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Using a concept mapping software as a knowledge construction tool in a graduate online course

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Abstract: Stemming from a twenty-month pedagogical experience using a concept mapping software for higher education students in an online course, this paper reports findings from what became an exploratory study. The objectives were to support the students' knowledge construction process and to stimulate metacognitive reflection. After having read some instructional texts, students used an object-oriented modeling tool (called MOT) to graphically represent a network of at least fifteen knowledge units of their choice. They also had to "explain" their concept map in a narrative format. Based on questionnaire data, comments expressed spontaneously by students in the online forums, and the analysis of their concept maps, the following themes are discussed: (1) students' attitudes toward concept mapping, (2) how they executed the concept mapping task, and (3) characteristics of the maps produced. In conclusion, some research issues are outlined.

Introduction

Research and development have flourished in recent years in the domain of telelearning and eLearning. Nevertheless, the majority of existing web-based learning environments can still be characterized as follows: essentially text-based, limited in terms of assistance provided to students (either by human or machine), and demanding for students in terms of autonomy and metacognition. Thus, many researchers in educational technology and distance education stress the need to provide telelearners with powerful "cognitive tools" aiming at supporting their knowledge construction process, text comprehension and reflection (Lin, Hmelo, Kinzer, & Secules, 1999; Ruelland & Brisebois, 2002).

For nearly twenty years, concept mapping (CM) has been suggested as one of those powerful cognitive tools that can support active knowledge construction and enhance significant learning (Holley & Dansereau, 1984a; Jonassen & Marra, 1994, Jonassen, Reeves, Hong, Harvey, & Peters, 1997; McAleese, 1998); Novak & Gowin, 1984; Wandersee, 1990). The emergence of computer-based concept mapping software in the last decade 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 CM task, especially revision and formatting of the maps (Anderson-Inman & Ditson, 1999; Bruillard & Baron, 2000). Those functionalities encourage users to elaborate and revise their maps and, consequently, help them self-monitor their knowledge construction process (McAleese, 1994). Moreover, based on the assumption that external knowledge representation is governed by semantic and syntactic rules, some CM software put constraints on the types of knowledge units and links that can be represented graphically. Developers hypothesize that this helps the user in elaborating and structuring concept maps.

Much research has been done on educational applications of concept mapping (Dansereau & Holley, 1982; Horton et al., 1993; Novak, 1998), but few of them have been conducted in a distance education context (e.g. De Simone, Schmid, & McEven, http), and very few have investigated the effect on learning and metacognition of imposing a representational syntax (e.g. Holley & Dansereau, 1984b).

Since May 2001, graduate distance learners have been using a CM software in an online course. The software includes a syntax that can be used to distinguish graphically the types of knowledge and links represented in the concept maps. The experience is described in the paper, followed by a description of the research issues that evolved.

The course

The CM activity is integrated into a distance course delivered on the web, entitled *Cognitive science and learning.* This 135-hour course is offered every semester on a 15-week basis at Télé-Université, a French-Canadian university devoted exclusively to distance education. Since the first delivery of the course in May 2001, thirty-four students registered to the course held in small online groups (between 5 and 16 students). The course is part of several graduate programs (at a master level) in Educational Technology, Education and Information Technologies.

The course is composed of five learning activities, the second one being the CM activity. Instructions for each activity are given in HTML format, with hyperlinks giving access to the learning resources and tools (texts, software tools, guides, forums, etc.) on a just-in-time basis. The course was delivered on *Explor@,* a virtual learning center developed at LICEF Research Center[1] (Paquette, de la Teja, & Dufresne, 2000), allowing students to have access at any time to the learning resources and tools using the *Explor@* learning resource manager. In *Explor@,* tools and resources are grouped in five spaces (Self-management, Information, Production, Collaboration and Assistance). The CM software was accessible in the production space. Some resources were delivered in printed format.

