

17. Collaborative Knowledge Modelling with a Graphical Knowledge Representation Tool: A Strategy to Support the Transfer of Expertise in Organisations

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Abstract. This chapter presents a strategy for collaborative knowledge modelling between experts and novices in order to support the transfer of expertise within organisations. The use of an object-typed knowledge modelling software tool called *MOT* is advocated, to elaborate knowledge models in small groups composed of experienced and less experienced employees within organisations. A knowledge model is similar to a concept map, except that it is based on a typology of links and knowledge objects. This technique is used to help experts externalise their knowledge pertaining to concepts, principles, procedures and facts related to their work and to support the sharing of knowledge with novice employees. This chapter presents the rationale behind this strategy, the tool used, the applications of this method and the manner in which it can be integrated into a global knowledge management strategy within organisations.

17.1 Introduction

Over the last few years, economic and technological changes have sparked major challenges in the workplace. To remain competitive and efficient, organisations must rely upon the competencies of their human resources. Indeed, organisational know-how is often intrinsically linked to the tacit knowledge acquired by employees while working for the organisation. Hence, it is lost once the employees leave the organisation (Nonaka & Takeuchi, 1995; Polanyi, 1966). Jacob & Pariat (2001) claim that such tacit knowledge can represent up to 70% of the organisation's knowledge and competency assets. Since most Western societies will soon experience a substantial turnover of manpower, issues pertaining to the elicitation, representation, sharing, validation, re-use and evolution of knowledge has become particularly critical for organisations in recent years (Beazley et al., 2002; De Long, 2004). Consequently, many of them began to set up knowledge management (KM) strategies supported by information and communication technologies.

According to Apostolou et al. (2000), two approaches to KM can be distinguished. The first one, called a “product-oriented approach”, focuses on the creation, storage and re-use of documents. Such an approach aims to create an “institutional knowledge memory”. The second one, called a “process-oriented approach”, addresses the social communication process and strives to transfer expertise directly among people: “in this approach, knowledge is tied to the person who developed it and is shared mainly through person-to-person contact. The main purpose of Information Technology in this approach is to help people communicate knowledge, rather than store it. This approach is also referred to as the ‘personalisation approach.’ (Apostolou et al., 2000, p. 2).

Traditional strategies used in the process-oriented approach to KM in organisations include formal training in groups, as well as informal training on a one-on-one basis. For example, an experienced worker who is about to leave the organisation is asked to train his successor over a period of a few days or weeks. Some other strategies include job sharing between senior and newer staff members, buddy systems, mentoring, sponsorships, and communities of practice (McDermott, 2001; Wenger, 1998).

However, transferring one’s own knowledge to someone else does not constitute a simple task. Knowledge-transfer aptitudes and pedagogical competencies are not innate. Moreover, those who excel in their field are not necessarily aware of the manner in which they perform their work. Tacit knowledge is difficult to externalise. Most of the time, experts use their knowledge “live” and rarely have the opportunity to consciously reflect upon what they are doing. They basically find it hard to verbalise what they know or to explain their “action model” (Sternberg, 1999). Cognitive psychology research conducted within the “mental model” paradigm indicates that expertise consists of a highly organised structure of different types of knowledge (Chi et al., 1981; Ericsson & Charness, 1994; Glaser, 1986; Sternberg, 1997). A mental model is activated in the context of a specific task in an economical and situated fashion; specifically, the expert activates only the knowledge necessary to perform the task. Moreover, much expert knowledge becomes “encapsulated”. Consequently, it is difficult to express it into words (Chi et al., 1988; Gentner & Stevens, 1983). Transferring one’s expertise thus requires that the proficient practitioners delve deeper into their knowledge and spell out for others what seems clear and easy for them to understand. 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 et al., 2001). The lack of means available to deal with these cognitive and metacognitive difficulties creates somewhat of a bottleneck for organisations that aspire to address expertise transfer.

A possible solution to approach this problem consists of creating situations where experts have to provide novices with a structured external representation of their knowledge of the field. This requires the integration of two aspects: (1) verbal interactions in the context of professional activity and (2) a means to trigger the externalisation of the expert’s knowledge according to the novice’s needs and knowledge level. The co-construction of graphical representations of knowledge offers great potential for this purpose. Indeed, many studies conducted in educational settings

demonstrate that creating graphical representations in groups, such as concept maps, is beneficial to learning (Basque & Lavoie, 2006).

This chapter presents a strategy to support the transfer of expertise in organisations that consists of having small groups of experts and novices co-construct graphical knowledge models using an object-typed knowledge modelling software tool called *MOT* (Paquette, 2002). The strategy has some similarities to the concept mapping technique used by Coffey and his collaborators to elicit knowledge (Coffey, 2006; Coffey & Hoffman, 2003). However, our strategy differs in that (1) knowledge modelling here is jointly conducted with experts and novices (not solely with experts), (2) it is done within a KM perspective that is primarily *process*-oriented, although it can also be integrated into a product-oriented KM program as discussed further on and (3) it is completed using a semi-formal graphical representational language.

The remainder of this chapter is organised as follows. The knowledge modelling software tool is described in Sect. 2, followed by a presentation of the knowledge transfer strategy in Sect. 3. Then, in Section 4, the rationale behind the strategy is addressed. In Sect. 5, we report first applications of the strategy in two Canadian organisations. In Sect. 6, we explain how the strategy can be integrated into a more global knowledge management project within an organisation. Finally, to conclude, research issues emerging from our work are identified.

17.2 The Knowledge Modelling Tool

It is often said that a picture is worth a thousand words. This can be applied to sketches, diagrams and graphs used in various fields of knowledge. Concept maps are widely used in education to represent and clarify complex relationships between concepts (Novak & Gowin, 1984). Flowcharts serve as graphical representations of procedural knowledge or algorithms. Decision trees are another form of representation used in various fields, particularly in decision-making and expert systems. All these representation methods are useful at an informal level, as thinking aids and tools to communicate ideas, albeit with limitations. One of these is the imprecise meaning of the links represented in the model. Non-typed arrows can have various meanings, sometimes within the same graph. Another limitation consists of the ambiguity around the type of entities. Objects, actions performed on objects, conditions applied to actions and statements of properties about the objects are often not distinguished, which results in a missed opportunity to “disencapsulate” knowledge and makes graph interpretation imprecise and risky. Ambiguity can also arise when more than one representation is introduced into the same model. For example, concepts used in a procedural flowchart as entry, intermediate or terminal objects could be given a more precise meaning by developing them using part-whole or class-subclass relationships in sub-models of the procedure. This also applies to procedures included in concept maps that could be developed as procedural sub-models described by flowcharts along with decision trees.

