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EFFECTS OF SHORT TERM TRAINING IN CONCEPT-MAPPING ON THE DEVELOPMENT OF METACOGNITION

Johanne Patry, Ph.D., Marguerite-Bourgeoys School Board, Canada
E-mail: patryjo@videotron.ca

Abstract: Considering the fact that academic curricula asks of students to perform better in an ever increasing information world and to be able to solve problems efficiently, this study was aimed at verifying if students will develop metacognition, the ability to reflect on one's own cognitive processes to a significant degree, after receiving a short term training in concept-mapping, an information organizing tool. The research was done with subjects in a 10th grade Physical Science course. Through the course of three types of tests such as a questionnaire on metacognition, predictive self-evaluation of exam results and "thinking aloud" problem solving sessions, it has been found that there were no significant differences between the subjects who had a short term training in concept-mapping without an explicite accent on metacognitive behavior and those who had not. Thus, in the context of this study, short therm training in concept-mapping has no apparent effect on the development of metacognition.

1 Introduction

As educational reforms engulf many countries, the priority is not concentrated as much on teaching but rather on learning. Notions and concepts belonging to a given domain come second. For Alvin Toffler, "the illiterate of the 21st century will not be the ones who do not know how to read and write but rather the ones that will not be able to learn, unlearn and relearn." These reforms place a lot of importance on the development of competencies which are linked to information treatment and problem solving. Actually, in general, today's academic curicula doesn't yet encourage "the conscious control" of learning. Study programs should incite students not to search to increase their academic performance but rather to improve their cognitive processes (Glaser and Pellegrino, 1987). It would therefore be essential to develop "how to think" processes, the consciousness and regulation of learning strategies called metacognition.

The infatuation for metacognition has pushed many to search for an efficient training method which would enable students to become more metacognitive. It is therefore a rather recent preoccupation and little research and pedagogical documentation have yet proposed as of today any reliable method which is easily adaptable to develop metacognitive abilities in the classroom. There has been research which describe the efficiency of certain approaches but, most of the time, these methods were specific to a given context and hardly transferable. It is our opinion that such training programs require either a heavy and long term training or are practically unapplicable in the classroom. In fact, training programs in metacognition suggested to this day often possess deficiencies at one or many levels such as: adaptability, transferability, applicability, reliability, and contextualization.

There doesn't seem to exist researches which have demonstrated that concept-mapping training has an effect on the development of metacognition. Also, teachers are confronted to important time constraints and an impressive quantity of concepts to cover during the school year. With this in mind, the inclusion of a short term training program in concept-mapping should avoid an increase in the teachers' workload. Before proposing such a training to teachers, it is preferable to find the answer to a pressing question: what are the effects of a short duration training in concept-mapping on the development of metacognition?

2 Concept Mapping

In education, concept-mapping holds its origins in Ausubel's (1963) work on meaningful learning. Other researchers, such as Lindsay and Norman (1980) and Collins and Quillian (1969) from cognitive psychology and information treatment, have also studied cognitive processes, modelization of memory and the representation of knowledge according to a theoretical approach of semantic networks. Later, Ausubel's theory has led Novak, Gowin and Johansen (1983) and Novak and Gowin (1984) to develop more specifically the strategy of concept-mapping.

Concept-mapping (conceptual or semantic networks) correspond mainly to the process of putting together a map with concepts. Concept-mapping in this research is based on the works of Novak and Gowin (1984) and as such is considered as a tool for the synthesis of information which facilitates the organization of knowledge. Some theorists, such as Lindsay and Norman (1980) and Collins and Quillian (1969), perceive these networks as representations of what is stored in memory. Seen in this light, Novak's concept-maps would be the tool itself, an educational adaptation of the semantic networks of Collins and Quillian.

Metaphorically, Wandersee (1990) views concept-mapping as a road map. As in such a map, a concept-map would contain elements enabling us to find our way or to go from one point to another. In concept-mapping, the territory to explore would be the memory and its cognitive structure. The destinations and the cities would become the concepts. Then, the roads to get there would be the links between the concepts. The links reach all the destinations. They render explicite knowledge that is relatively implicite or organized (Patry, 2003). We can simply say that concept-mapping is the process through which a concept-map (the end result) is assembled.

There are many components in a concept-map that render it relatively rich and precise. Concept-maps developed by Novak and Gowin (1984) should contain the following components: concepts, links, link propositions, crosslinks and exemples.

In our view, the process of building a concept-map starts with the person who makes the map, from his life, experience, his knowledge, his motivation, etc.. The building is "holistic" in the way that its forces the individual to touch his overall knowledge and experience on a given subject. Through an iterative process, the concept-mapper searchs first the concepts important to the subject studied. Afterward, he categorizes them in groups and sub-groups. Then he puts them in hierarchies from the most general concept to the most inclusive one. Finally, he establishes relationships with links, link propositions and crosslinks and examples if need be. To make sure of the "solidity" of his concept-map, it is recommended that the concept-mapper has it evaluated by another person. In this way he vould receive valuable feedback on his creation.