The concept mapping activity

In this activity, students were invited to construct a concept map after having read four texts (one being optional), for a total of 128 pages. One text is an introduction to cognitive sciences and each of the other texts describes a different approach to cognition (symbolic, contextual, and connectionist). Students were asked to synthesize their understanding of the texts by representing graphically at least fifteen key knowledge objects drawn from at least two of the instructional texts. They were asked to link each knowledge object represented in their CM with at least one other and to label the links. They were also asked to write an accompanying text explaining their concept maps. This work (map + text) was submitted as a part of their summative evaluation (15 % of the total mark). The time required to complete the activity was estimated to about 36 hours distributed over 4 weeks. A textual guide was provided, which included a definition of concept map, examples of concept maps and a procedure to construct concept maps. Peer-tutoring was encouraged: students were invited to ask and answer questions and to share their experience in the online forums all along the activity.

The concept mapping software

To construct their concept map, students were invited to use a knowledge modeling tool, called MOT (*Modélisation par objets typés),* developed at LICEF (Paquette, 1996, 2002).[2] In MOT, four knowledge types can be distinguished by using different graphic shapes: *concepts* (rectangles), *procedures* (ovals), *principles* (hexagons) and *facts* (rectangles with indented corners). Those knowledge objects can be linked to each other by arrows, the arrowhead indicating the direction of the link. Letter labelling is used to specify the link type: *Composition*, *Regulation*, *Specialization*, *Precedence*, *Input/Product* and *Instantiation*. Some rules, built into the software, constrain the type of links that are possible between two knowledge objects. For example, a specialization link can only be used between two objects of the same type. Consequently, the specialization link is not accessible from the menu when the user is in the process of labelling a link between two different object types. However, MOT includes a link, which is “untyped” thus allowing the user to put his or her own labels. A specific shape is also provided for “untyped” objects.

An example of a concept map created with MOT is displayed in Figure 1. This map represents a very small part of the knowledge related to the procedure “Driving a car”.

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[1] The LICEF Research Center, based at Télé-université in Quebec, Canada, is a laboratory that is dedicated to cognitive informatics and training environments.

[2] For further details on this product, refer to the LICEF Research Center website: http://www.licef.teluq.uquebec.ca

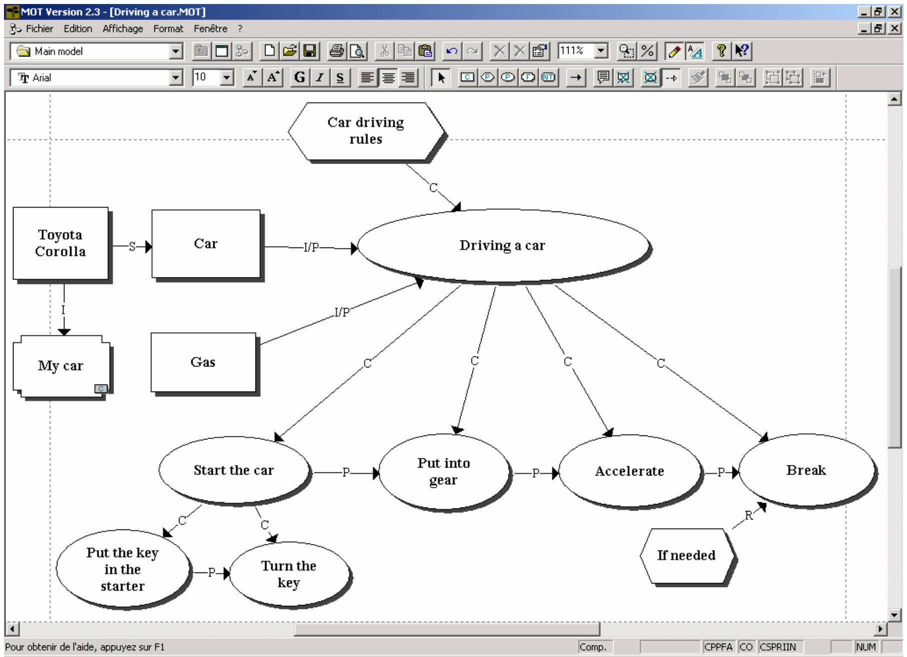

Fig. 1 - An example of a concept map created with MOT

Among the basic features of MOT count the following: creating knowledge objects by choosing graphic icons in a menu and moving the cursor on the screen until the object is the desired size; drawing the links between them by simply drag-and-drop; changing objects and links types by choosing in a menu; moving objects on the screen by dragging them; modifying labels and directions of links using the mouse right button; changing text and graphic attributes, zooming in and out as well as creating sub-maps. This function is especially useful to simplify large maps with numerous objects and cognitively challenging because the user must determine what knowledge units are best represented at top level and what are those related to sub-levels.