In software engineering, many graphic representation formalisms have been or are used, such as entity-relationship models (Chen, 1976), conceptual graphs (Sowa, 1984),

object modelling techniques (OMT) (Rumbaugh et al., 1991), KADS (Schreiberc et al., 1993), or Unified Modeling Language (UML) (Booch et al., 1999). These representation systems were built for the analysis and architectural design of complex information systems. The most recent ones, such as UML-2, require the use of up to fifteen different kinds of models so that links between them rapidly become hard to follow without considerable expertise.

The initial goals of *MOT* developers were different. They intended to develop a graphical representation system that was simple enough to be used by individuals without a computer science background, yet sufficiently general and powerful to let them represent knowledge in a semi-structured way.

17.2.1 Background in Schema Theory

The syntax and semantics of the *MOT* graphical modelling language are based on the notion of schema. The concept of schema is the essential idea behind the shift from behaviourism to cognitivism. Cognitivism, a dominant theory in the field of psychology and other cognitive sciences for some years, is based on the pioneering ideas of Inhelder & Piaget (1958) and Bruner (1973). For Piaget, a schema is essentially a cognitive structure that underlies a stable and organized pattern of behaviour. In the early seventies, Newell & Simon (1972) developed a rule-based representation of human problem solving activities on the same basis, while Minsky (1975) defined the concept of “frame” as the essential element to understand perception as a cognitive activity and a means of reconciling the declarative and procedural views of knowledge.

Schemata play a central role in knowledge construction and learning. They guide perception, defined as an active, constructive, and selective process. They support memorisation skills seen as processes to search, retrieve, or create appropriate schemata to store new knowledge. They make understanding possible by comparing existing schemata with new information. Globally, through all these processes, learning is seen as a schema transformation enacted by higher order processes. Learning is seen as schemata construction and reconstruction through interaction with the physical, personal, or social world, instead of a simple transfer of information from one individual to another.

17.2.2 The Typology of Knowledge in MOT

In educational sciences, there is a consensus to distinguish between four basic types of knowledge entities (i.e., facts, concepts, procedures, and principles), despite some differences of opinion relative to the terminology and associated definitions (see for example, Merrill, 1994; Romizowski, 1999; Tennyson & Rasch, 1988; West et al., 1991). All four types of knowledge are also considered in the framework of schema theory. The distinction between conceptual and procedural schemata has long been accepted in the cognitive sciences. Later, the third category, conditional or strategic schemata, was proposed (Paris et al., 1983). These schemata have a component that specifies the context and conditions required to trigger a set of actions or procedures,

or to assign values to the attributes of a concept. These categories map very well onto the existing consensus within educational sciences.

This categorisation framework has been retained as the basis of the *MOT* graphical language for representing knowledge entities. *Concepts* (or classes of objects), *procedures* (or classes of actions) and *principles* (or classes of statements, properties or rules) are the primitive objects of the *MOT* graphical language. These objects are visually differentiated from one another through different geometric figures, as shown in Fig. 17.1. Individuals from the three basic classes of knowledge objects are linked to them through an “instantiation” link (I), yielding three kinds of individuals (or facts): *Examples*, *Traces*, and *Statement*. Each set of individuals is obtained by providing precise values to the attributes that define a concept, a procedure or a principle.

Concepts can be object classes (country, clothing, vehicles, etc.), types of documents (forms, booklets, images, etc.), tool categories (text editors, televisions, etc.), groups of people (doctors, Europeans, etc.), or event classes (floods, conferences, etc.). *Procedures* are actions or operations performed by humans, systems or machines (add numbers, assemble an engine, complete a report, digest food, process students’ records, etc.). *Principles* can state constraints on procedures (the tasks must be completed within 20 days), cause/effect relationships (if it rains more than 25 days, the crop will be jeopardised), laws (a sufficiently heated metal will stretch out), theories (economic laws), rules of decision (advising on an investment), or prescriptions (medicinal treatment, instructional design principles, etc.).

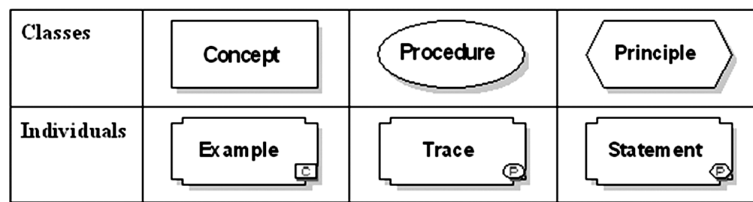


Fig. 17.1. Types of knowledge entities in *MOT*

17.2.3 The Typology of Links in *MOT*

Graphs similar to UML object models could very well be used to represent the attributes that describe a schema with different formats according to their type. However, the graphical *MOT* language (Paquette, 2002, 2003) strives to improve the readability and the user-friendliness of graphs by externalising the internal attributes of a schema into other schemata with proper links to the original one.

For example, in Fig. 17.2, the link between the schemata “Triangle” and “Rectangle Triangle” is shown explicitly through a specialisation (S) link from the latter to the former concept. Links between the “Triangle” concept and its sides or angles attributes are shown using a composition (C) link. The links from an input concept to a procedure and from a procedure to one of its products are both shown by an input/product (I/P) link. The sequencing between actions (procedures) and/or conditions (principles) in a procedure is represented by a precedence (P) link. Finally, the relation

between a principle and a concept that it constrains, or between a principle and a procedure (or another principle) that it controls, is expressed by a regulation (R) link. Using these links, this simple example on the triangle concept becomes a *MOT* model, where relations between knowledge entities are made explicit and where the types of entities (procedural, conceptual and strategic) are amalgamated in the same model.

The *MOT* model such as this one includes different types of schemata whose attributes are all explicitly externalised and related to each other using six kinds of typed links that are constrained by the following grammar rules:

1. All abstract knowledge entities or classes (*concepts, procedures, principles*) can be related through an *Instantiation* (I) link to a set of *facts* representing individuals called *examples, traces, and statements*.
2. All abstract knowledge entities (concepts, procedures, principles) can be specialised or generalised using *Specialisation* (S) links.
3. All abstract knowledge entities (concepts, procedures, principles) can be decomposed using the *Composition* (C) link into other entities, generally of the same type.
4. Procedures and principles can be sequenced together using the *Precedence* (P) link.
5. Concepts can be inputs to a procedure using an *Input/Product* (I/P) link to the procedure or products of a procedure using an I/P link from the procedure.
6. Principles can regulate, using a *Regulation* (R) link, any procedure to provide an “external” control structure, to constrain a concept or a set of concepts by a relation between them, or to regulate a set of other principles (e.g., to decide on conditions of their application).

