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COLLABORATIVE KNOWLEDGE MODELING BETWEEN EXPERTS AND NOVICES: A STRATEGY TO SUPPORT TRANSFER OF EXPERTISE IN AN ORGANIZATION

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Abstract. We report a strategy of collaborative knowledge modeling between experts and novices implemented in a Canadian organization since 2002 to support the transfer of expertise and knowledge management in this organization. Participants use an object-typed knowledge modeling editor called MOT to elaborate knowledge models in pairs. A knowledge model is similar to a concept map, except that it is based on a typology of knowledge objects and on a typology of links, and its structure is not necessarily hierarchical. This technique is used to represent concepts, principles, procedures and facts related to a specific aspect of the work done by employees in the organization. The paper presents the rationale behind this project, describes how it is implemented and identifies some research issues.

1 Introduction

Over the last few years, economic and technological changes have brought major challenges to the business world. To remain competitive, businesses must rely upon the competence of their human resources. Indeed, business know-how is often intrinsically linked to the tacit knowledge acquired by employees while working for the organization. As almost all Western societies will soon experience substantial turnover of manpower (Advisory Council on Labour and Manpower, 2002; Treasury Board Secretariat, 2002), unless concrete efforts are deployed to save it, much knowledge will be lost. Indeed, much of the expert knowledge of an organization is implied and directly linked to the personnel; hence, it is lost once the employee leaves the organization (Lave & Wenger, 1991; Polanyi, 1966; Nonaka & Takeuchi, 1995). Jacob (2001) claims that depending on the realm of expertise, the implied knowledge of an organization can represent up to 70% of its competency assets. The issues revolving around the identification, the representation, the sharing, the validation, the re-use and the evolution of valuable knowledge are thus critical for organizations. Thus, many of them began to set up a knowledge management strategy supported by information and communication technologies.

According to Apostolou, *et al.* (2000), two approaches to knowledge management can be distinguished: (1) a product-oriented approach, which focuses on creating, storing and re-using documents. Such an approach aims to create an institutional memory; (2) a process-oriented approach, which focuses on the social communication process: "*in this approach, knowledge is tied to the person who developed it and is shared mainly through person-to-person contacts. The main purpose of Information Technology in this approach is to help people communicate knowledge, not to store it. This approach is also referred to as the 'personalisation' approach*" (p. 2). This approach aims to transfer expertise among people more directly.

The traditional strategy used to transfer expertise in organizations simply consists in matching less-experienced staff with more-experienced workers to allow the latter to share their know-how. However, this strategy is no longer suitable for our current challenges. Nowadays, people generally agree that transfer of expertise requires well structured activities anchored in real work situations. Some of these strategies recently developed in organization are job sharing between senior and newer staff members, buddy systems, mentoring, sponsorships, and communities of practice (McDermott, 2001; Wenger, 1998).

From an individual standpoint, knowing how to transfer one's own knowledge remains challenging. Knowledge-transfer aptitudes and pedagogical competencies are not innate. Moreover, those who excel in the field are not necessarily aware of the manner in which they perform their work. Tacit knowledge is difficult to externalize. Most of the time, experts use their knowledge ''live'' and rarely have the opportunity to consciously reflect upon what they are doing. Basically, they cannot verbalize what they know, nor can they explain their "action model" (Bourassa, Serre, & Ross, 1999). Transferring one's expertise thus requires that the experts delve deeper into their knowledge. It also requires that the experts spell out what seems clear to them, although that is not the case for other people. Many studies have shown that experts have difficulties formulating concrete and detailed explanations of a task even if they are aware that their explanations are intended for novices (Hinds, Patterson, & Pfeffer, 2001). Cognitive psychology research conducted in the mental model approach indicates that expertise consists of a highly organized structure of different types of knowledge stored in long-term

memory. As this mental model is activated by a task, in a given context, in an economical fashion (much knowledge is encapsulated in automatic procedures), it is difficult to express it into words (Chi, Glaser, & Farr, 1988; Ehrlich, Tardieu, & Cavazza, 1993; Gentner & Stevens, 1983; Johnson-Laird, 1983). The lack of means available to deal with these cognitive and metacognitive difficulties creates somewhat of a bottleneck for organizations which aspire to address expertise transfer (Barjou 1995).

