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Chapter 16 - Modeling for Learning

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Abstract

Some years ago, we have introduced in the pedagogical scenario of a distance university course a learning activity consisting at having students create their own knowledge models with the knowledge modeling software MOT developed by Paquette (2002).

At the same time, was initiated a series of studies[1] aiming at evaluating the learning benefits and exploring the meditating effect of the use of this tool in the learning process, both in individual or collaborative conditions, as well as in face-to-face or distance educational settings. In our research, MOT is mainly used as a mean to support students' text comprehension, but we also proposed this tool to professionals engaged in a vocational university program to help them reflect on how the curriculum knowledge domain is instantiated in their own professional practice. In addition, we provided training sessions to faculties and produced some documentation (available on the web) on the educational uses of knowledge modeling software in higher education (Pudelko & Basque, 2005).

In this chapter, we will first situate the MOT tool among other node-link visual knowledge representation tools used in educational settings. Next, we will describe how we used MOT to support learning in three different learning contexts at the postsecondary level (individual learning by distance learners; collaborative learning in dyads at a distance; collaborative learning in large group in a face-to-face setting) and report some of the results of our studies.

16.1. External Representations and Cognitive Tools

External representations (text, graphic, table, picture, etc.) play a significant role in the teaching/learning process. Learners can be invited either to study external representations elaborated by the teacher or by other authors, or they can be invited to elaborate some themselves. Constructivist and generative learning theories (Duffy & Cunningham, 1996; Grabowski, 1996) tend to favor the second option because students have then to identify the knowledge units to be represented and to provide a substantial effort in searching for how they are related (O'Donnell,

[1] We acknowledge Télé-université and the *Fonds Québécois de Recherche sur la Société et la Culture* for financial contribution to some of these studies.

Dansereau, & Hall, 2002). This active and deep mental process would help the learner in constructing more elaborate internal structures of knowledge.

To construct any external representation, a representational notation system must be used. Each representational notation system manifests a particular “representational guidance” (Suthers, 2003) in two major ways: (1) it constrains the expressiveness of how the knowledge units can be expressed and (2), it makes some of that knowledge more salient. Hence, representational notation systems structure provide a specific approach how to reason about knowledge domains.

Node-link diagrams constitute a family of external representations which is more and more used for educational purposes. In fact, the construction of node-link diagrams such as concept maps (Novak, 1998; Novak & Gowin, 1984); mind maps (Buzan & Buzan, 1996) or knowledge maps (Holley & Dansereau, 1984) by learners has been proposed as a learning strategy for nearly three decades in the educational field. Since the mid-eighties, much research has been conducted on this issue with students of all educational levels and in several disciplines. In general, research shows that this activity leads to beneficial effects on learning (Horton *et al.,* 1993; Nesbit & Adesope, 2006).

The most popular representational technique explored in these studies is the concept mapping technique proposed by Novak and Gowin in their seminal book *Learning how to learn* published in 1984. A concept map is defined by these authors as “a schematic device for representing a set of concept meanings embedded in a framework of propositions” (p. 15). A proposition is a semantic unit formed by two or more concept linked by words. Then, a concept map is a node-link representation, where nodes denote concepts of a certain knowledge domain, and links denote the relationships among concepts. Concepts are specified by textual labels, which could be a noun, or a noun complemented with one or more adjectives or adverbs for denoting a more specific concept (for example, *living things* instead of *things*). Links are specified by lines, usually arrowed, on which textual labels are also put, more specifically verbs (such as *contain, involve, change, are in, can be*, etc.) or “linking phrases” (such as *then, by, as in, with, that,* etc.). The general spatial layout and the directions of the links aim to express the idea of a hierarchy of concepts, going from the most general to the most specific ones.

The emergence of computer-based concept mapping software in the nineties has provoked a renewed interest in the construction of concept maps by students as a learning activity. Compared to paper-and-pencil, these software tools have much more to offer in facilitating the concept mapping operations, especially in formatting and modifying the maps (Anderson-Inman & Ditson, 1999; Bruillard & Baron, 2000; Lin, Strickland, Ray, & Denner, 2004). Those functionalities encourage users to elaborate and revise their maps and, consequently, help them self-monitor their knowledge construction process.

Moreover, since these tools integrate representational functionalities which guide the user’s activity not only at the operational level but also at the cognitive level and even at the metacognitive level, they have been described as “cognitive tools” (Bruillard & Baron, 2000; Kommers, Jonassen, & Mayes, 1992; Lajoie & Derry, 1993), “mindtools” (Jonassen, 2000) and “metacognitive tools” (Coffey, 2007). Such tools facilitate external representations of information and enhance cognitive functioning by making users think harder or differently about knowledge (Kommers, Jonassen, & Mayes, 1992). This notion of cognitive tool is somewhat similar to the notion of "cognitive artefact" proposed in the field of Human-Machine Interaction by Norman (1991) and by other authors involved in Computer-Supported Collaborative Learning (CSCL) (Suthers, 2006) or working within the Activity Theory framework (Engeström, Miettinen, & Punamäki, 1999; Nardi, 2001).