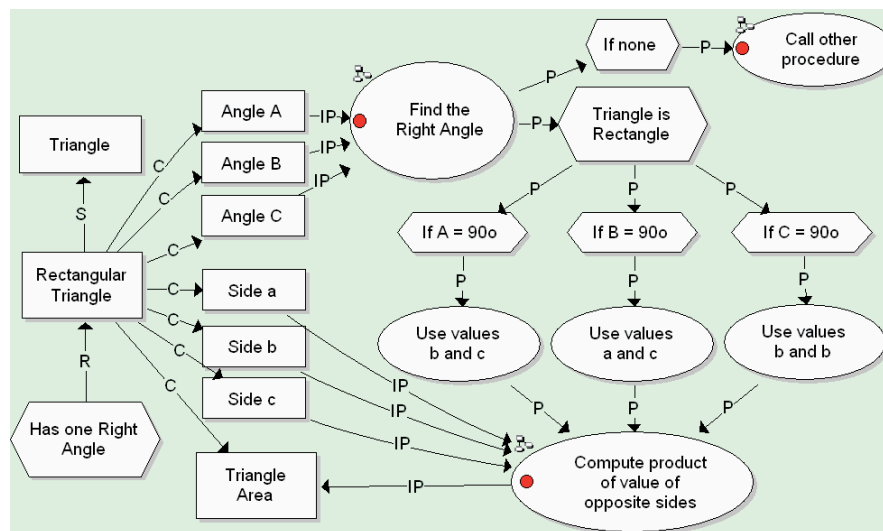


Fig. 17.2. A simple MOT model to provide a definition of the concept of a rectangle triangle

The first three links are based on traditional distinctions in the field of Artificial Intelligence between instantiation (I: “is-a”), composition (C: “is part-of”), and specialisation (S: “a kind-of”) links that are used to represent relationships between classes. The Input/Product (I/P) and Precedence (P) links are fundamental in procedural or algorithmic representations. The first one helps to represent data flows between information sources and operations, where they serve as input or product, while the second helps represent sequences of operations or tasks. The Regulation (R) link consists of an essential innovation to relate principles to other types of knowledge. It is inspired by knowledge-based or expert systems where the control structure (usually conditional rules) is external to the task it controls. Typically, principles are processed by an inference engine that will apply these rules to trigger operations or to produce (other) objects.

Figure 17.3 summarises the grammar rules of the *MOT* graphical language in the form of an abstracted graph whose nodes illustrate types of knowledge objects with arrows that depict valid links between them. Based on these grammar rules, the *MOT* software restrains the types of links that users can create between two specific types of knowledge objects. For example, since a specialisation link can only be used between two objects of the same type, the user will be suggested a default link (the most probable valid one) if he tries to link two objects of different types with the “S” link. However, users can use the “untyped” links if they want to put their own labels on links. A specific shape is also provided for “untyped” objects.

With this set of primitive graphic symbols, it has been possible to build from simple to complex representations of structured knowledge in graphical models. For example, we can build representations that are equivalent to concept maps, flow-charts (including iterative procedures), decision trees and other types of models such as models of processes, methods and theories. All of these types of models have been elaborated in a number of projects conducted at the LICEF Research Center (Montreal, Canada) since the publication of the first version of *MOT* in 1996. Following are a few examples: a computerised school model (Basque et al., 1998), an assistance model

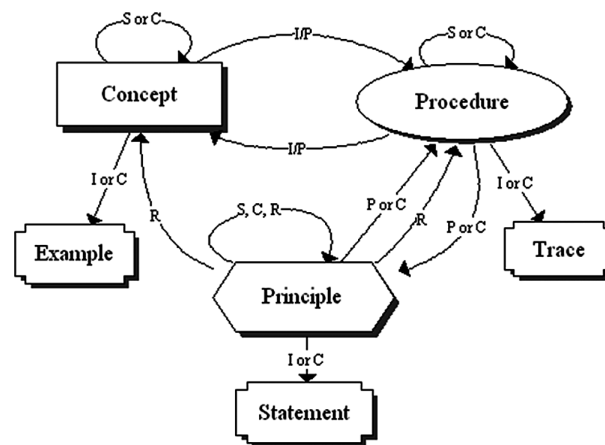
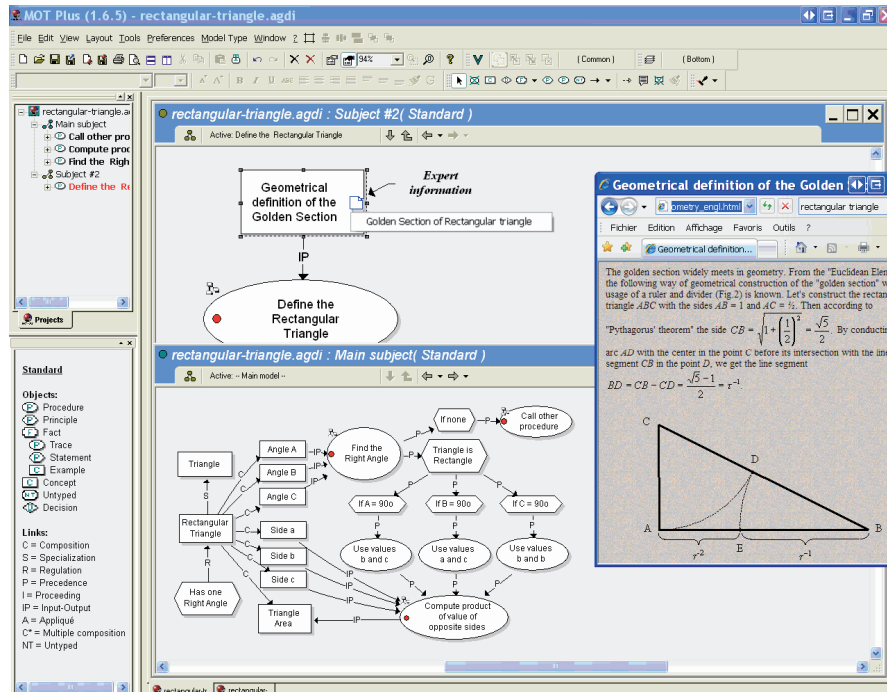



Fig. 17.3. The *MOT* metamodel

Fig. 17.4. The interface of the *MOT Plus* tool

for distance learning (Dufresne et al., 2003), a troubleshooting model (Brisebois et al., 2003), a Web-based professional training model (De la Teja et al., 2000), a model of processes and methods in a virtual campus (Paquette et al., 2002), a knowledge base model (Henri et al., 2006), a learning objects' management process model (Lundgren-Cayrol et al., 2001), skills and competencies models (Basque et al., 2006; Paquette, 1999; Paquette et al., 2006), a self-management of learning model (Ruelland, 2000), etc.