A possible solution to address the transfer of expertise consists in creating situations where experts have to explicitly provide their mental model of their field in an external representation. Research has shown the dynamic and contextual nature of such a strategy (Gentner & Stevens, 1983; Johnson-Laird, 1983). This requires the integration of two processes: verbal interactions in the context of professional activity and some means to trigger the externalization of the expert's knowledge according to the novice's needs and knowledge level. The co-construction of concept maps shows some interesting potential in the field. Many studies conducted in educational settings show that creating concept maps is beneficial to learning (Holley & Dansereau, 1984a; Horton et al., 1993; Novak & Gowin, 1984). Creating external representations such as concept maps gets people deeply involved in knowledge processing of a given field and forces them to reflect on the knowledge they already possess or the knowledge they are in the process of creating (Jonassen, *et al.*, 1997). Pair-building concept maps by an expert-novice team has the potential to favor intersubjectivity and establish a common ground for knowledge construction (Rogoff, 1990; Lave & Wenger, 1991), to provide instances of cognitive and socio-cognitive conflicts and triggers conflict-solving processes (Doise & Mugny, 1991; Hinde, Perret-Clermont & Stevenson-Hinde, 1988) as well as to support the use of scaffolding strategies by experts (Bruner, 1987). It has also been suggested that collaborative knowledge modeling prompts subjective discussions about the experience within a structured framework (Ballay, 2002).

This paper presents a collaborative knowledge modeling strategy by dyads of experts and novices that has been ongoing for two years in an organization of 20 000 employees, where over 60% of the staff will be retiring before 2014 (Charlebois, 2002). This strategy is similar to those used in the studies of Coffey and his colleagues (Coffey & Hoffman, 2003; Coffey, Hoffman, Cañas, & Ford, 2002) and of Cañas, Leake, & Wilson (1999). However, it differs in the fact that knowledge modeling is jointly conducted by experts and novices (not solely by experts) and that it is a knowledge management strategy that is primarily process-oriented. Our hypothesis is that collaborative knowledge modeling by expert-novice teams is particularly helpful in addressing the cognitive and metacognitive difficulties related to transfer of expertise in a professional setting.

2 Description of the Project

The collaborative knowledge modeling strategy was first used in 2002 at Hydro-Québec, the main producer, provider and distributor of electricity in the province of Quebec, in Canada. Up to now, over 150 experts and 150 novices from various departments (management, electrical engineering, civil engineering, etc.) have participated in this pilot project.

Instrumentation. MOT[1], a knowledge-modeling editor developed by Paquette (2002) from the LICEF Research Center[2] is used in this project. The knowledge modeling technique suggested by Paquette is somewhere between the formal techniques used in Artificial Intelligence (AI) and concept mapping techniques developed by Novak & Gowin (1984). Indeed, on one hand, the knowledge models produced with Paquette's technique are supported by a more structured representation language than the one used in concept maps, but less structured as those used in AI. The modeling language suggested by Paquette distinguishes graphically four types of knowledge (*concepts*, *procedures*, *principles* and *facts*), based on a typology used by Merrill (1994) and by Romizowski (1981) in the field of instructional design. Paquette also proposes a typology of six types of links (*is composed of; is a sort of; precedes; is an input/product of; regulates; is an instantiation of*). Although some researchers working with the concept mapping or the networking approaches also use some predefined labels for links (Chung, O'Neil, & Herl, 1999; Chiu, Huang, & Chang, 2000; Holley & Dansereau, 1984b; Osmundson, Chung, Herl, & Klein, 1999), the represented knowledge is generally treated as a single type of knowledge object (concepts). According to Paquette, specifying the type of knowledge objects and the type of links adds more precision and coherence to knowledge representations, thus facilitating their interpretation and communication. On the other hand, the structure of a MOT knowledge model is not strictly hierarchical, as it is