Methodology

The first goal of this exploratory study was to identify research issues on concept mapping as a knowledge construction tool in the context of web-based distance education. The second goal was of a more practical nature: feedback was needed from students to help us improve the pedagogical quality of the learning activity. Another objective was to evaluate the adequacy of concept maps as a diagnostic tool in order to identify the main difficulties students have with understanding the instructional texts.

Different types of data have been examined (N=24):

- Spontaneous comments on the concept mapping activity made by students in the online forums;
- Data collected by a short questionnaire;
- Comments made by students in the last written course assignment requiring an analysis of the course from a cognitivist point of view;
- The concept maps .

To obtain a whole picture of the main characteristics of the students' concept maps, we count: (1) the number of typed and untyped objects and links represented in the maps, (2) the number of each category of typed objects and links and (3) the number of sub-models created. Each map 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, all maps representing knowledge related to the same topic (the human information processing) were selected (N = 14) in order to evaluate them with a CM evaluation method devised by our research group (Pudelko, Basque, & Legros, 2003). This method is based on the cognitive semantics theory Jackendoff (1985) and Talmy (2000) and, more specifically, on a system analysis approach proposed by Baudet & Denhière (1991; Denhière & Baudet, 1992) in the domain of text comprehension. The method is based on the assumption that the construction of concept maps implies a semantic as well as a special form of linguistic processing. The semantic representation, which determines language representation, is the result of the activation of a network of representations of the "experienced" world and takes the form of a mental model. This mental model is in itself determined by culture, individual experience and knowledge. In the systems analysis approach, at the macro level, the mental model is structured as a system being defined as a complex network of interrelated semantic units. Three types of systems have been identified: *relational* systems, *transformational* systems and *teleologic* systems (which include *functional* and *intentional* systems). At the micro level, the mental model is structured by cognitive invariants (objects, states, events, action) and by local coherence relations (especially temporal and causal relations). The instructional text, a description of the classical symbolic view of the human information processing system, was analysed using this approach in order to elaborate the coding scheme serving to evaluate the concept maps. The system described in this text was classified as a *functional* system, composed of different processes in the information processing model (encoding, storing, retrieving, etc.) and decomposed in three subsystems (sensory memory, short term memory and long term memory). Finally, the concept maps were coded with the coding scheme to examine whether the human information system represented by students was of the same kind.

Preliminary findings

How did students like the concept mapping activity and software?
It was expected that students would be reluctant to take the time necessary to learn how to use the CM software, which demanded to be done on a self-instructional basis[3]. This assumption explains why we did not oblige students to use MOT to construct their concept maps; they were free to choose whatever graphical tool they wanted. Twenty out of the 24 students chose to use the MOT software. Surprisingly, among the 4 students not using MOT, two used the MOT syntax to represent knowledge objects and links. Data from the post questionnaire confirm that students found MOT very *easy to learn*, *useful*, *simple* and *user-friendly* and all respondents estimated that they were at least moderately familiar with the software. They declared having spent from half an hour to 5 hours to familiarize themselves with MOT before beginning to construct their map. In all, they were very enthusiastic toward this software and everybody were ready to recommend it to someone else. The majority said they would use it in the future, either in other courses to help them learn and understand new concepts or to facilitate their work tasks.