Most concept mapping software tools promote flexibility of expressiveness (Alpert, 2004), that is, they impose minimal constraints on the activity of representing the nodes and the links in the map. For example, Cañas & Carvalho (2004) state that the CMapTools offers a reasonable compromise between flexibility and formalism in knowledge representation" because they believe that "the freedom in the selection of concept and linking phrases gives the tool a lot of its power and makes it user-friendly and easy to learn" (p. 3).

Other authors suggest that a more constrained representational notation system could optimize the beneficial learning guidance offered by concept mapping tools. For example, Kharatmal & Nagarjuna (2006) argue that we should introduce some more "discipline" in the Novakian concept mapping language to assist the learner in specifying valid relationships among concepts. One way to do this is to introduce a typology of links in the representational language, as did Holley & Dansereau, (1984) in their spatial learning strategy called "networking". This limit imposed on the link representation process would help in disambiguating the natural language used to designate links and in making students more aware of the various types of relationships that could be established among knowledge objects (for instance hierarchical, temporal or causal relationships), making these different types of knowledge structures more salient to them.

The MOT knowledge modeling language goes a step further. In addition to a typology of links (which includes six basic generic links), a typology of knowledge objects is proposed, which differentiates "concepts" from "procedures", "principles" and "facts", so that learners must reason not only in terms of interrelated concepts but also in terms of interrelated *types* of knowledge entities. Moreover, some semantic rules determine the type of links that can be drawn among the different types of knowledge entities, as presented in detail in chapter 2.

Thus, the MOT language is much more formalized than most other representational languages used by learners when creating node-link diagrams in educational settings. In fact, the representational notation implemented in the MOT software would be considered a "semi-formal" language in the Artificial Intelligence community. It is not as much rigorously formalized as is the MOT+OWL ontological language (Paquette, 2007) that has been implemented in the recent versions of MOTPlus and MOWL presented in chapter 10, but it is less ambiguous than the typical concept mapping languages used in educational settings, as discussed in part I of this book. In Figure 16.1, we position different types of node-link diagrams according to their degree of formalization.

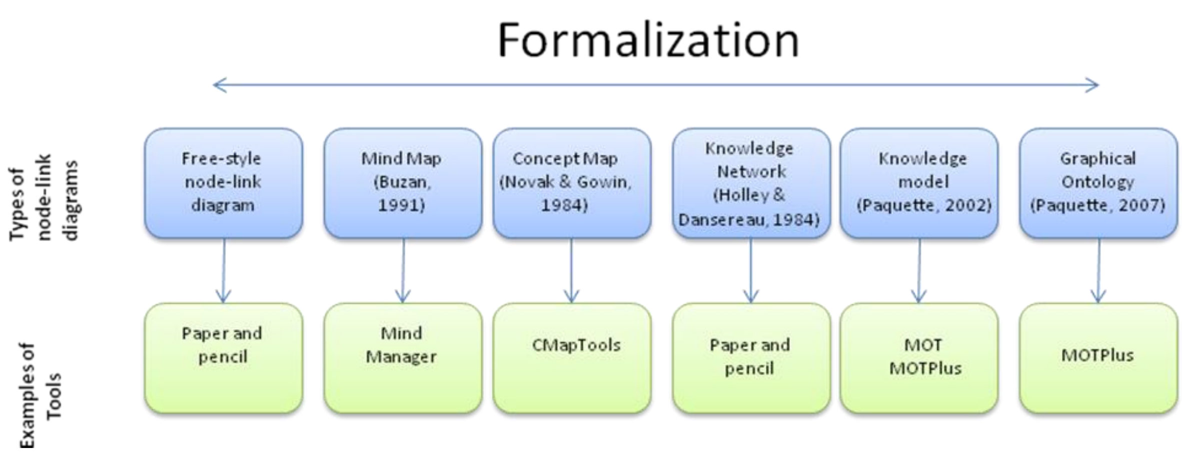

Figure 16.1 : Degree of formalization of different types of node-link representations

Moreover, the MOT tool offers direct guidance to the user by prompting him to conform to the semantic rules of the objet-typed representational language. For example, if the user draws a link between two knowledge entities that is not conform to the MOT grammar, the software will automatically display a default link, that is, the most probable one considering the types of the knowledge entities involved. If the user disagrees with the suggested link, a right-click on the link enables him to select another one from the pool of "permitted" links (the invalid links not being clickable). Thus, the MOT tool not only includes a more formalized knowledge representation language than most computer-based tools for node-link representations, but it also intervenes dynamically in the knowledge representation activity of the user. However, the user may choose to by-pass this limitation by using the "untyped" knowledge object and the "untyped" link which are also implemented in the software.

