BUT WHO LEARNS WHAT ? ON THE RISKS OF KNOWLEDGE ACCUMULATION THROUGH NETWORKED LEARNING IN R&D

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1 INTRODUCTION

Product development has long been recognized as an activity vital for a company success (Roussel et al., 1991; Cooper, 1998; Golder, 2000). Many factors influence it and there is no consensus among researchers which of them have positive or negative effects (Balachandra and Friar, 1997). Similarly, there exist different points of view on what product development process is (Brown and Eisenhardt, 1995). Clearly, when people communicate with each other they exchange knowledge. Researchers study such issues as knowledge transfer, knowledge sharing, knowledge management in R&D teams (Cummings and Teng, 2003; Boutellier et al., 1998). These issues are important since new products are often complex and their development requires multidisciplinary areas of expertise (Zirger and Maidique, 1990). So every new product can be seen is a result of collective work, utilizing individual knowledge brought in by the team members.

According to Cohen & Levinthal (1989) – a view that we also share – the product development processes not only create new information, but also enhance the firm's ability to assimilate and exploit existing information. Thus, as Cohen & Levinthal state, innovation and learning are two coinciding and interacting faces of the R&D activity, and while the product development work itself is more important for the current fiscal year, we may even argue that the learning facet is what makes the firm's success in the long run. This view, again, is shared in the majority of the organizational learning literature.

The question that is seemingly less discussed is how organizational learning actually takes place. Three levels in which learning occurs within an organization have traditionally been identified (Huber, 1991; Crossan et al., 1999): the level of an individual, the work group, and an organization. There are many technical descriptions that stem from the idea of managing the organizational knowledge, that suggest that the learning is equal to establishing the formal material that describes the correct and effective ways to work. This would mean that the knowledge accumulates in the organizational systems and procedures, especially on the mentioned organizational level. But, returning to the two facets of the product development process, that normally takes place within a work group or

team, not the whole organization, the effective ways of working do not bring the actual innovation aspect in the product development task. If product development creates a capacity to assimilate and exploit new knowledge (Cohen and Levinthal 1989), and because this new knowledge still is to a great deal tacit and cannot be made fully explicit, it follows that the capacity at least partly means that the individual members of the personnel of the company learn things that are useful in the following projects, such as fault-seeking procedures, shortcuts, tiny informationlets that make the development quicker and more effective. Using the capabilities and learning capacity of individuals, operating models and solutions can be generated inside companies and within networks of workers. Learning by individuals is the prerequisite, the foundation and the key for the learning of these networks and the companies (Kekäle & Viitala, 2003). In this vein, the base of the current paper lies in the autopoietic tradition of epistemology: "unlike the congnitivist epistemology, a theory of knowledge rooted in autopoiesis theory suggests that knowledge is not abstract but embodied: 'everything known is known by somebody'." (von Krogh & Roos 1995:50, italics in original).

The next step from the individual learning to the work group learning is the learning of who-knows-what in the work group, often called transactive memory. As with the term "organizational learning", it is generally accepted that the organization does not have a "memory". Nevertheless, it seems that a great deal of the tacit cultural learning in an organization concerns persons' roles and past heroic deeds such as success in difficult tasks in the past; mostly people know who has done something even if they do not know the details of what has been done. Since people use others as "external repositories" of information, they may provide answers to questions that are far beyond their own personal expertise. Thus a memory system of a group is larger than memories of its members. It develops over time and may be understood as a property of the group. The main stream of research on transactive memory is based to on the seminal work of Wegner (1986, 1995) who defines a transactive memory system as "a set of individual memory systems in combination with the communication that takes place between individuals." (Wegner, 1986).

Some individuals may be recognized as experts in certain domains. In this case they become responsible for encoding, storage and retrieval of any incoming information relevant to this domain. Other members of the group deliver new appropriate information to them, thus storing this information externally in the experts. People may be recognized as experts on the basis of their personal expertise or as a result of circumstances in which they take responsibility for the information encountered by the group. Formal groups may assign responsibility for certain domains to individuals, but if it is not done and if there is no obvious expert in a certain domain, a group may have difficulties with information allocation within the group. Thus efficient group memory system requires accurate knowledge of every group member of others' domains of expertise.