However, concept mapping seems to appeal more to some students than to others. Some comments lead us to believe that spatial ability and cognitive style could be important variables to consider. For example, one student expressed that he was "more auditive than visual", and therefore did not understand the utility of constructing a knowledge graph to learn. Another one said that, on the contrary, "*being visual, I learn better when the concepts are structured this way*". Some research results indicate that if the CM activity is constrained by a syntax, it would be more suited for students with less verbal abilities (Holley & Dansereau, 1984b). A study conducted by Okebukola & Jegede (1988) demonstrates that cognitive preference and learning mode significantly influence meaningful learning through concept mapping. The influence of cognitive styles (auditive-visual; holistic-analytic; field dependence-independence, etc.), verbal and spatial abilities, and learning styles and preferences on the efficacy of concept mapping for learning would certainly be an issue for further investigation.

The MOT syntax – especially the links syntax, as Fisher (1990) already noted – appears not to be so easily understood in general, which was confirmed by our students and further revealed by our analysis of the maps (see further). Nevertheless, students did not complain about the built-in constraints of MOT. On a five-level Likert scale, respondents to the questionnaire judged MOT as being more *open* than

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[3] Few students asked the tutor to have a brief introduction to MOT by phone.

constraining, probably due, in part, to the fact that MOT does allow the possibility of naming objects and links as you wish, thus the syntax can be overruled.

Many students made positive comments on the impact of the CM activity on learning and text comprehension, either in the questionnaire or spontaneously in the online forums as well as in their cognitivist analysis of the course assignment: (1) "*I loved to draw schemas, but now I understand better why they are so efficient and so important for learning (…) Without them, it seems that the synthesis of knowledge, and even the transfer of knowledge, are difficult to do*." (2) "*What I found interesting in this exercise was the 'insight" I had at different moments in the process of discovering the links between theoretical concepts and their applications in concrete situations*". One student qualified the concept map as an "*enlightener"* of knowledge: "*it is the concept map that shows us the missing elements and that suggests where to add new concepts and new links* ".

How do students construct their concept maps?
In the post questionnaire, students were asked to briefly describe how they executed the activity. Most of them did the activity as prescribed, that is, essentially, following this sequence: (1) read the texts, and, while reading, take notes and identify key concepts; (2) draw the concept map with MOT; (3) write the accompanying text. Only one student declared having written the text before drawing the map. They spent from 6 to 50 hours on reading the texts (mean = 18), from 2 to 20 hours on the concept map (mean =8.3) and from 4 to 20 hours on writing the description (mean = 8.6). For the majority of students, the CM was the least time-consuming part of the task.

Many students said they did modify their map after having produced the text. The writing activity seems to act as a verification tool for the CM: "*I realize that some knowledge appearing in my text was not represented in my map*"; "*In trying to translate our concept map in a speech format, we discover errors in our concept map. The text enlightens what we want to express in the map*." This influence between the concept map and the written text could be reciprocal and it would be another interesting avenue to investigate.

It is noteworthy that some students revealed having constructed a first draft of their map on paper. The reason for this is not obvious. However, some comments indicate that their knowledge of the software functionalities was poor. For example, a student wrote: "*It is not possible to copy/paste a knowledge object*", which is not true. The self-instructional approach to MOT proposed in this course is obviously insufficient. It would probably be a good idea to introduce a tutor led activity on how to use the software.

Some remarks on the concept maps
An exploratory analysis of the 24 concept maps revealed the following.

There are many more knowledge units represented in the maps than the required (15). Up to 112 knowledge units was counted in a single map (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 maps.

The most frequently represented objects in the maps of those who used the MOT syntax are the concepts (see figure 2). Students often confounded the type of objects and type of links. For example, some concepts have been identified with the procedure shape, and vice versa. Some students have a tendency to label some objects with whole sentences, denoting their difficulty to isolate the objects from the links between the objects and to formulate them in a graphical proposition.

Eleven students self-labelled some links, but only 3 did this on all their links. It was observed that some of them used self-labelled links that are, in fact, very similar to MOT links (*is composed of*; *is a product of*; *is an example of*; etc.). Some students considered that a link would be better defined as an object; for example, *Representations*; *Behavior*; *Interaction*. The composition link is the most frequently used (see fig. 3). On a total of 1001 links, 111were unlabeled, which were mostly concentrated in one map counting for 82 of these.