[1] MOT is an acronym for *"Modélisation par Objets Typés"*, which means *"Object-typed modeling"*. The French term "*mot*" also means "*word*".
[2] The LICEF Research Center is a laboratory that is dedicated to cognitive informatics and training environments (www.licef.teluq.uquebec.ca).

in concept maps. With MOT, it is also possible to illustrate networks, tree diagrams, causal diagrams, flowcharts, etc., as well as models which combine different types of structures. In fact, the choice of the structure is left to the knowledge modeler. Among other functionalities of MOT, we find the possibilities of creating a sub-model of each knowledge object represented in the first-level model (also called principal knowledge object) and of linking documents of different formats (with OLE links) to each knowledge object included in a model.

Figure 1 illustrates an example of the principal knowledge model produced by an expert-novice dyad working in the field of civil engineering. This example shows the procedure "Devise an urban station project", which is regulated (R-link), at Hydro-Quebec, by some specific actors named "Designers". The main input (I/P-link) of this procedure is a document labeled "Pre-Project" and its main product (I/P-link) is "Construction plans and estimates". The procedure is composed (C-link) of seven sub-procedures, some of which precede others (P-link). Finally, the dyad indicated that this procedure is regulated (R-link) by some organization standards for urban station projects.

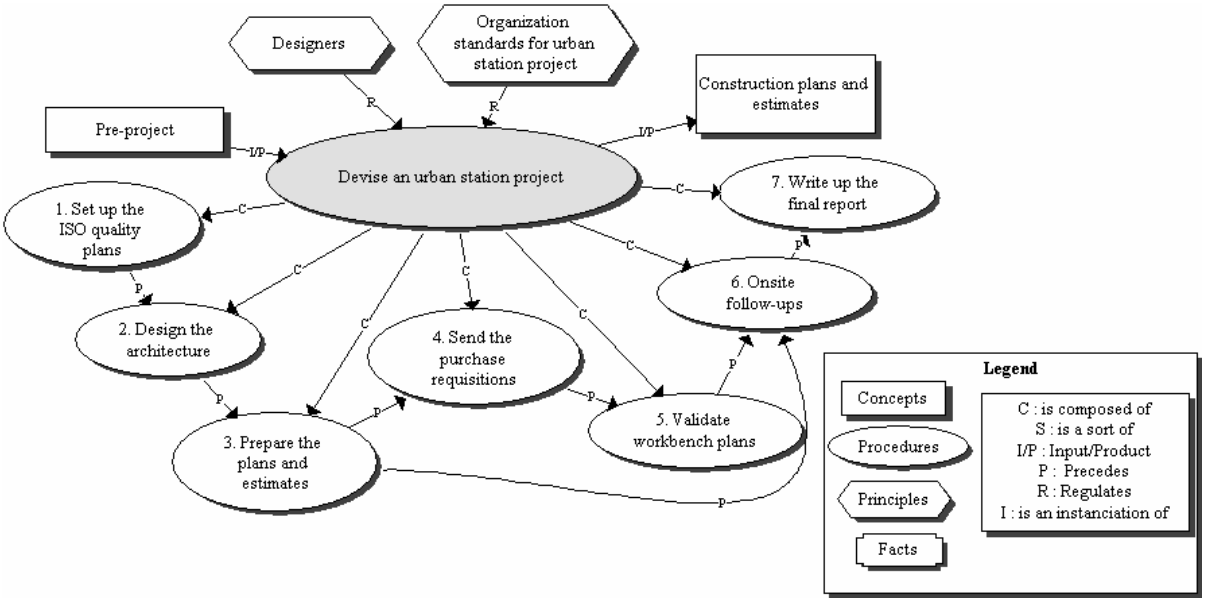

Figure 1. Example of a first level model produced by an expert-novice dyad at Hydro-Quebec.

Procedure. The procedure used to implement the expert-novice knowledge modeling strategy in the organization includes many steps. First, the selection of the expertise to model stems from the head managers' priorities. Heads of sectors select the "knowledge modeling project": for each of them, they identify the main goal of the project, the type of expertise to model, the novice and the expert involved, the potential end-users and the resources required. Once the teams are set up, members of each team delimit more precisely the domain of their modeling activity. Most of the time, it consists in a challenge faced by the novice when performing a specific task (for example, conducting a compliant wastewater treatment, producing a preliminary study for a given project, approving or inspecting equipment, etc.) or some other procedures that have not yet been documented.