Among other *MOT* functionalities, we find the possibility of creating a sub-model for each knowledge object¹ represented in the first level of the model and to link documents of different formats (with OLE or URL links) to each knowledge object. It is also possible to link a "comment" to a knowledge object or a link. The last version of the software, called *MOT Plus*, adds functionalities to depict specific types of models (ontologies, flowcharts, learning scenarios), enhanced exportation facilities (HTML, XML, OWL, IMS-LD, etc.), navigation improvements into sub-models with hierarchical menus, etc. The *MOT Plus* interface is presented in Fig. 17.4.

¹ Represented by the icon  attached to knowledge objects developed further in a sub-model.

17.3 The Knowledge Transfer Strategy

As briefly defined above, the knowledge transfer strategy essentially consists of creating small groups of experts and novices for the purpose of co-constructing a knowledge model related to specific fieldwork using the *MOT* software. The entire procedure used to implement this strategy in organisations includes different steps that can be operationalised differently from site to site. The main steps are the following:

Specifying the domain to model: This decision usually stems from head managers' priorities. A systematic methodology can be used to identify, at a high-level, the most critical knowledge in the organisation (Ermine et al., 2006).

Selecting participants: This step consists of identifying the experts and novices who subsequently become involved in the project. Experts can be workers near retirement possessing strategic knowledge or individuals who possess rare knowledge. They usually are explicitly recognized as experts by their peers. The term "novice" is not automatically synonymous with new staff: this can be an employee who recently changed position within the organisation or an individual who needs to extend his knowledge on some work processes to be able to substitute other employees at times. In other words, the degree to which an individual can be considered a novice in a field varies significantly. Moreover, criteria other than degree of expertise (or apprenticeship) in the targeted field need to be considered to select participants: availability, willingness to share knowledge, familiarity with graphical representations, etc. This being said, the selected participants do need to be well-informed of the goal and the process of the knowledge modelling strategy. In order for the project to be a success, they must clearly be willing to become involved in the activity.

Knowledge modelling training session: Training will differ according to the role assigned to the experts and novices involved in the project. If they are to manipulate *MOT* in order to create their own knowledge models (even if this is done with the assistance of a knowledge modelling specialist), training relative to the *MOT* software and to its knowledge modelling language is necessary. In this case, an initial on-site 2-day session given to groups of 8–12 persons, followed by individual and group consultations with the instructor, have shown to be effective for basic training. If the organisation asks that the software be manipulated by a knowledge modelling specialist, participants' training for the *MOT* software will be minimal. Indeed, in such a case, a brief presentation of the typologies used in *MOT* suffices. Participants become quite easily and naturally familiar with the knowledge modelling language simply by observing a knowledge modelling specialist manipulate the software and use the representational language.

Collaborative knowledge-modelling sessions: The duration of the sessions can vary depending on the scope of the target field and the availability of the participants. In our case, we propose starting with an intensive 2- to 3-day session that allows participants to elaborate a global, relatively stable and consensual representation of the field. Additional sessions may be required in order to add details or sub-models to the initial model. Such sessions can take place in small groups of 2–4 experts and novices. As already mentioned, two approaches can be used. In the first one, experts and novices co-construct the model at the same computer, with

on-demand assistance of a knowledge modelling specialist whose role is essentially to provide feedback on the model and answer questions. Many small groups of experts-novices (dyads or triads) can work simultaneously in a computer room. In the second approach, two knowledge modelling specialists worked with a single group. The first one interviews participants in order to elicit overtly their knowledge, while another one creates the map on a computer. The map is projected on the wall so that all the members of the group could visualise it. In this second approach, it is important that, prior to the session, the knowledge modelling specialist who moderates the session read some documentation supplied by experts. With this information, he can even develop a sketchy first-level model, which will be suggested to participants in order to accelerate the knowledge modelling process and stimulate the negotiation of meaning at the beginning of the session. The first level of the model usually represents the main procedure and major sub-procedures used by the experts in their work. Then, the procedures and sub-procedures inputs and outputs (concepts) are added iteratively to the model, as are the principles that regulate the procedural knowledge. Sub-models are also developed progressively, if and as required. Throughout the process, knowledge modelling specialists help participants to elicit their knowledge at the appropriate level of granularity. They are also invited to be specific and consistent when labelling knowledge objects. Careful attention is paid to explicit redundancy. Indeed, when the same knowledge object is used at different levels of the model, it is to be copied and pasted with a special *MOT* function that adds a visual (red dot) on the graphic shape and that allows users to search all sub-models displaying the knowledge object. At any given moment during the session, participants or knowledge modelling specialists can suggest a complete re-structuration of the entire knowledge model, a task that is facilitated by the use of the software.

Validation of the co-constructed knowledge model: Once the first version of the model is produced, a final validation can be performed by one or more experts who participated in the session and/or peer experts involved in the field. Also, the validation process can intertwine with the participants' real work practices. While "instantiating" the knowledge represented in the model based on actual work situations, modifications to the knowledge model can be more easily identified. Electronic documents or URLs can also be attached to knowledge objects in order to provide them with a more detailed and contextual meaning.

Presentation of the models by the participants to managers and colleagues: The participants usually appreciate presenting and explaining their co-constructed knowledge model to their managers and colleagues. This acts as a means of promoting their work, as well as allowing them to deepen their comprehension of the model.

Implementation of a maintenance strategy of the knowledge model: It is important to consistently continue to improve the model. This task can be performed by an individual or (preferably) a group of people endowed with a sufficient level of expertise in the field, while also being sufficiently familiar with the representational language used.

17.4 Rationale for the Knowledge Transfer Strategy

How can the collaborative knowledge modelling strategies conducted with groups of experts and novices promote the transfer of expertise to the latter? To answer this question, three aspects of the activity are examined: (1) the cartographic nature of the representational language used; (2) the semi-formal nature of this language and (3) the collaborative dimension of the activity. These three components are addressed in the following sections.

17.4.1 The Cartographic Nature of the Representational Language Used

The knowledge cartography strategy that we propose to support the transfer of expertise has some background in meaningful learning theory (Ausubel, 1968), which is at the origin of the seminal work of Novak & Gowin (1984) on concept mapping in education. It is also based on cognitivist work on hierarchical structures of knowledge and schemata (Kintsch, 1996; Rumelhart & Ortony, 1977; Schank & Abelson, 1977; Trabasso & van den Broek, 1985).