Eleven out of 24 students elaborated sub-maps, usually extended into only two levels though.

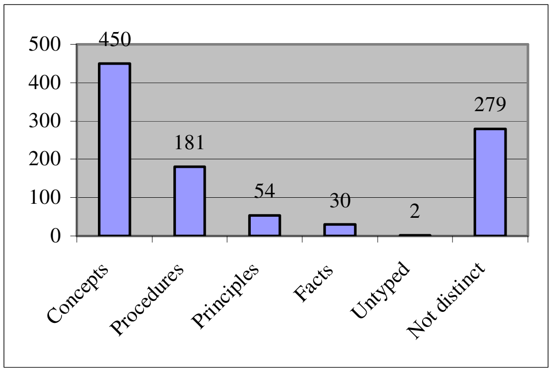

Fig. 2 – Total number of different types of objects in the 24 concept maps

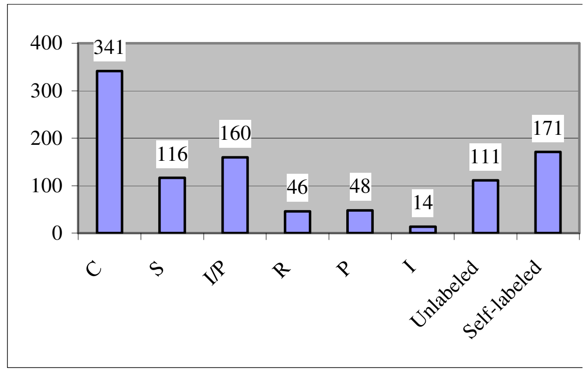

Fig. 3 - Total number of different types of links in the 24 concept maps

The systems analysis method applied to the sample of 14 CM representing the human information processing system shows that 8 students represented this system as *relational*. In the systems analysis approach, this system is described as static, with objects defined by their attributes and related by composition and specialization links. Typically, students represented only two dynamic processes expressing information state modifications (*Register* and *Retrieve*). This analysis demonstrated that students neglected or were not capable of expressing many aspects of the functional system described in the instructional text.

Conclusion

On the whole, the observations show that students generally found the concept mapping activity useful but its full potential as a knowledge construction support tool was far from being optimized. Further research is needed to identify best conditions for using concept mapping software as a knowledge construction tool for telelearners. Some research questions appears to be especially relevant:

- Do certain cognitive and learning styles, learning preferences as well as verbal and spatial abilities affect the process of constructing the maps and the quality of the maps produced? Does the fact of being at a distance reinforce the influence of these variables?
- What is the reciprocal influence of constructing narrative and graphical representations of the same knowledge domain?
- Why is the linking operation so difficult for students?
- What are the impacts of imposing constraints on knowledge objects and links to be used?
- What are the impacts of using CM software on metacognition?
- Which evaluation method of concept maps would be the most effective to determine students' misconceptions of the domain knowledge? How can this evaluation serve to ameliorate instructional documents?
- What kind of support can we provide to the learners to help them construct their maps and to activate metacognitive reflection?
- Based on socioconstructivist assumptions, does the co-construction of concept maps at a distance with a suitable CM software encourage metacognitive interactions and consequently enhance learning?

Our research group is particularly interested with the last three issues. Experimental data are collected to try to put some light on these issues.

References

Anderson-Inman, L., & Ditson, L. (1999). Computer-based concept mapping: A tool for negotiating meaning. *Learning & Leading with technology, 26*(8).

Baudet, S., & Denhière, G. (1991). Mental models and acquisitoin of knowledge from text: Representation and acquisition of functional systems. In J. P. Rossi (Ed.), *Text and text processing* (Vol. 155-187). Amsterdam: North-Holland.

Bruillard, E., & Baron, G.-L. (2000). *Computer-based concept mapping: A review of a cognitive tool for students.* Paper presented at the IFIP, Beijing, China.

Dansereau, D. F., & Holley, C. D. (1982). Development and evaluation of a text mapping strategy. In W. Kintsch (Ed.), *Discourse Processing*.