A two-day knowledge modeling training session is then provided on-site to groups of 8 to 10 people. In the first half-day, an instructor introduces participants to the knowledge modeling technique with MOT. Then, over the next day and a half, under the supervision of the instructor, each team starts to co-model the knowledge associated to the challenge problem previously selected. After these two days, each team continues to develop its own model. The group meets again two weeks later to present the models of each team: all participants and the instructor can then suggest modifications and ways to complete the models. Depending on the complexity of the expertise represented and the ease each team shows with the technique, up to five additional workdays can be required to produce a model that could be considered an appropriate reference tool for the actors who will subsequently apply the expertise represented. Up to now, more than 80 % of the knowledge models have been completed by participants. Interestingly, some participants spontaneously used OLE links to join some job aids already in use in the organization to their knowledge model. Finally, the teams present their respective final models to managers and colleagues of their work sector.

3 Preliminary Observations

Collected data are still scarce. We recorded on video one training session and screen-captured (with *Windows Media Encoder*) the collaborative knowledge modeling session of three of the five dyads participating in this session, but we just began an in-depth data analysis. Thus, we will present only a few of the spontaneous commentaries shared by participants during this recorded training session. As the second author of this paper is the coordinator of the pilot project at Hydro-Quebec and the last one is the MOT training session instructor, we also report other anecdotal data based on their own interaction with participants and on one informal focus group session conducted by the coordinator of the pilot project. We will also first describe how the knowledge models produced by dyads have been used up to now in the organization.

Uses of the knowledge models. Knowledge models produced by the expert-novice teams have been downloaded in a computerized knowledge management system (*LiveLink*): they can then be consulted, reused, adapted, updated, commented, etc., in order to share the expertise on a larger scale within the organization[3]. Thus, although the collaborative knowledge modeling strategy has been defined primarily as a process-oriented approach to knowledge management, it is also compatible with a product-oriented approach. About 20% of the novice participants have begun to use the models as live reference documents. Some competency development specialists have also begun to use them for training purposes. However, the usage of the knowledge models is still limited. A planned and systematic adoption strategy such as the one proposed by Rogers (1983) remains to be implemented. Hydro-Québec is currently drafting a corporate program to deploy this strategy, rendering it available to all of the members of the organization, starting in January 2005. As the use of this type of graphical representation of tacit expert knowledge seems to represent a major innovation for employees, it will probably take some time for them to discover how to integrate them efficiently in their own activities: the knowledge models have to become a genuine *instrument* for their own activities (Vérillon & Rabardel, 1995).

Attitudes of the participants. In general, the knowledge modeling strategy was considered positive by both the experts and the novices. However, we found a certain number of nonpartisans, especially among the experts who seemed to lack time to participate in these activities due to their heavy workload. Most found the software very user-friendly, although some had difficulties with the process of categorizing knowledge. Many commented that the strategy helped them to organize their own knowledge. Some experts lamented that collaborative knowledge modeling with novices slowed down their own modeling process; however, for others, the interaction with novices was essential to externalize what seemed obvious for them and MOT helped them capture a very large body of their knowledge in an economical fashion. Others recognized the inherent advantages of graphical representations while adding that they remained more comfortable sharing their knowledge by spelling it out in a written text or through live demonstrations. On the other hand, novices appreciated having a reference document that will prevent them from constantly referring to the expert: “By using the model, I will be able to do my job without asking lots of questions to the expert”, commented one of the participants. The instructor noted that the dyads interactions seemed to permit to each employee to become more aware of the complexity of the others’ duties and of the similarities of some tacit knowledge used in many tasks.

4 Discussion

The collaborative knowledge modeling strategy experimented at Hydro-Quebec seems promising for expertise transfer within the organization. However, it brings up many research questions. A survey of the literature (Basque & Pudelko, in press) allows us to identify, among others, a series of factors which are likely to influence its efficiency. These issues must be addressed.