Significant learning is defined as an assimilation process of concepts in propositional networks (Ausubel, 1968). According to Novak & Gowin (1984), concept maps allow students to externalise personal knowledge in the form of significant propositional networks. Creating concept maps would then favour significant learning (Novak & Gowin, 1984), allowing learners to clarify links between concepts that they establish implicitly (Fisher, 2000; Holley & Dansereau, 1984) and involving them in deep knowledge-processing (Jonassen et al., 1997). This will lead them to “learn how to learn” (Novak & Gowin, 1984). Similarly, Holley & Dansereau (1984) argue that “spatial learning strategies” enhance deep knowledge-processing (Craik & Lockhart, 1972), hierarchical structuring of propositional representations and schemata, and inference making, especially causal inference making (Trabasso & van den Broek, 1985).

17.4.2 The Semi-formal Nature of the Representational Language Used

MOT can be described as a semi-formal knowledge representation tool. From an Artificial Intelligence perspective, a formal representation is defined as a representation that is machine-readable. Uschold & Gruninger (1996) describe four levels to formalisation of representations: “highly informal” (expressed in natural language), “semi-informal” (expressed in an artificial, formally defined language), “semi-formal” (expressed in a restricted and structured form of natural language) and “rigorously formal” (meticulously defined terms with formal semantics, theorems and proofs on properties such as soundness and completeness). It was stated above that knowledge models created with *MOT Plus* are machine-readable to a certain degree. For example, they can be exported in XML or into a relational database.

We also use the term “semi-formal” from a cognitive perspective to express the idea that, compared to typical concept mapping tools, *MOT* imposes some additional constraints on the representational activity based on schema theory that forms the set of grammar rules defining a formal grammar of graphic symbols.

Some authors argue that a constrained or semi-formal approach to concept mapping adds more precision, exhaustiveness and coherence to the knowledge representation, thus facilitating its interpretation and communication between humans (Gordon, 2000; Moody, 2000). Others warn about the danger of reducing the complexity of the knowledge domains. For example, Faletti & Fisher (1996) argue that “there are advantages in systematicity and ease of net generation associated with using a parsimonious number of relations [...], but the price of parsimony is the reduction of potentially valuable distinctions. On the other hand, a tendency toward profligacy can overwhelm” (p. 201).

However, although certain authors cite the flexibility of expressiveness as a major factor to consider in the design of concept map tools for learning (Hereen & Kommers, 1992), few studies have examined the specific contribution of the constraints associated with the use of semi-formal languages implemented in domain-independent digital tools dedicated to knowledge modelling (Alpert, 2004). Many hypotheses can be formulated in order to guide future research on this issue. A first hypothesis deals with the fact that typologies constitute some sort of meta-language which, if shared by members of a group, allows them to work on a common representation of the field. Knowledge modelling that uses typologies of knowledge and links would force participants to confront and recognise similarities and differences in their respective representation of the field, while offering the advantage of making the model subsequently easier to read for other individuals who are familiar with the typology.

A second hypothesis states that knowledge modelling that uses a finite set of categories of types of knowledge and links would help experts make their knowledge explicit and guide them in representing knowledge as typical schematic structures of work situations, that is, procedural models of production and of transformation of objects using artifact-mediated actions guided by rules, heuristics and norms.

In *MOT*, procedural knowledge is represented by nodes rather than links, as is the case with other concept mapping tools. Such a strategy seems an interesting solution for issues pertaining to distinguishing generic from specific links in a given field and to eliciting procedural knowledge.

Certain authors disagree with the use of canonical links by arguing that each field possesses its own set of relations and, therefore, they cannot be predetermined (Fisher, 1990). However, this researcher became more flexible after eight years of observing students creating biology concept maps with the SemNet software (Faletti & Fisher, 1996; Fisher & Moody, 2000). The data collected indicates that three of the relations used in the maps account for over 50% of all the relations in the field. These included “is composed of”, “is a kind of” and “is a characteristic of”. Other relations are specific to a field or a set of fields. For example, in the field of reproductive physiology, relations included “synthesises”, “secretes”, “stimulates”, “inhibits”, etc. For this reason, Faletti & Fisher (1996) compromised by distinguishing between the generic and specific relations of a field. According to this approach, Osmundson et al. (1999) include 21 predefined concepts and 14 predefined links in the menus of the concept mapping software developed for their research in the field of human biology (respiration, circulation and digestion). Experts in the field were consulted and the links that they identified are composed of links that are generic

links to all fields (e.g. “is composed of”) and links specific to the field (e.g. “absorbs”, “digests”, “pumps”, etc.).

As mentioned above, in *MOT*, field-specific relations are represented in (procedural) nodes rather than in links. Therefore, the links used in the model only represent *generic* relations, resulting in a more economical and more parsimonious representational system.

It is noteworthy that, in *MOT*, users can also put their own labels on links using the “untyped link” category of the typology. However, we observed that often, these labels are used to express links that are already defined in the typology. For example, in a study conducted by Basque & Pudelko (2003), the label “results in” introduced by university students as an untyped link in their model corresponds to the Input/Product (I/P) link. The fact that users multiply labels for a single link type can actually indicate that it is difficult for participants to structure their own knowledge and recognize that similar meanings can be hidden behind words. It also makes it more difficult or time-consuming for others to read the map, obviously resulting in a limitation in cases where such maps are subsequently made available to other employees in the organisation.

We also believe that *MOT* language is a powerful tool to represent procedural knowledge (albeit in a declarative format)². Current concept mapping tools essentially enhance representations of declarative knowledge, that is, representations of objects and their attributes (Fisher, 1992; Hereen & Kommers, 1992). *MOT* offers the possibility of representing actions as “knowledge objects” that can be decomposed into sub-actions. Actions (procedures) can be linked to each other with composition (C), precedence (P) or specialisation (S) links. The activity of representing knowledge can, therefore, be focused from the start on representing actions and, secondly, on representing objects and concepts used to perform actions and principles that guide actions. This is a value-added advantage because the experts’ schemata imply much *procedural* knowledge (the *know-how*), along with knowledge regarding explicit conditions as to its applicability known as *conditional* or *strategic* knowledge (the *know-when* and the *know-why*) and with object schemata that can be instantiated at will (the *know-what* or *declarative* knowledge) (Chi et al., 1982, 1988; Ericsson & Charness, 1994; Glaser, 1986; Schmidt & Boshuizen, 1993; Sternberg, 1997).

Novice and experts then have the means to represent their field work as their own procedural model, with structures staying consistent no matter which level of the procedure is represented. This characteristic of the representational language can also bring the novice to interrogate experts during the co-construction of the knowledge model, the objects and principles linked to procedures in the model acting as anchors for interactions.