Clearly, these processes require that experts have been identified. In other words, this means people know who knows what. Such memory about memories is

called metamemory (Kitaygorodskaya & Kekäle 2005). By analogy with computer memory it is seen to have directories about others' memories. These directories are created and updated during the process of directory updating, but they cannot include the complete learned "sum" knowledge of the organization. The autopoiesis theory also states that knowledge develops in an autonomous manner in individuals, and thus cannot be transferred directly to other humans. The trial and error processes, For example, can only partly be captured by individual retrospection and representation (von Krogh & Roos 1995). Furthermore, all these processes require at least reasonably complete communication between members of the group.

Cohen & Levinthal (1990) and Helo & Kekäle (2006) claim that the work group-level learning is a path-dependent process. Cohen and Levinthal state that prior knowledge permits the assimilation and exploitation of new knowledge. This prior knowledge "should be closely related to the new knowledge to facilitate assimilation, and some fraction of the knowledge must be fairly diverse, although still related, to permit effective, creative utilization of the new knowledge" (1990:206). Our own standing stems from the emergency school that we have understood is also seen as the basic mechanism of culture creation (Schein 1997). This idea is based on the preferred selection idea (Barabasi 2002) and the thoughts on transactive memory presented above: whenever a difficult task arises, any individual faces the options of either solving it by him/herself, or asking for help from somebody. In a system where the transactive memory of who knows what is effective and communication channels are well developed, the individuals tend to prefer asking for the person with the right kind of knowledge and skills for help, for the benefit of the project.

Learning takes place by doing: by solving problems, people increase their knowledge. It seems, in line with the path-dependency idea, that in small knowledge-based/specialist companies or work groups the knowledge of others' specialized skills and ease of communication lead individuals to ask for help in problems that they cannot solve. This leads to learning for both the person who asks and the one who solves the problem. However, only for the person who solves the problem based on his/her previous skills this learning becomes embedded as Cohen and Levinthal state (1990:136): he/she firstly learns by accumulating capacity to do the next similar task more effectively than the previous; but this accumulated capacity also makes him/her better suited to study intermediate or new but related technology advances, thus again accumulating his/her expertise in relation to that of the others. For the original problem stating person, the learning is of transactive memory character only.

Learned preference in asking help leads to learning taking place with the people who already know most about the problem ("Pareto principle"; this idea is quite widely discussed e.g. in Barabasi 2002:90-99). This leads, over time, to centralization of knowledge about the most difficult tasks to a couple of individuals in a power-law fashion.

2 AGENT-MODEL SIMULATION

As stated above, some people may be recognized as experts on the basis of their personal expertise or as a result of circumstances in which they take responsibility for the information encountered by the group. This leads to the persons in the work group or otherwise persons who share the common product development task to use preference tactics in sharing the actual work: work is given to those who know how to do it, and their knowledge in the area then expands as explained above. This phenomenon should be exaggerated the more remote technology areas that are involved in the tasks; it is increasingly unlikely that somebody would be expert in every aspect of complex products and systems. One such example that still is readily available for study might be embedded systems. According to Simon (1999) embedded systems programmers must handle problems beyond those involved in typical application software. They must respond to external events that are solution-specific rather than general, and they must also understand the unusual conditions that may take place as well as the deadlines (time frames) that there are in the embedded systems. For example, while we readily wait a minute or two for Excel to start, a core meltdown at a nuclear plant given a one-minute head start before the security systems start to operate would not be good. Simon gives further examples such as elevators, automobile engine and industrial control equipment, and scientific and medical instruments; all these include embedded systems where the electrical or mechanical systems are operated by software without human intervention.

We first have computer simulated the development this theory would lead to. Preference-based actions in a group are reasonably simple to model by the agent-based modeling techniques. We have attempted such a model, comprising a network of 20 individuals ("software coders", named in the model by numbers from 1 to 20). In the model, we have assumed them an initial level of coding-related expertise of 1 (low, P=0,66) or 2 (high, P=0,33). The probabilities are just proposed on the basis of the idea that the top-level experts might anyway be a minority in a real software team, and most of the team would be junior coders. In Table 1, these initial levels of expertise are shown in the left-side yellow field. The model then assigns tasks in random order to individuals; each time an individual receives a task and "completes" it, his/her skill level is increased with 1 (=learning).