First, there are a series of *factors which are related to the individuals involved*. We can wonder, for example, how individual variables, such as the experts’ level of motivation to share their knowledge, the individual’s spatial or verbal skills or their cognitive style affect the efficiency of such an activity. The few studies that investigated these topics were conducted in school settings (Obekula & Jegede, 1988; Stensvold & Wilson, 1990; Reed & Oughton, 1998; Oughton & Reed, 1999; 2000). It would be valuable to conduct such research with adult participants in their professional setting. For example, Stensvold & Wilson (1990) have shown, in a study conducted with Grade 9 participants, that creating concept maps was more beneficial to the students with low verbal skills than to those with high verbal skills. We may thus hypothesize that concept maps

[3] All of the graphics of a MOT model can be converted into XML (Extensible Mark-up Language), thus facilitating such an activity.

aimed to represent knowledge would be particularly effective for certain types of employees (for example, manual workers).

Second, there are some *factors which are linked to the organization of the co-modeling situations*. For example:

- *The active contribution of each participant involved in the activity*: A setting where the participants are involved in the creation process together (as is the case in this project) would be more effective than a situation where only the results of the activity are shared (Stoyanova & Kommers, 2002).
- *The level of asymmetry of the partners' expertise paired up for the activity*: A gap that is too severe could be detrimental. According to various studies conducted in adult-children dyads, asymmetric relations tend to trigger relational regulation, rather than sociocognitive regulation of the conflicts. Hence, for the interaction to be effective, problem-solving activities must be conducted on a sociocognitive level, and not on a social level (Doise & Mugny, 1981; Perret-Clermont & Brossard, 1988). Moreover, once aware of this asymmetry, the participants' representations of the relationship constitute a factor which can affect their partnership. Hence, participants with low self-esteem will tend to overestimate the competency of their partners, thus influencing their interactions.
- *The knowledge modeling training method*: Research conducted in the field of concept mapping provides little indication as to the most efficient method to train people for this type of activity. To what extent, and how, should people involved in collaborative knowledge modeling in a professional setting be trained to a knowledge modeling language in order to minimize the cognitive load of such an activity (Chang, Sung, & Chen, 2002)? Moreover, how can we guarantee sufficient freedom of expression to allow the representation of different knowledge structure to suits the needs of the knowledge modelers? How can we help them to make links among knowledge in the most significant and useful manner, an activity considered very difficult by many researchers (Basque & Pudelko, 2003; Cañas *et al.*, 2003; Faletti & Fisher, 1996; Fisher, 1990; Novak & Gowin, 1984; Roth & Roychoudhury, 1992)? Are there any aspects of collaboration that should be the target of specific training? These questions should be investigated further.
- *The representation language and the representation tool used:* Once again, a series of questions deserve to be explored further. For example, is the representation system suggested by the tool appropriate for all fields and sectors? Does it allow the representation of a variety of knowledge structures that can be organized into temporal script, in causal diagrams, etc? Is it best to impose the use of knowledge and link typologies? If strategic knowledge is at the heart of expertise, can we say that expertise is mostly represented in the "principles" included in a model?

Third, there are *factors related to the global organizational environment*. Among those, we find, for example, the level of competition (between individuals or between various groups) that exists within the organization, the level of hierarchy present in the organization, the feelings of confidence and safety that employees have towards the organization, the manner in which knowledge is shared within the organization, the existence of incentives associated with expertise transfer (tokens of recognition, rewards, release time), etc.

Aside from investigating these different factors, it would be relevant to evaluate the effects of collaborative knowledge modeling on the expertise transfer and the productivity of the organization. We believe that these effects cannot be investigated without also analyzing the knowledge construction processes instigated by the experts and novices during collaborative knowledge modeling. As mentioned earlier, we have initiated an exploratory research study on the topic.. We hope to identify the various types of mediations that occur during the activity, using the instrumental approach, based on Vygotsky's (1978) sociocultural theory and developed by Rabardel (1995; 1999) among others.

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