² The term “declarative” when applied to the term “knowledge” comprises two different meanings which are often confused. In a first sense, all knowledge that is overtly “verbalised” (that is, expressed with words) is said to have a declarative format. In a second sense, the term “declarative” defines a specific type of knowledge (declarative knowledge), that is, knowledge about objects and on properties of objects (the *know-what*), as opposed to “procedural” knowledge or knowledge on actions (the *know-how*). Procedural knowledge can then be represented in a declarative format.

17.4.3 The Collaborative Dimension of the Strategy

Finally, the proposed strategy implies that experts and novices interact during the elaboration process of the knowledge model. As mentioned previously, some studies conducted in educational settings have shown that, compared to individual concept mapping or other types of collaborative learning activities (e.g. producing an outline or a matrix representation), collaborative concept mapping is more beneficial to learning (see Basque & Lavoie, 2006, for a review). Different socio-cognitivist and socio-constructivist theories can be evoked in order to explain these results.

According to social cognitive theory (Bandura, 1986), observing an expert in action promotes learning. Learning cognitive skills can be facilitated by having human models verbalise their thought strategies out loud as they engage in problem-solving activities. The covert thoughts that guide actions are thus made observable through overt representation. "Modeling both thoughts and actions has several helpful features that contribute to its effectiveness in producing generalized, lasting improvements in cognitive skills" (Bandura, 1986, p. 74). Therefore, through *observation* and *modeling*, learners develop internal rules that help them self-regulate their own behaviour.

Other researchers, working with the Vygotskian paradigm (Vygotsky, 1978), emphasise the intrinsically social aspect of human cognition as well as the idea that cultural tools (symbols, rules, conventions, uses, etc.) mediate mental activities (Bruner, 1987; Cole & Engeström, 1993; John-Steiner & Mahn, 1996; Wertsch & Stone, 1985). An *internalisation* process takes place when a more competent person offers scaffolding to a less competent one.

Based on the piagetian theory, Doise & Mugny (1984) propose that situations most likely to generate *sociocognitive conflicts* between learners promote learning. The divergent points of view that emerge in social interactions may involve individuals making efforts to coordinate their personal perspectives, in order to maintain a "cognitive equilibrium" in their own cognitive structure. Certain educational studies show that collaborative concept mapping constitutes a situation where sociocognitive conflicts would actually occur through argumentative discussions (Osmundson et al., 1999; van Boxtel et al., 2000).

Justifications for the use of a collaborative knowledge modelling strategy to support the transfer of expertise can also be found in symbolic interactionist theories based on Mead's assumption that meaning is the result of a social negotiation process that is based on verbal interactions (Mead, 1934/1974). Basically, individuals are unable to interact in social situations when their mental representations differ too significantly (Clark & Wilkes-Gibbs, 1986). There is a need to establish mutual understanding, also called *common ground* or *intersubjectivity* (Rogoff & Lave, 1984), which is negotiated throughout the interactions. This shared understanding requires a common focus of attention and a set of common assumptions. A number of authors have emphasised the role of external representations, such as concept maps, to support the negotiation of meaning in learning contexts (Osmundson et al., 1999; Roth & Roychoudhury, 1993). Roth & Roychoudhury (1994) use the metaphor of "social glue" to describe how concept maps can lead learners to develop a shared vision of tasks and meanings that they attribute to concepts and relations between these concepts.

Finally, in the situated learning paradigm, the *legitimate peripheral participation theory* (Rogoff & Lave, 1984) states that novices should be given opportunities to participate regularly and actively in “communities of practice” in their field in order to promote the development of their competencies. Mentoring and apprenticeship as well as reflective discussions among practitioners in real-world or virtual spaces would be particularly beneficial to learning (Wenger et al., 2002). Collaborative knowledge modeling could well complement these strategies. Indeed, Roth & Roychoudhury (1992) observe that collaborative concept mapping promotes the development of a “culture of scientific discourse” in science classes.

17.5 Applications of and Research on the Knowledge Transfer Strategy

The collaborative knowledge modelling strategy was first used in 2002 at Hydro-Québec, the main producer, provider and distributor of electricity in the province of Québec, Canada (20,000 employees). By 2004, over 150 experts and 150 novices from various departments (management, electrical engineering, civil engineering, etc.) had already participated in a pilot project initiated by this large company (Basque et al., 2004). Experts and novices were first trained to use the *MOT* software. They were then asked to construct a knowledge model in dyads or triads. Based on anecdotal data collected by local representatives, Basque et al. (2004) report that, in general, both experts and novices tended to show a positive attitude towards the strategy. Many commented that this tool helped them “organise” their own knowledge. However, the authors noticed a certain amount of reticence, especially among experts who seemed to lack time to participate in these activities due to their heavy workload. Most participants found the software user-friendly, although few mentioned they had difficulties with the process of categorising knowledge, especially of identifying principles and of distinguishing them from procedures. Some experts lamented that collaborative knowledge modelling with novices slowed down their own modelling process; however, for others, the interaction with novices was essential to externalise what seemed obvious to them and *MOT* helped them capture a very large body of their knowledge in an economical fashion. Others recognised 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 prevented them from constantly referring to the expert.

More recently, another public organisation in Québec began using this strategy. This time, a more rigorous research process was implemented, based on action-research methodology.³ This ongoing project has the following objectives: (1) to evaluate the feasibility and efficiency of the strategy to transfer expertise, (2) to single out conditions that influence the efficiency of the strategy and (3) to identify

³ This research project is supported by the CEFRIQ (*Centre francophone de recherche sur l'informatisation des organisations*), which is a liaison and transfer centre that comprises university, industrial and governmental members and researchers in Quebec, Canada.

how the knowledge models can be exploited within the organisation in a global knowledge management perspective. A first group of four employees⁴ participated in a 3-day session of collaborative knowledge modelling with the help of two knowledge modelling facilitators: one manipulating the software and one conducting the session, as described above. The knowledge model was projected on a widescreen. Participants included two experts and two “less expert” employees. These “novices” had already developed specific competencies in the targeted work field but lacked a global view of it. We videotaped the participants during the collaborative knowledge modelling session. Screen-captures of the work performed on the computer were recorded using the *Windows Media Encoder* software. Finally, individual interviews were conducted with each participant before and after the session. Although data analysis is still on-going, some results are briefly reported here, based essentially on the analyses of the model produced and the interviews conducted.