However, randomly (P=0,50) the model makes this individual ask for help from someone in the team. In order to duplicate what we think would be a realistic action in a team, we have made this model ask help from the physically closest neighbor. The model solves this by asking help from the programmer whose number is closest to the programmer in need of help (e.g. if programmer 12 needs help and programmer 13 and 16 have expertise levels higher than he/she does, then programmer 13 is approached. After 20 the list goes back to number 1, and if two programmers with a higher expertise level are precisely as close physically then they both are asked for help in the model). After having completed the task with the help of a colleague, the skill level of the original

individual and of the closest neighbor(s) with same or higher skill level who help in the task are all increased with 1 (even if the theory of Cohen and Levinthal would suggest that the higher expert actually would gain more in reality).

The development in Table 1 shows that in the simulation, the expertise starts to clearly accumulate to a couple of persons after a relatively short time (middle yellow field: expertise levels after 100 task assignment repetitions, right-hand yellow field after 200 task assignments). The orange fields in the table indicate programmers whose expertise is within 25 % of top skill level; the top-expertise programmers defined in this way decrease in number, which suggests a power-law accumulation of skills in such a team.

1	3	4	2	6
2	9	11	8	19
1	7	8	6	14
1	16	17	19	36
1	3	4	9	13
1	5	6	7	13
2	5	7	10	17
1	4	5	9	14
1	12	13	12	25
2	6	8	7	15
1	9	10	10	20
2	12	14	20	34
1	0	1	4	5
2	8	10	6	16
1	6	7	6	13
1	4	5	8	13
1	10	11	10	21
2	10	12	8	20
1	7	8	9	17
1	6	7	7	14
1		16		31

Chart 1. Accumulation of expertise in an agent model computer simulation.

(Columns from left: initial expertise; learned expertise, during first 100 tasks, then after the 100 tasks; then during the next 100 tasks and finally after the 200 allotted tasks. The dark grey fields show the programmers within 25 % of the expertise level of the top programmer).
The bottom cells show average expertise level at each stage.

The increase of average expertise level in the simulation shows that the organization is indeed learning, but some programmers learn much more than some others; the organizational learning does not spread evenly even in such a small team. Depending on a task an organization has, either differentiated or integrated transactive memory will facilitate its fulfillment. If the task requires that all members of the organization carry out the same functions (e.g., sales persons), integrated transactive memory where the same items of information are stored in individual memories is desirable. On the other hand, if task requires generation of new knowledge, differentiated transactive memory will ease its fulfillment. Transactive memory is called differentiated if different people store

different items of information. Discussions in organizations with differentiated transactive memory can lead to integration of these different items and generation of new ones.

3 REALITY: COMPANY X

To study whether the simulation makes any sense, and to eventually find reasons why it would be so also in reality, we have conducted an one-case study in a company working with embedded software. The company "X" had been working in this field for about 5-6 years at the time of the study, and expanded relatively rapidly at a pace of about 5 persons the first year, then about 10 persons annually.

"Communication networks are the patterns of contact that are created by the flow of messages among communicators through time and space" (Monge and Contractor, 2003). In the context of organizational communication, people are identified as nodes of the network where links represent such relations as "provides information to", "gets information from", "knows about" or "provides information to".

In addition to communication networks, knowledge networks are recognized. In such network there are two types of nodes: people and knowledge. They, in effect, answer the question "who knows what". Within this network knowledge may reside with one actor (be centralized) or exist among many (be distributed). Distributed knowledge refers to two phenomena. First, it may describe the flow or diffusion of knowledge, which increases the level of knowledge among all actors. Second, it may refer to the situation when separate network actors bring different types of knowledge that allows the group to accomplish difficult tasks.

Further, people usually have their own ideas of who knows what, that in other words can be called their "cognitive" perceptions of knowledge networks. These perceptions may be incomplete and/or inaccurate but they do exist, and should, according to theory, get more accurate over time when the common activity continues.