It should be noted that the MOT software has been developed initially not for educational but for instructional design purposes, that is, to assist the instructional designers in specifying the knowledge content as well as the pedagogical, media and delivery scenarios of a learning system to be developed (course, module, lesson, program, etc.) (Paquette, 2003). Nevertheless, after using this tool for our own benefit for some years, either as an instructional design tool (Basque, Doré, & Henri, 2000; Doré & Basque, 2002) and as a general modeling tool to assist our thinking on processes, methodologies or concepts in our research activities (Basque, 2004; Basque, Rocheleau, Paquette, & Paquin, 1998; Dufresne et al., 2003), we felt it might be useful as a learning strategy for students. Some evidence to support this hypothesis can be found in studies where there are some kinds of constraints based on typed links or on predefined "micro-structures" made up of combinations of typed links and nodes introduced in the task of building node-link diagrams (Fischer, Bruhn, Gräsel, & Mandl, 2002; Komis, Ergazaki, & Zogza, 2007; Reader & Hammond, 1994; Suthers, Toth, & Weiner, 1997).

The main question that we explored in our research is the following: How does knowledge modeling with a tool using a semi-formal representational language such as MOT may influence learning? As we will see, this question leads us to examine not only the *results* of the activity (i.e. the knowledge models produced by the learners and post-learning measures) but the knowledge modeling *process* and its mediating effect on learning.

16.2. Knowledge Modeling as an Individual Learning Strategy

Knowledge modeling with MOT in individual learning contexts has been the focus of two of our studies conducted with students in a distance course. Our aim was to enhance text comprehension. Multimedia-based and web-based learning environments flourished in recent years, but this does not mean that text is leaving the educational sphere. In fact, most existing web-based learning environments can still be characterized as essentially text-based. Moreover, they still are quite limited in terms of assistance provided to students (either by human or machine). They are also quite demanding for students in terms of autonomy and meta-cognition. Thus, many researchers in educational technology and distance education stress the need to provide distance learners with powerful cognitive tools aiming to support their knowledge construction process, text comprehension and reflection (Lin, Hmelo, Kinzer, & Secules, 1999; Ruelland & Brisebois, 2002).

In an initial stage, a first exploratory study has been conducted to pinpoint research issues on MOT as a knowledge construction tool in the context of web-based distance education (Basque & Pudelko, 2003). The second goal of this exploration was more pragmatic: feedback was needed from students to help us improve the pedagogical quality of the learning activity in our real-world educational setting at Télé-université. Another objective was to evaluate the adequacy of node-links diagrams as a diagnostis tool in order to identify the main difficulties students had with the course content.

Secondly, Pudelko (2006) conducted a study in which she examined with great scrutiny the tool-mediated thinking of three voluntary students while they were constructing knowledge models with MOT. We will report briefly each of these studies.

In the first study, we analyzed knowledge models produced by students in a graduate distance course delivered on the web, entitled “Cognitive Science and Learning”. In one of the course activities, students were invited to construct individually what we call in the context of this course a “knowledge network”, which must include at least fifteen key knowledge objects drawn from four texts that are part of course material. MOT was made available to them but it was not imposed, although most students chose this tool to perform this task. Even those that did not use MOT (some used a generic graphical tool or even the graphic functionalities of the Word software) employed the MOT typologies of nodes and links when building their knowledge network. They were also asked to write a short text explaining their network. This work was a graded assignment in this course. The time required to complete the activity, including reading, modeling and writing, was estimated to about 36 hours distributed over four weeks. A textual methodological guide was provided, which included a definition of “knowledge networks”, together some examples and a procedure to construct them. Although this assignment was individually produced, peer-tutoring was encouraged: students were invited to ask and answer questions and to share their experience in an online forum all along the activity.

Data examined in this exploratory study (Basque & Pudelko, 2003) come from comments made spontaneously by students in the forum (N=34), a short questionnaire administered to one group (N=17), comments made by students in the last written course assignment requiring them to evaluate the course from a cognitivist perspective (N=18) and the knowledge models themselves (N=34). To obtain a whole picture of the main characteristics of the students’ models, we count: (1) the number of typed and un-typed objects and links represented in the models, (2) the number of each category of typed objects and links and (3) the number of sub-models created. Each model was also examined to determine if the MOT syntax was used correctly and whether students simply reproduced the hierarchical structure of the instructional texts as shown by their subtitles or whether they constructed their own representation of key concepts. To refine these exploratory analyses, fourteen models were selected because they were all representing knowledge related to one of the topics covered in the instructional texts (that is, the classical view of the human information process, as described in cognitive science handbooks) and were examined more in depth with a method that we devised (Pudelko, Basque, & Legros, 2003). The method is inspired by the theoretical work of Baudet and Denhière (1991) who proposed a cognitive semantics approach called “analysis in systems” to the study of text comprehension.