The first-level of a knowledge model produced during this 3-day session is reproduced in Fig. 17.5. Although the model was not totally completed at the end of the session, it comprised over 500 knowledge objects, which are distributed among 55 sub-models. All six types of links of the MOT typology were used. Procedures are the most numerous (217), followed by concepts (179), principles (123) and facts (11). These results confirm that a procedural perspective was used and that much strategic knowledge, which is usually tacit, was elicited. Interestingly, participants attached 29 comments to various knowledge objects, reminders for a future completion of the model. These reminders specify needs for future elaboration in sub-models, validation of information with other sources, addition of links to existing institutional documentation, development of new institutional documents or addition of illustrating examples. We also found self-questioning comments for future elucidation (e.g. “*Should we add this link here?*” “*Are these two terms equivalent?*”).

During the interviews and debriefings, participants declared that they were quite satisfied with this model considering the short time they devoted to its development. The knowledge modelling activity was also very positively evaluated by participants, even though they found it quite cognitively demanding. They mentioned that this activity (1) stimulated reflexive discussions and negotiation of meaning between experts and novices, (2) lead them to simultaneously conceptualise the domain in “its totality and its components” and (3) lead them to elicit knowledge that they initially judged “trivial” but that they finally admitted as being central to expertise in their domain, or knowledge that they considered, before the mapping activity, as being “not elicitable”. Indeed, some comments by the participants lead us to think that some tacit knowledge has actually been elicited. For example, one participant said: “*It is the first time that we illustrate the mechanics of this procedure. We used to refer to the 5 phases of the process, but now we clearly see that there are many other things which underlie the process*”. Another one commented: “*It was interesting to concretely describe things that were not defined anywhere else*”. It seems that the knowledge model is not a simple repetition or a collection of knowledge already documented in the organisation, but a real new creation that gives them new insight on the required expertise to perform the process described in the model.

⁴ Two other groups recently participated in the study.

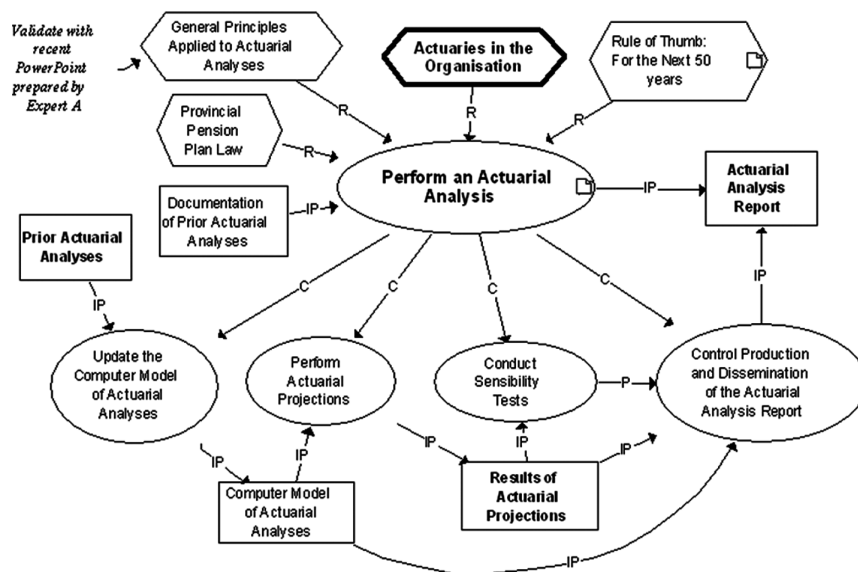


Fig. 17.5. A first-level of a knowledge model of the procedure “Perform an actuarial analysis” (translated from French)

Participants suggested that the model, when completed, would be useful as a complement to coaching techniques, by quickly introducing a new employee to the targeted knowledge domain. It would give him/her an integrated overview of the activities and actors engaged in the process delineated in the model, as well as the main principles that regulate the activities. One participant noted: “*The model will not tell new employees what they must do, but it helps them find their place in the larger process. When I began working for this organisation, it took me many years before I could situate my own activity in the whole picture. I think that maps can speed up the development of this knowledge.*” An expert said that the model will help him transfer his knowledge to new employees: “*Instead of starting from scratch, at least, they would have a good basis from which to start. They can read documentation and study the knowledge model, providing them with a ‘big picture’. Then, they can ask more specific questions. This prevents us from having to spell out everything and frees us to concentrate on specific activities.*”

Some participants noted that since the model gives a clear representation of activities performed by several different actors, it can prevent the “silo” effect often associated with strong specialisation of the workers in organisations. Thus, by providing the “big picture” of a contextualised professional knowledge, maps can be used as “boundary objects” (Star, 1989) in the organisation, that is, entities shared by different internal “communities of practice” but viewed or used differently by each of them. All actors do not necessarily fully understand the detailed knowledge represented in the common entity, but they can situate themselves within the larger organisational context and thus give new meaning to their own activities.

17.6 A Knowledge Management Perspective

The collaborative knowledge modelling strategy described so far is primarily a *process-oriented* strategy of KM. However, the knowledge models produced during this process can be subsequently integrated into a product-oriented approach to KM, with aims to share expertise with a larger audience within the organisation. Three types of usages can be identified in the product-oriented approach.

Firstly, as mentioned above, knowledge models created jointly by experts and novices can be made accessible to all employees within the organisation as reference documents. *MOT Plus* makes it possible to export the knowledge models in HTML format to facilitate sharing on the Web. Each model serves as a kind of interface for navigation within a knowledge network to which various file formats can be attached (text, audio, video, etc.). All individuals in the organisation could also be invited to annotate models, suggest additions or discuss the models in virtual forums.

Secondly, knowledge models can be used to design training sessions for employees in the organisation. Indeed, the models provide instructional designers a clear idea of the targeted learning content to be addressed in training sessions. Several authors have already suggested using concept maps for instructional design (e.g. Coffey & Canas, 2003; Inglis, 2003). In his book entitled *Instructional Engineering in Networked Environments*, Paquette (2003) proposes a method called MISA⁵, in which the object-typed knowledge modelling technique described in this chapter is proposed in order to specify the learning content and the target competencies of learning systems. This very technique is also suggested to instructional designers to help them elaborate the pedagogical (or instructional) model – which can take the form, in e-learning systems, of IMS-LD⁶ compliant learning scenarios (Paquette et al., 2005) –, the media model, and the delivery model of learning systems.