The programmers who were working at X (40 engineers aged 20 and 34, all within the same physical premises in an open office floor partitioned by loose half-height cubicle walls) were asked to list the five colleagues that they most often asked for help in their tasks, and for each of these also to assess the number of times they requested coding help from these during a typical month. It turned out that asking for help was much less common occurrence than what was expected. Only a few persons "ever" had asked a colleague to help with difficulties in software programming (total N= 40, edge values relate to the number of times help was asked on average within a month; the 30 outsiders with edge value of 1 or less omitted in picture 1). While this study was conducted without names, on request of the management at "X", we do not know for sure who asked whom for help; it might make sense that the persons requesting help might be the relative newcomers at that given moment. However, in line with the

previous theory, most of the events where programming help of some kind was needed included one of two "knowledge wells" at the company.

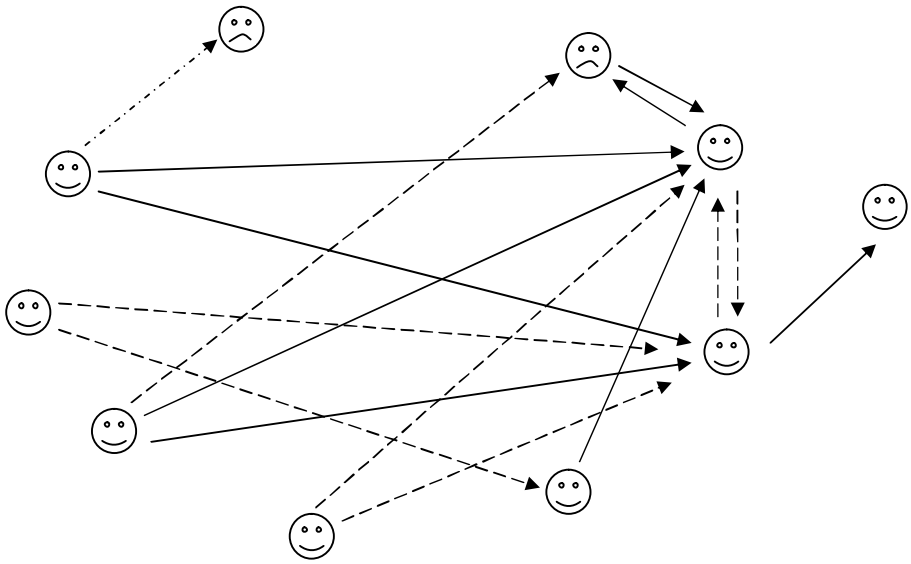

Figure 1. *Programmers asking for help or second opinion (the network is drawn here so that the "asking for help" goes from left to right, and the programmers who haven't asked, or haven't been asked, for help at least once a month have been left out; original N=40).*

Legend: dash dotted line: about once-monthly request for help;
dashed line: about once-weekly request;
solid line, about daily request for help or opinion.

For a better comparability with the computer simulation, we then arranged for an interview with the two central persons in the expertise network. While the management refused to reveal the identities of the persons behind the numbers, this interview was conducted by the secretary of the company according to our list of questions. Naturally, in such a setting, a complete thematic interview – that would have led us towards the "why" – was too difficult to arrange. However, even with this small-scale interview managed to confirm that the solving of others' problems is a necessary source of increasing expertise. Individuals 5 and 7 stated that up to 10-20 % of their software skills are due to solving others' problems (the answer alternatives for this question were for simplicity of analysis classified "none", "less than 10 %", 10 to 20 %" and so on).

Furthermore, another important finding in X was the unanimity of the other workers; it seems that a full 100 % of the "transactive memory", of the knowledge who knows what and thus also the future preferences on where to find help, is due to the previous events where the experts have managed to help. No telephone books, knowledge catalogues, knowledge brokers or such were used in this smallish company. This would suggest that the knowledge spreads in the legends and myths of organizational heroes precisely as culture is seen to be

strengthened (Hatch 1993) and after that the knowledge helps to strengthen the previous preferences on where to ask for help, which again at least to some extent leads to increased expertise among the preferred experts. This seems to be quite in line with what the computer modeling suggested.