Results show that most students expressed positive comments on the knowledge modeling activity and those who used MOT found it easy to learn, user-friendly and useful. There was many more knowledge units represented in their models than the number required (15). Up to 112 knowledge units was counted in a single model (mean: 42 units). From 14 to 102 links (with a mean of 42 links) were counted but the number of links varied greatly in the models. We noticed that they did not simply reproduce the structure of the instructional texts (as denoted by subtitles) and, instead, constructed what seem to be personal interpretations of the meaning of the interrelationships among their selection of key concepts. Many students also made positive comments on the impact of the knowledge modeling activity on their learning and text comprehension. However, it seemed to us that the full potential of MOT as a learning tool was far from being optimized. The MOT syntax appeared not to be so easily understood for all students. For example, a number of students confounded concepts and procedures and labelled some objects with whole sentences denoting their difficulty in isolating the knowledge objects from the links. Our analysis of the 14 models representing the human information processing system showed that students tend to represent this system essentially as a static one, with objects defined by their attributes and related to each other essentially by composition and specialization links, and that they neglected or were not capable of expressing many functional aspects of the human information processing system described in the instructional text.

Surely, the activity was promising but we thought that students probably need more training and practice in elaborating node-link diagrams and in familiarizing themselves with the MOT language and tool. In fact, this has been confirmed since by data collected by questionnaire and interviews with students and tutors (Gérin-Lajoie & Basque, 2006). One example of a training module to knowledge modeling with node-link diagrams for distance learners has been recently designed by one of our graduate students (Gérin-Lajoie, 2008).

We also thought that we needed to explore more in depth what was going on during the knowledge modeling process. In her doctoral thesis, Pudelko (2006), conducted a detailed analysis of the transformations of the external and internal activity structures induced by the use of the MOT tool in students who registered to this same course in a subsequent semester. She based her work on the notion of mediation of cognition by psychological tools as devised by Vygotsky (1978) in his socio-historical theory of cognition and on his Activity Theory, especially as interpreted by Leontiev (1978) and Rabardel (1995). Vygotsky stated that thinking is regulated by external activities, which are instrumented with cultural tools. In that perspective, Pudelko studied the instrumental contribution of the MOT tool in the process of text comprehension by observing the qualitative transformation of this process in one of the three subjects who participated in her study. This subject participated in three knowledge modeling sessions with MOT on a three-week period. In each session, the subject has to read a different short text and to elaborate a knowledge model representing the meaning of the text. Data consist in screen-captures of the student's activity and videotapes of retrospective verbal report interviews.

Results show that the typology of knowledge objects implemented in the software had a beneficial influence on the subject's text comprehension process. For example, the participant represented the term "cognition" initially as a "concept" in his model. It seems that because "cognition" is a noun, it inferred him to think naturally about this knowledge entity in terms of a "static thing". Then, he asked himself "Is cognition a concept or a process?". This self-questioning led him to change this entity into a "procedure" type, referring then not to "cognition" as a "static thing" but as a "process". Hence, the subject added a new property (it is a "dynamic thing") to his initial meaning of the word "cognition", resulting in a more elaborate conceptualization of this knowledge entity. This "dynamization" of substantive words could enhance comprehension of scientific texts, which make frequent use of substantives to refer to processes. Moreover, due to the semantic rules embedded in MOT which determine the type of links that can be drawn between the different types of knowledge entities, changing the type of a knowledge entity in a model leads the subject to make a new series of inferences about the relationships that this knowledge entity has with the other ones represented. For example, representing the knowledge entity "cognition" as a procedure led the subject to represent not only its sub-components (e.g. its sub-processes such as "perception", "encoding", etc.) but also how it is temporarily related (precedes or succeeds) to other procedures (e.g. "actions"), what are its inputs and outputs, etc. The micro-genetic study conducted by Pudelko (2006) brought to light this type of qualitative transformations inferred by the representational properties of the MOT tool into the reasoning chains of the subject.

The results of these studies lead us to think that the use of the MOT tool can be beneficial to text-based learning in scientific domains. Knowledge modeling with this tool would enhance a deep understanding of the meaning of text and consequently would favor significant learning (Ausubel, 1968; Fayol & Gaonac'h, 2003; Graesser, Leon, & Otero, 2002; Kintsch, 2004; Ramsden, 1992).

16.3. Collaborative Knowledge Modeling as a Learning Strategy for Distance Education

In the last two decades, the socio-constructivist paradigm has become increasingly predominant in the scientific literature in education. This paradigm, which places special emphasis on collaborative learning, is at the core of educational reforms, notably in Quebec, Canada.

The collaborative construction of node-link diagrams by small groups of students or whole classes is a learning activity that fits well with the socio-constructivist paradigm. Thus, a number of researchers began in the nineties to investigate collaborative construction of node-link diagrams (essentially concept maps) in educational contexts (Basque & Lavoie, 2006). With the increasing popularity of distance and online learning at all educational levels and contexts, the remote, computerized collaborative construction of concept maps has also sparked researchers' interest over the last few years.