De Simone, C., Schmid, R. F., & McEven, L. A. (http). *Supporting the learning process with collaborative concept mapping using computer-based communication tools and processes*. http://evnet-nt1.mcmaster.ca/network/workingpapers/Ere_Schmid/Schmid.htm

Denhière, G., & Baudet, S. (1992). *Lecture, compréhension de texte et science cognitive*. Paris: Presses Universitaires de France.

Fisher, K. M. (1990). Semantic networking : The new kid on the block. *Journal of Research in Science Teaching, 27*(10), 1001-1018.

Holley, C. D., & Dansereau, D. F. (1984a). *Spatial Learning Strategies. Techniques, applications, and related issues.* New York, London: Academic Press.

Holley, C. D., & Dansereau, D. F. (1984b). Networking: The technique and the empirical evidence. In D. F. Dansereau (Ed.), *Spatial learning strategies: Techniques, applications and related issues* (pp. 81-108). Orlando: Academic Press.

Horton, P. B., McConney, A. A., Gallo, M., Woods, A. L., Senn, G. J., & Hamelin, D. (1993). An investigation of the effectiveness of concept mapping as an instructional tool. *Science Education, 77*(1), 95-111.

Jackendoff, R. S. (1985). *Semantics and cognition*. Cambridge, MA: MIT Press.

Jonassen, D. H., & Marra, R. M. (1994). Concept mapping and other formalisms as mindtools for representing knowledge. *Association for Learning Technology Journal, 2*(1), 50-56.

Jonassen, D. H., Reeves, T. C., Hong, N., Harvey, D., & Peters, K. (1997). Concept mapping as cognitive learning and assessment tools. *Journal of Interactive Learning Research, 8*(3/4), 289-308.

Lin, X., Hmelo, C., Kinzer, C. K., & Secules, T. J. (1999). Designing technology to support reflection. *Educational Technology Research and Development, 47*(3), 43-62.

McAleese, R. (1994). A theoretical view on concept mapping. *ALT-J, 2*(1), 38-48.

McAleese, R. (1998). *Coming to know: The role of concept map - mirror, assistant, master?* Paper presented at the Euroconference, University of Aveiro, Portugal.

Novak, J. D. (1998). *Learning, creating and using knowledge.* Mahwah, NJ: LEA.

Novak, J. D., & Gowin, D. B. (1984). *Learning how to learn*. Cambridge: Cambridge University Press.

Okebukola, P. A., & Jegede, O. J. (1988). Cognitive preference and learning mode as determinants of meaningful learning through concept mapping. *Science Education, 72*(4), 489-500.

Paquette, G. (1996). La modélisation par objets typés: Une méthode de représentation pour les systèmes d'apprentissage et d'aide à la tâche. *Sciences et techniques éducatives, 3*(1), 9-42.

Paquette, G., de la Teja, I., & Dufresne, A. (2000). Explora: An open virtual campus, *ED-MEDIA '2000* (pp. 844-849). Montréal.

Paquette, G. (2002). *Modélisation des connaissances et des compétences*. Sainte-Foy (Québec): Presses de l'Université du Québec.

Pudelko, B., Basque, J., & Legros, D.. (2003). Vers une méthode d'évaluation des cartes conceptuelles fondée sur l'analyse en systèmes. In C. Desmoulins, P. Marquet, & D. Bouhineau (Eds) (2003), *EIAH2003 Environnements Informatiques pour l'Apprentissage Humain. Actes de la conférence EIAH 2003*, Strasbourg, 15,16 et 17 avril (pp. 555-558). Paris : INRP. Online : http://archiveseiah.univ-lemans.fr/EIAH2003/

Ruelland, D., & Brisebois, A. (2002). *An electronic performance support system for the eLearner.* Paper presented at the ICCE 2002 Conference, Auckland, New Zealand.

Talmy, L. (2000). *Toward a cognitive semantics*. Cambridge, MA: MIT Press.

Wandersee, J. H. (1990). Concept mapping as a cartography of cognition. *Journal of Research in Science Teaching, 27*(10), 923-936.