Due to the arrangement with the empirical part of the research in the case company, we could not study the eventual effects of distance (e.g. Gerstberger and Allen 1968) or practical obstacles (Hatch 1987) to the communications (see Savolainen 2006 for a more complete discussion of the "spatial effects on communication" research tradition). From our visits to the company we know the following: the office is smallish, about 30 meters times 15 meters, open "landscape" type office with movable partitions of about 1.20 meters height dividing the area to the programmers. The maximum distance between two programmers thus would be about 30 meters, which can, according to the above-mentioned studies, reduce the time spent for communication significantly. However, one corner of the office is a coffee area where everybody gathers for joint coffee breaks twice each day, sometimes more often. This could enhance the knowledge of the programmers on who is the specialist in which type of software-related problems and counteract the effects of the distance. Furthermore, the person in the study are software programmers, a group that a higher than average propensity of using electronic, distance-independent methods of communication.

Typically, no partition of the office forms a "cubicle; the partitions are raised only on two sides of every workstation, leaving two sides open to others. Thus the distance and the partitions would not to our opinion restrict the communication. The distance could, however, to some extent steer the communication; it is possible that the two persons that get most of the queries are "local" authorities close to the persons who need help, maybe one at each end of the office. This does not in any way affect our conclusions, but it may affect the preference mechanisms that lead to these two persons becoming the authorities among the programmers, and may also thus affect the bipolar development of the communication patterns.

4 CONCLUSION

In big organizations, the managerial arrangements traditionally are generally seen to direct the queries for help and resources to some key individuals. In more self-directed small organizations and organizations based on open-source mentality, these are based on preferences to get the work done, and emerge informally through learning and cultural myths in a path-dependent way (even if it is possible that they can also change when the skill base of the work at hand changes).

The management can to some degree – but ONLY to some degree – affect the human processes of communication flows and knowledge management. A major

part of the reality of the organizational knowledge could be created by complexity/emergence phenomena and, thus mainly unaffected by management actions (and path-dependent). Even in work groups of bigger organizations with open-enough communication, similar "wells" or informal communities-of-practice of top knowledge can emerge through learning. The theory emerging from these two small cases does not tell us whether there is any threshold in organization size where the system would cease to work. However, it is generally held that the increasing physical distance diminishes communication. Again, communication can be similarly path-dependent: for example, Keller (1986) found that through communication team cohesion is built that, in its turn, breaks communication barriers further and thus increases information flow.

Brown and Eisenhardt (1995) define cross-functional teams as "those project groups with members from more than one functional area such as engineering, manufacturing, or marketing". Dougherty (1992) found that different functional departments not only possess different knowledge but have different "systems of meaning" as well, which is a good thing for creativity when these people meet for a project. However, that also means that when people from different functional areas communicate they may have different interpretations of the same thing, thus communication barriers between different functional areas appear. Projects could then be similar wells: projects generate knowledge on some persons, and in the end of the project it is very possible that the knowledge walks out with the key persons.

Researchers also pay attention to external communication of team members that facilitates acquisition of new information by the team and helps keep abreast with new technological and scientific developments (Ancona and Caldwell, 1990, 1992; Tushman and Katz, 1980). As, according to Cohen & Levinthal (1990) and similar micro-level learning theories (e.g. Kolb 1984, Knowles 1980) suggest, the persons with the tacit knowledge that the person has acquired through experience are also best suited to learn new related matters, this uneven accumulation of knowledge may even accelerate further with the addition of external learning.

While learning a skill and acquiring knowledge are beneficial for individuals, there clearly is a risk for the company that the key persons disappear. It might be a good idea for the management to really keep track of the learning and knowledge levels and ranges of individuals, rather than monetary investments; the human capital and personnel accounting schools are currently working with just this. The manager of our case study company indeed asked us not to publish the name o the company nor refused to reveal the names of the persons in the company, because it would make the buying-out of the knowledgeable persons too easy for competitors. The often-quoted phrase "the staff is our main success factor" should be true in all knowledge-based work, but it might turn out that the real success factor is sitting in room 236. And he/she might be on his/her way off to the competitor.

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