Studies conducted with primary and high school students showed that such collaborative concept mapping triggers discussions and sociocognitive conflicts (Doise & Mugny, 1984), which are beneficial to learning (Osmundson, Chung, Herl, & Klein, 1999; van Boxtel, van der Linden, & Kanselaar, 2000). Concept maps have been described as a "linguistic shorthand" of concepts which facilitate sharing of ideas (Kealy, 2001), as "discussion detonators" which help students construct knowledge jointly (Rojas-Drummond & Anzures, 2006), and as a "social glue" that brings learners to share a common conceptual space and to engage in a sustained discourse that replicate interactions in scientific communities, which include co-construction interactions, adversarial interactions and formation of alliances (Roth & Roychoudhury, 1993; Roth & Roychoudhury, 1992, 1994; Sizmur & Osborne, 1997).

Other studies conducted with university students also reveal that social interactions during collaborative concept mapping were quite cognitively engaging and productive (Immonen-Orpana & Åhlberg, 2008; Prezler, 2004; Ryve, 2004; Steketee, 2006). Moreover, some empirical evidence shows that students who constructed concept maps collaboratively outperformed students who constructed concept maps individually or who were engaged in other collaborative activities at post-test learning measures (Chiou, 2006; Czerniak & Haney, 1998; Prezler, 2004; Stoyanova & Kommers, 2002).

Some researchers found that the quality of maps produced at a distance with the use of communication tools (chat tool or audio or videoconferencing) do not differ significantly from maps created collaboratively in a face-to-face (Fischer & Mandl, 2001; Khamesan & Hammond, 2004). The latter authors concluded that "computer-based concept mapping can be used in collaborative learning with remote communication as effectively as with face-to-face communication, although more research is needed to clarify issues how performance is mediated by different CMC [Computer-Mediated Communication] modes” (p. 391).

We contributed to this line of research by investigating the effect of three modes of interaction during a collaborative knowledge modeling activity with MOT on the quality of the models produced and on individual learning. The three modes of interaction included two remote contexts (synchronous and asynchronous) and one face-to-face context. Learning was measured with a text comprehension pre and post-test.

Forty-eight persons volunteered to participate to this study. They had been randomly distributed into three groups: synchronous distance group (N=16), asynchronous distance group (N=16) and face-to-face group (N=16). To facilitate data collection, we asked participants to come to the university and we simulated the distant conditions by using partitions to isolate each computer workstation and ensure that participants could not see one another. Six to eight subjects participated in each experimental session.

After a short text comprehension pre-test (six open-ended questions) and a 75-minute training period to the MOT software and technique, participants practiced knowledge modeling individually for 20 minutes. Then, they were paired arbitrarily and asked to perform the collaborative knowledge modeling task consisting at representing their understanding of the content of a one-page text on the main components of the Human Information Processing System (Sensory Memory, Short-Term Memory and Long-Term Memory) and the Cognitive Information Process. After having read the text individually for 5 minutes, pairs were allotted 45 minutes to construct their knowledge model using the MOT tool. They had access to a printed version of the text during the activity. At the beginning of the session, one member of each pair was arbitrarily identified as the "editor" of the map, yet participants were told that they could freely change roles during the session. Finally, participants filled out the post-test (identical to the pre-test).

Partners in the *synchronous group* communicated with each other via the NetMeeting software (see Figure 16.2). Participants in the *asynchronous group* used e-mail to send the co-constructed map to their partner. While waiting for the map from their partner (i.e. the user acting as the editor), participants were instructed to help their partner by sending him/her messages, to think of the next step, or to re-read the text. Pairs in the *face-to-face group* worked side by side at one computer and used only the MOT software.

