor is situated between others in the network, in terms of mediating information between them.

After conducting SNA, nine knowledge brokers were interviewed about their practices of sharing and developing knowledge. The semi-structured interviews concentrated on their working background and competencies, and on the working practices concerning knowledge brokering. Interviews took on average 100 minutes. The material was transcribed word by word and analyzed according to the qualitative content analysis. In addition, the researchers had documented several workshops, meetings and other everyday work discussions in which expert of the company reflected on their activities and visioned future work. Even though the workshop data is not reported here, it had served in constructing the analytic scheme for the study. The categories for analyzing the brokerage were constructed in several iterative analysis rounds, and convey the different element of knowledge brokering. These categories are indicated in the following, exhibiting the results of interview analysis.

Results

The results indicate how human actors may function as intermediaries between different parts of heterogeneous networks. According to social network analysis, knowledge brokers’ position in communication network was characterized as exceptionally thick communication network (involving above average communication links) across organization-
functions and diverse people, and thus a central position in the communication flow. This is exemplified in Figure 1.

By assessing the knowledge brokers’ betweenness centrality value, they could be considered being in a favored position to the extent that more than the other workers they were positioned on the geodesic paths (shortest paths in a network between actors) between other pairs of actors in the network. Thus, their position in the network highlighted the possibility that they were exposed to extensive information circulation in the network.

The interview data emphasized that knowledge brokering does not take place in an empty context; elements such as hybridization of otherwise separated domains and organizational units, relational knowledge of organizational potentials and pitfalls, and transactive knowledge of organization’s resources were brought up. Knowledge brokers’ objects of work were on two main levels. Firstly, in their daily work they worked on their primary appointments as sales managers, product managers, or support managers. The second level of work could be described as managing and coordinating the multiprofessional objects of work, which were highly emerging by their nature; these objects, or ill-defined problem solving situations, could not be seen beforehand, e.g., generating and enabling fluid knowing around new demands from the customers, which had no existing, crystallized solutions inside the company.

Hybrid expertise of the knowledge brokers did not emerge from scratch, but had required lengthy efforts of working in and with different domain fields and people. As the following excerpt shows from the Product manager, who had a background originally in psy-
chology and usability and who had educated himself later to technical product development:

“My present job description is versatile. It consists of managing the requirements raised mainly by customers for new existing and new products, and also coordinating this development process between customers and the company. One important aspect of this was developing the roadmap for the product together with her superiors. Also describing product’s fact sheets and product overviews including the technical elements.”

Nishiguchi’s (2001) distinction between functional and relational skills is useful when analyzing knowledge brokering. Functional skills refer to skills of exploiting already existing knowledge and competence for accomplishing specific tasks and pre-given goals. Relational skills, in contrast, “refer[s] to capabilities of a requisite variety to connect and reorder one’s own and other’s functional skills as necessary in relatively localized field or context of activities” (p. 216). Relational knowledge of the organization was brought up by Development services manager, who had a vast experience of working in the company:

"I’m involved in product development to pretty much everything which is not the actual technical development, that is, productization and the related services, and customer support. I consider my work more like managing peoples work, I do not concentrate on any specific element of the product. Because of that, in order to make some decisions I have to crosscheck the aspects from several people. That I do also for showing the possible pitfalls of single peoples’ perspectives.”

In an organization trying to combine different fields of expertise it becomes remarkably important to know who has the expertise, and how accessible it is. This was illustrated in the interviews as the form of transactive knowledge. As put by Services manager with a long history working in the company and several people:

“People come to ask me about old solutions and who has done something in previous projects. For me it is important to assure that people have the knowledge they should have. Its also important to make sure that many people know where the knowledge exists, because that information does not keep inside of my head or memory only.”

In organizational transactive memory the double-bind nature appears to be important; on the one hand, the services manager had the transactive knowledge about who knows what, and on the other hand, the other people knew that services manager had the transactive organizational knowledge.

The most central knowledge brokers formed a network of their own, a kind of metabrokering network. This interaction network worked as a mean of gaining insight from different ground-level working activities and sharing it with other knowledge brokers. Such interaction indicates that knowledge brokers not only transfer information from one part of organization to another, but that they are heavily bound to combining and developing new knowledge using their brokering position. The knowledge brokering activity was connected to both formal hierarchical structure (e.g. certain knowledge brokers being in management position with several horizontal links) and informal horizontal relations representing links which were based more on trust and personal relationship than exact contracts (e.g., certain knowledge brokers connected people through informal relations
and intentional relations across organizational boundaries).

An essential nexus of the brokers’ networking activities were different organizational artifacts, such as technologies, documents, and practices using an organization’s information and communication systems. In problem situations, the brokers not only consulted other fellow experts, but heavily relied on a variety of bug reports, manuals, quality books and other material. Knowledge brokers referred to these artifacts when helping others to pilot their work. Knowledge brokers used different artifacts to transform their knowledge and skills to other domains by writing, for instance, ‘white papers’ to explicate promising technological possibilities for the sales department and other non-technical departments. These documents were a reference point for developing product features or new working practices. These mediating artifacts represented transformative brokering from one field to another, involving the elaboration of shared ‘object’ of work. Through the brokering activities, different domain fields’ overlapping interests or potential complications were explained and made visible. These artifacts can be understood as trialogical entities (Paavola, Lipponen, & Hakkarainen, 2004) that guided and constrained the participants’ activities. They functioned as boundary objects (Star, 1989) that assisted stakeholders’ interaction, knowledge sharing, and negotiation of knowledge advancement.