Finally, the knowledge models co-produced by experts and novices can serve as input in the process of developing an “intelligent” digital knowledge management system that will hopefully be able to make inferences and be used with natural language queries. We believe that having experts and novices interact during the knowledge acquisition stage of the expert system development process, represents an interesting alternative to classical approaches of knowledge elicitation. However, as models co-constructed with *MOT* happen to be semi-formal, they cannot be interpreted by a machine. Indeed, ambiguities inherent to this level of knowledge modelling need to be removed. One way to achieve this is to transform the semi-formal models into ontological models. The advantage of formalising models as ontologies, using the standard OWL-DL format for example, is to make them available for computer-based processing. The resulting OWL-DL format is an XML file for which there are an increasing quantity of software components that can process a file for different

⁵ MISA is a French acronym (*Méthode d'Ingénierie d'un Système d'Apprentissage*), which stands for “Engineering Method for Learning Systems”.

⁶ IMS-LD is a standardized language used for the specification of e-learning instructional scenarios (LD stands for “Learning Design”). These scenarios are machine-readable: they can be delivered on different elearning platforms that are compliant with IMS-LD.

purposes: describing documents in databases, searching for documents according to the classes of models, summarising or classifying documents, etc.

In the context of the *MOT* representation system, ontologies, particularly OWL-DL constructs, correspond to a category of models called “theories”. Ontologies can thus be graphically modelled using the *MOT* syntax with certain extensions (see Fig. 17.6, for example). A new extension of the *MOT* editor introduces new graphic symbols acting as abbreviations, such as new links that replace one or two links plus a ruling principle or labels on knowledge objects that correspond to stereotyped properties: for example, stating that the relation is transitive or functional. Such an extension aims to simplify the graphic model when the goal is to build standardized models such as a learning design or an ontology (Paquette, 2006; Paquette & Rogozan, 2005).

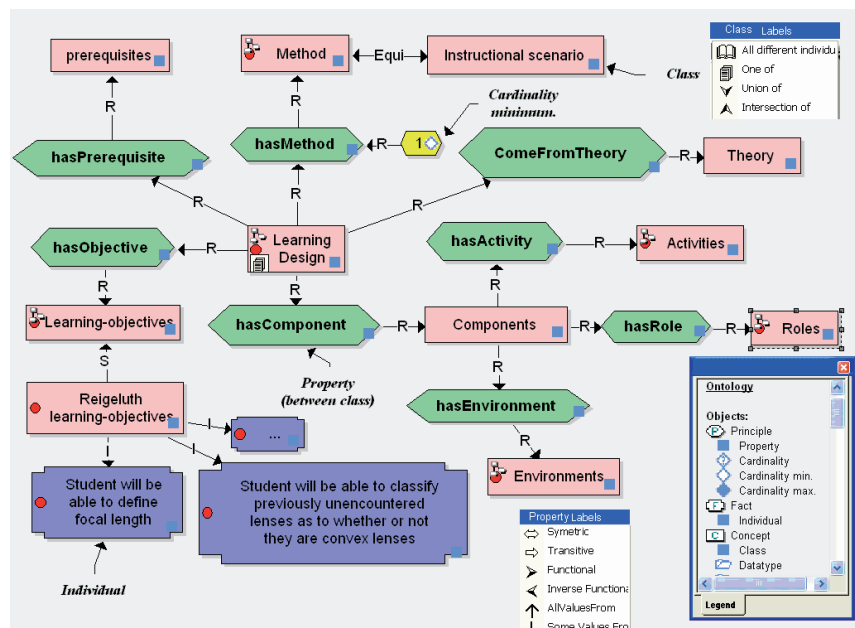


Fig. 17.6. First level of an ontological model representing knowledge from the Learning Design domain

17.7 Conclusions

The collaborative knowledge modelling strategy described in this chapter seems promising for the transfer of expertise within organisations. However, it brings up numerous questions that need to be addressed with rigorous research. The first question is obvious: Is this strategy efficient? In other words, does it result in transfer of expertise?

Another concern involves the factors that are likely to influence the efficiency of the strategy. Briefly, here are some of the factors that need to be investigated according to our perspective.

First, a series of factors are related to the individuals involved. We wonder, for example, how individual variables, such as an expert's level of motivation to share his/her knowledge and/or the individual's spatial or verbal skills or his/her cognitive style affect the efficiency of such an activity. The few studies that investigated these topics were conducted in school settings (Okebukola & Jegede, 1988; Oughton & Reed, 1999, 2000; Reed & Oughton, 1998; Stensvold & Wilson, 1990). It would be valuable to conduct such research with adult participants in professional settings. For example, Stensvold & Wilson (1990) have shown, in a study conducted with Grade 9 participants, that creating concept maps was more beneficial to students with low verbal skills than to those with high verbal skills. We can thus hypothesise that concept maps representing knowledge would be particularly effective for certain types of employees.

Second, some factors are linked to the organisation of the co-modelling situations. For example:

- *The active contribution of each participant involved in the activity.* A setting in which participants are involved in the creation process together has been shown to be more effective than a situation where only the results of the activity are shared (Stoyanova & Kommers, 2002). It would be helpful to know more about the nature and types of interactions that correlate with successful expertise transfer. Also, sharing tacit knowledge can possibly detract the expert from his status as an expert. If tacit knowledge is at the heart of the expertise, individuals may wish to keep the knowledge tacit. Indeed, as soon as tacit knowledge becomes explicit and coded, it is no longer a source of individual differences and, consequently, no longer presents a competitive advantage for the individual (Sternberg, 1999).
- *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 rather than on a social level (Doise & Mugny, 1984). Moreover, once aware of this asymmetry, the participants' representations of the relationship constitute a factor that 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 modelling 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 modelling in a professional setting be trained in a knowledge modelling language in order to minimise the cognitive load of such an activity? How can we help them make links between knowledge in the most significant and useful manner, an activity considered very difficult by many researchers

(Basque & Pudenko, 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?

- *The representation language and the representation tool used.* 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 organised into temporal script, in causal diagrams, procedural models, 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? How do we promote the expression of this heuristic and often idiosyncratic knowledge? How can we guarantee sufficient freedom of expression to allow the representation of different knowledge structures to suit the needs of the knowledge modellers? How can we guarantee the convergence between the experts’ words and actions, since they can distort their knowledge representations when they express it verbally? In other words, the externalised representation of actions may not reflect what actually occurs (Wilson & Schooler, 1991). It is difficult to separate tacit from explicit knowledge because these two types of knowledge are often tightly intertwined. An expert can describe rules which guide his action (explicit knowledge) without being able to describe which specific aspects of the situation triggered the application of the rules. However, he will be able to use the rule appropriately in context (tacit knowledge). How can constraints imposed by the representational language promote the elicitation of such situated strategic knowledge?

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

We hope that further research will shed some light on the contribution of any, or all, of these factors to the success of the knowledge modelling strategy.

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