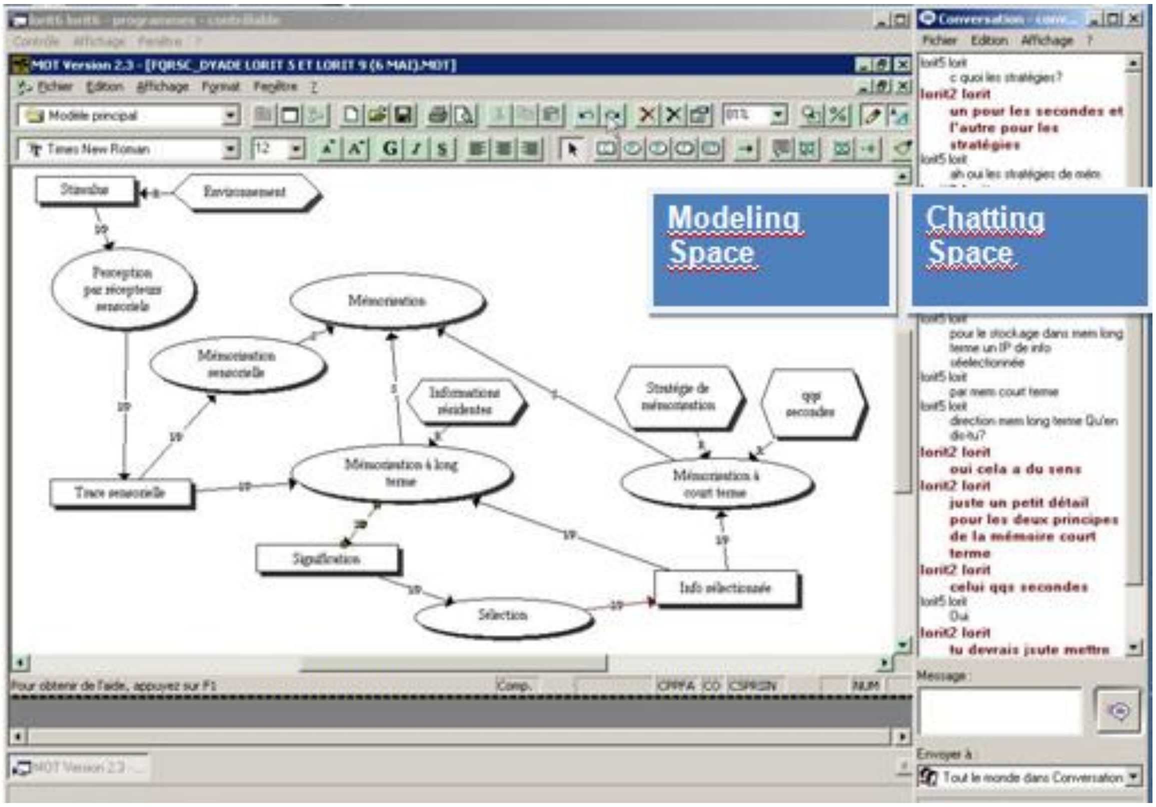

Figure 16.2: Screen capture of the MOT and NetMeeting Windows for the Synchronous Case

Participants' knowledge models were compared to an "expert knowledge model" that was created by a small group of content experts and of MOT experts. Two scores had been calculated. A *Knowledge Objects score* was calculated by summing up the total number of participant's knowledge objects that were also represented in the experts' model, and a *Propositions score* was calculated by adding the total number of experts' knowledge propositions represented in the participant's model; for each proposition, one point was attributed if the same two knowledge objects were paired (regardless of the type of link), one point for each correctly typed knowledge object included in the proposition, one point if the link was correctly typed, and one point for the correct link direction.

In summary, our study shows that the quality of the collaborative knowledge models was superior for pairs working face-to-face at the same computer than for those who communicated asynchronously at a distance, but only in terms of knowledge objects represented (and more precisely in terms of specification of the type of the knowledge objects), not in terms of the propositions elaborated. No significant difference was found between the scores attributed to the models constructed by the synchronous group and by the face-to-face group, as well as between the scores attributed to the models produced by the asynchronous and the synchronous groups. We also found that groups did not differ on learning as measured by the text comprehension test, although we found a tendency for remote partners who communicated synchronously to have learned more than participants in the two other groups.

If we consider the shared workspace as a "mediating tool" in the activity in the face-to-face and the synchronous distance settings, then the fact that the quality of the knowledge models was not significantly different in these two conditions could mean that the shared visual display in the synchronous context was sufficient enough to establish the basic common ground for communication (Clark & Brennan, 1991) and to compensate for the lack of conversational gesture.

Regarding the significant difference between the scores attributed to the knowledge models constructed by the face-to-face and the asynchronous groups, it is possible that participants of all groups had enough time to identify a similar number of knowledge objects, but only those interacting in face-to-face had sufficient time to negotiate the *categorization* of the knowledge objects represented in the map. This would have been the case because face-to-face participants not only shared a common perceptual and action space but could also interact in a verbal and gestural mode.

Now, how can we explain the fact that we found no significant between-group difference on the Proposition score? It may be that the method used to evaluate the maps underestimates the participants' capacity to elaborate valid propositions and was not sensible enough to discriminate the groups on the quality of the propositions that they co-elaborated. For example, we observed that experts systematically specified (sometimes by inferring them) all the inputs and outputs of each procedure that they represented in their map, while many participants tended to use instead the Precedence link between procedures (and consequently did not represent the inputs and output of the procedures). These propositions were valid, although they were less complete and less informative than the ones represented in the experts' map. However, they were not considered valid in our coding scheme. This could explain, at least in part, the very low performance of subjects on the Proposition score. Besides, the method used to evaluate the concept maps does not tell us much about participants' misconceptions in the target domain, or about the adequacy of the global knowledge structure represented in their models.