Summarizing the findings, the study indicated how the network of human actors and artifacts complement an interwoven system. Different vertical fields of expertise are bridged by elements of hybrid expertise, which are constituted by people and mediating artifacts. The findings highlight the relevance of knowledge brokering in heterogeneous settings, but also the vulnerability of the network when the knowledge brokering is exhibited with only a few people. In addition, the design and use of mediating artifacts, e.g., boundary objects, remains most relevant for organizations that rely on overlapping work between different working domains. Knowledge brokers are not only linking the crystallized knowledge in information network, or who possess metaknowledge about organizational resources. In addition, they receive the freshest ideas from multiple and diverse sources, enabling them to create fluid synthesizes of knowledge. The knowledge brokering is double-edged; on the one hand it serves for the new hybrid solutions for the company, on the other hand they are the bottle necks of information flow. The interviews brought up contradictory knowledge brokering situations and work practices which had lead to one-sided and biased treatment of information. Even though knowledge brokering was approached in this study from certain individual key actors, it can be seen to be heavily bound to the system it is linked to and whose knowledge and communication structures it serves.

Discussion

The point of departure of the present article was sociopsychological research on expertise. While this body of research provides information of basic features of human competence, it is only now moving toward addressing real world expertise taking place in collective knowledge networks and higher-level cognitive systems. The two presented case studies indicate that there are essential collective aspects of expertise that are easily lost if expertise is dissociated or considered apart from heterogeneous networks of activity. The investigations revealed that it was difficult to describe the participants’ expertise individually; the professional competences analyzed were usually defined relationally
and, frequently, involved hybridization or brokering across internal (research & development, design, marketing, manufacturing) and external (customers, subcontractors) practice fields. The studies revealed various ways in which expertise is shared between the participants and cultivated by workplace communities' shared practices. In the case of design expertise, the role of mediating artifacts was illustrated as part of heterogeneous expertise networks. In the case representing hybrid and relative expertise, the socially distributed and culturally bound nature of collective expertise was highlighted. The two cases represented intermixing dialogical (participation perspective) and trialogical (knowledge-creation perspective) characteristics where individual, social, and material elements are intertwined in object-oriented and long-term activity.

The studies revealed that the social and technical organization of work was under constant transformation within the organizations, which forced the participants to struggle with frequent instability, discoordination or breakdown of activity. The expert cultures investigated had cultivated specific knowledge practices to systematically deal with novel, unanticipated problems emerging, for instance, while moving toward mass customization. Many of the organizations investigated had created special product development laboratories involving certain experts, many of them self-educated oldtimers, who were allowed to pursue, fulltime, new innovations and explorations. These experts functioned as knowledge-practice brokers that helped the expert community to carry out routine and innovative practices in parallel. Rather than working with traditional well-defined and stable objects, all of the expert communities were working with fluid and transforming objects (Law & Singleton, 2005; Engeström, 2005) that were under constant redefinition and in process of becoming. Simultaneously with relying on some pre-packaged and standard solutions, the communities were developing highly customized products and innovative services that were beyond their prevailing knowledge and at the edge of their competence.

One of the central observations of the present study was heterogeneity of knowledge practices both within and across the organizations. Tradition and innovation, exploitation and exploration (c.f., March, 1999) appeared to co-exist across extended periods of time. While some experts completely immersed themselves with 3D design environments, others were still relying on traditional engineering design, merging drawing boards with knowledge practices relying on 2D CAD applications. In all communities there appeared to be a need for human beings who carry the history of collective activities and create continuity between past, present, and future activities. Overall intelligence of a community or network increases when bold exploration of novelty and innovations is associated with skillful elaboration of prevailing tools and practices.

The trialogical approach to learning and knowledge creation appear to be needed in order to properly acknowledge the constitutive role of objects in experts’ personal and collective activity. The trialogical objects that the participants of the two cases worked on, represented a variety from marketing plans, white papers, and engineering designs to software applications, engineering products, and journal articles. While experts often discuss their work in face-to-face meetings, a great deal of their activity takes place in creating, elaborating, and commenting on various types epistemic artefacts, such as plans, designs, and white papers. These entities existed in various forms from graphically, textually, and mathematically modeled ones to physically embodied prototypes and packaged...
products. Trialogical objects have a central role in human discursive practices in terms of incorporating the “materiality” of knowledge. Technologies, texts, the physical environment perform the role of anchoring knowledge and interactional infrastructures between humans and non-humans (c.f., Latour, 1999). A field of practices can be regarded as a network of fragmented and distributed knowledge held together by the power to associate heterogeneous elements” (Gherardi, 2005, p. xxiii). Expert work appears to be always embedded in an extremely complex body of historically evolved knowledge, instruments, and practices.

REFERENCES