Stoyanova & Kommers, 2002) demonstrated that sharing the concept mapping process (which, in our study, was the case in the face-to-face and synchronous contexts) is more beneficial to learning than sharing only the maps constructed individually (which, in our study, was the case of the asynchronous group). In our study, participants who seemed to have learned the least (although this is only a tendency) are those who either shared the knowledge modeling process the most (face-to-face group), or the least (asynchronous group). The principle of the "least collaborative effort" (Clark & Brennan, 1991) could maybe explain in part these seemingly contradictory results. According to this principle, "in conversation, the participants try to minimize their collaborative effort – the work that both do from the initiation of each communicative contribution to its mutual acceptance" (p.135). We argue that this principle can be observed not only in conversation but also in collaborative *action*: participants try to minimize the collaborative effort they do from initiation to mutual acceptance.

Therefore, we think that the characteristics of the tools used during the activity influence the common grounding process. When constructing a knowledge model collaboratively with MOT, common grounding had to be established not only for the operations of selecting, labeling and linking knowledge objects, but also for the operation of specifying the type of knowledge objects reported in the model. Common grounding could have been equally established for the operations of selecting and labeling of knowledge objects in all three experimental contexts, but, as we already mentioned, partners working at the same computer would have had more time to negotiate about the type of knowledge objects. Consequently, it is possible that their attention has been focused more on the establishment of a common understanding of the MOT representational language than on discussing about the domain-related knowledge, which could explain their somewhat weaker post-test learning performance.

However, we did not conclude that the use of a representational language like MOT is not beneficial to learning and text comprehension. The duration of the task was probably insufficient and the complexity of the task probably too high for novice knowledge modelers to allow participants to take full advantage of the representational language.

16.4. Collaborative Knowledge Modeling in Face-to-Face Learning Situations

The work reported in this section is part of larger research project aimed at (1) developing a blended learning model for higher education inspired by socio-constructivist learning theories, (2) evaluating its incidence on students' persistence at university and academic persistence (Basque *et al.*, 2006). The learning model is developed at the curriculum level and embraces a whole-program approach. The pedagogical scenario of this model is inspired by the experiential learning theory proposed by Kolb (1984), who stated that knowledge is created through the transformation of experience in a four-stage cycle: *Concrete Experience, Reflective Observation, Abstract Conceptualization, Active Experimentation*. Various pedagogical strategies have been developed and associated to these stages: field-practice and mentoring (*Concrete Experience, Active Experimentation*), online learning community of practice (*Reflective Observation*), collaborative knowledge modeling and face-to-face seminars (*Abstract Conceptualization*). We will focus here on the collaborative knowledge modeling strategy.

The learning model has been developed in the context of a graduate program in the field of School Administration offered in a French-Canadian university and in partnership with a School Board (the largest one of the Montreal area). One part of the program was delivered on-site (at the School Board building) and another part at a distance (online community of learning). Although university rules prevent us to change the traditional course sequencing, we managed to integrate as much as possible the pedagogical strategies proposed in this program.

The learning model was tested with two groups of adult students. We will report here the experiment we conducted with the second group only. These students were eleven novice school administrators from the School Board, who had, by law, to complete graduate studies in this field and who had an average of 14 year-long previous teaching experience. At the beginning of the study program, each was assigned a mentor, who was an experienced school administrator in the School Board and whose role was to guide the student for the duration of the program.

Within the framework of this research, our goal, in designing the scenario of the specific strategy of collaborative knowledge modeling, was to support reflection-on-action within the context of professional training, as well as interactions between learners and more experienced working professionals in order to facilitate the externalization of organizational experts' knowledge in line with the learners' needs and knowledge level. The specific objective of this part of the research was to analyze the contribution of collaborative knowledge modeling to the reflective thinking on professional practice in students engaged in a university program.

The collaborative knowledge modeling activity was introduced in one of the course of the program. The specific topic selected by the instructor for the activity was: Budgeting in a School Board. The group of students was invited to collectively elaborate the knowledge model during three meetings of three hours each, at one month intervals. The instructor moderated the sessions and the researcher collaborated in manipulating the software and guiding the knowledge modeling process. The knowledge model was projected on a screen.

The whole process was conducted as follows:

- At the first class meeting, students were introduced to the knowledge modeling technique.
- At the second class meeting, a first high-level generic version of the model was built collectively, based on explanations related to the topic provided the instructor.
- During the following month, in teams of two or three, students documented one of the knowledge object represented at the first-level of the knowledge model into a sub-model. To perform this task, students collected information from experienced administrators in the School Board.
- At the third class meeting, all the information collected by the different teams were shared, discussed and integrated in the collective knowledge model.
- The fourth meeting was one with the mentor. Each student validated the model with his mentor and questioned him on his “tricks of the trade”, that is, his professional strategic knowledge. The student completed the knowledge model, based on the suggestions of the mentor.
- The last class meeting was held to discuss the collected information, to integrate it in the collective model as well as theoretical considerations presented by other instructors during the face-to-face seminars held throughout the program (animated by other instructors).

We interviewed the students and the instructor prior and after the program and collected reflexive texts produced by students, as well as the successive versions of the knowledge model produced collectively. Data also included minutes of an Advising Committee composed of representatives of students, mentors, instructors, researchers and School Board head administrators, that we put in place to help us guide the development and implementation of the study program. Finally, researcher took observation notes.

Data indicates that the students previously perceived the topic of budgeting process tedious and far from their concerns. They found that collaborative knowledge modeling activity was enriching for the following aspects:

- Training in the field : it enabled them to understand the “Why” and the “How” of the budgetary process, as well as its various stages, the interrelationships between actions and the interdependence of the main actors implied in this process;
- Attitude toward the field: students said they were “no longer afraid” of the budgetary process, and that they realized its strategic importance for school management, both for administrative and pedagogical purposes;
- Organizational learning: students said they discovered the richness of the organization’s resources. They identified documents and people who could help them in adopting their current and future role in the field. They also recognized the diversity of tasks and responsibilities implied in the budgetary planning and managing processes;
- Socialization: the strategy enabled them to create a network of contacts and even experience friendship with expert colleagues and discover their professional and human qualities;
- Professional valorization: the activity enabled them “to make themselves better known” as members of the community of school administrators in the organization.

Students found collaborative knowledge modeling with MOT cognitively demanding but very productive. According to them, this activity led them to structure their knowledge and to verbalize their thought, and therefore to “think better”. They also found that it helped them better identify knowledge areas which required own improvement, to consider different points of view, to work together toward a common understanding of the topic and to stimulate analysis and synthesis. Observations showed that all students contributed to the construction of the knowledge model: they questioned actively the instructor when they found that some knowledge entities or links were unclear and brought new ideas to add to the model.

During meetings with the mentors, the model seems to have helped the mentors to thoroughly describe their ways of doing things as well as the principles and attitudes guiding their practice. The final knowledge model contained 22 sub-maps distributed on three levels. It contained 42 concepts, 51 procedures and 95 principles. Strategic knowledge was thus well represented. The model was declared complete and relevant by students, who said that this type of representation would be an asset to support management practices in the School Board. Several students also expressed their intention to further use MOT for various projects in their schools.

At the end, it appears that the collaborative knowledge modeling strategy was a big success and proved to be one of the most appreciated components of the global pedagogical model for many participants of the study program. The managers of the School Board who participated in the Advising Committee particularly appreciated the community of practice created through exchanges between the trainees and the School Board personnel, which seems to lead to mutual recognition of professional expertise.

This research confirms results obtained in our previous work in the field of knowledge modeling for expertise transfer in organizations (Basque, Imbeault, Pudelko, & Léonard, 2004; Basque, Paquette, Pudelko, & Léonard, 2008). It seems that collaborative knowledge modeling with MOT has a great potential to support construction of professional knowledge also when implemented in a situated learning context, that is, in the context of a professional training program based on a partnership between university and workplace. Our research also shows the advantages of integrating techniques of graphical knowledge representation into teaching strategies, especially when these are designed collaboratively by all the actors of the training program. Future work invites for further developing resources to support university teachers in implementing this type of innovative teaching strategies strategy.

Conclusion to Chapter 16

From our work, we conclude that the representational properties of an object-typed knowledge modeling tool may have a substantial epistemic influence when used by learners in their learning process. Most of the time, it seems that they helped learners build knowledge which is valid from a scientific perspective. However, further research is needed to investigate the mediating and the resulting effects of using a constrained knowledge representation language like the one used in MOT (which includes typologies of knowledge objects and of links) on comprehension and learning.

It seems to us that it is necessary to analyze more in depth not only the *result* (knowledge models produced and learning results) but also the *process* of the individual and collaborative knowledge modeling activity. In the individual settings, we need to understand better how internal speech, considered, in a vygotskian perspective, as a “psychological tool of thought” (Carlson, 1997), is guided by representational properties of this tool and how it intermingles with action in this tool-mediated activity.

In the collaborative settings, we similarly need to examine in more depth how actions and communications contribute to interpretations jointly created by partners during a collaborative knowledge modeling activity with the tool. In a recent qualitative analysis of a dyad of adult participants involved in a face-to-face collaborative knowledge modeling activity with MOT, we found that co-learners are actively involved in intense meaning-making and meaning-negotiation processes (Basque & Pudelko, in press). In such a space of shared external representation, questions asked, arguments stated and rules inferred are strongly biased by the representational properties of the modeling software tool and language, as well as by the knowledge modeling technique proposed to learners. In this particular situation, where the knowledge representation tool integrates categorizing constraints for both nodes and links, as well as a grammar that determines valid links between different types of nodes, it is clear that the participants used such constraints to guide their meaning-making and meaning-negotiation actions.

We believe that this type of research contributes to shed some light on the issue of artifact-mediated activity in learning situations and, at the end, can lead us to propose recommendations to designers of cognitive tools and to teachers who propose those tools to their students to enhance learning.

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