3 Metacognition

In 1976, Flavell defined metacognition as such:

"Metacognition refers to the knowledge one has of his own cognitive processes and their products (...) it touches, among other things, the active control, the regulation, and the orchestration of these processes (...) so as to serve an objective or a concrete goal." (p 232)

According to Flavell (1987), metacognition can appear during many situations: 1) when the situation requires it explicitely; 2) when the cognitive situation is at once new and non-familiar; 3) during situations when it is necessary to make inferences, to use critical thinking, and during decision making; 4) when the individual has difficulties during problem solving.

Even though many nuances have been given surrounding the concept of metacognition, most researchers agree to the fact that metacognition contains two main components: metacognitive knowledge which an individual possesses and his self-regulation mecanisms (figure 1).

Metacognitive knowledge refers to the "what" of our cognitions. This knowledge is the set of knowledge that a leraner possesses on his own cognitive ressources and which could serve him to direct and organize himself during a learning or problem solving situation.

Flavell (1976, 1987) considers three different variables linked to metacognitive knowledge: the knowledge related to the individual, the knowledge related to the task, and the knowledge related to strategy. These three variables are in constant interaction. The variable "individual" refers to the knowledge and beliefs carried by the learner on himself; for example: "I know that I am able to...". The variable "task" covers the information and the constraints within a given problem and which the learner is aware; for example: "I know that task X is easy." The variable "strategy" is linked to the strategies which the learner possesses consciously and that will enable him to be efficient during problem solving; for example: "I know which strategy to use and which one is useless."

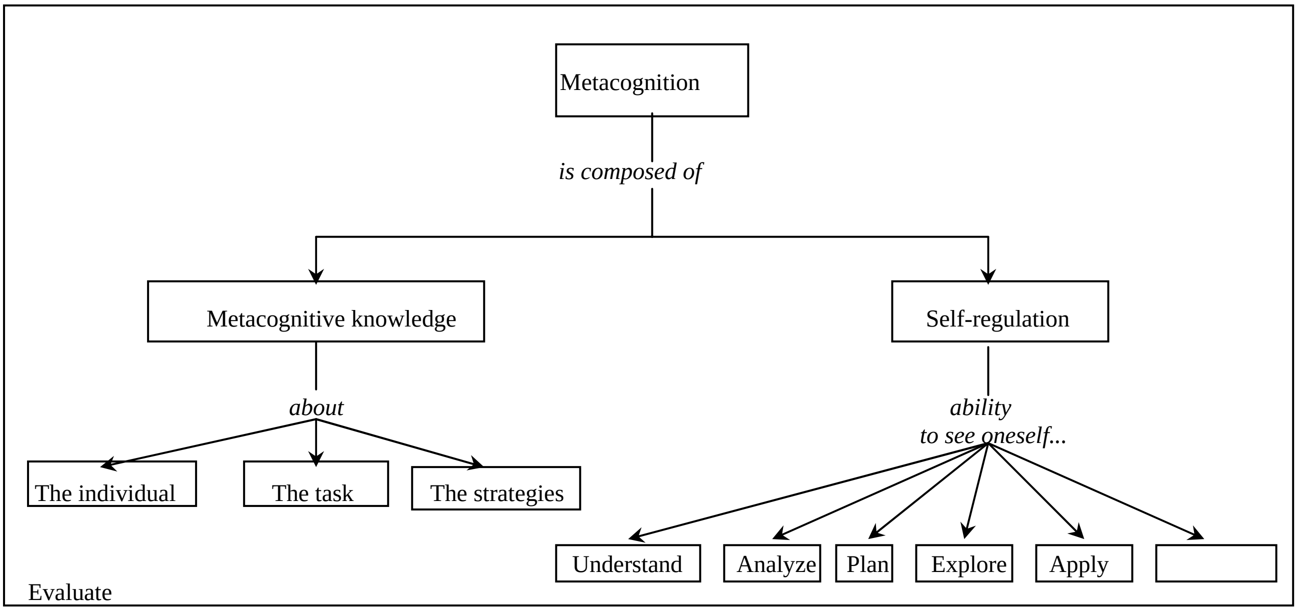

Figure 1**. Components of metacognition**

The other component of metacognition, self-regulation, is a complex concept whose definition is constantly evolving. Many authors such as Allaire, Pallascio, Lafortune, and Mongeau (1998) consider self-regulation as a set of metacognition abilities for it refers to the control of the "how to" of our cognitive processes.

Self-regulation would therefore be a conscious process which consists of the use of metacognitive abilities and strategies so as to execute a given task. According to Artzt and Armour-Thomas (1990), inspired by the works of Garofalo and Lester (1985) and Schoenfeld (1983), there are six such metacognitive abilities: understanding the problem, analyzing the problem, planning the stages of the task, exploring, applying, and self-evaluation (figure 1). An ability is said to be metacognitive when the learner sees himself executing a given cognitive process (ex.: to see oneself understanding the problem). The learner talks to himself outloud or in thought. The learner thinks about his thoughts (Pallascio, Benny, and Patry, 2002; Fisher, 1998). Table 1 presents a short description of each metacognitive abilities.

Metacognitive abilities (so see oneself...)	**Description**
... understand the problem	Examination of knowledge related to the task
...analyze	Breakdown of the problem in its basic elements and reformulation of the problem
...plan the task	Selection of the steps to solve the problem
...explore	Regulation of one's progress and action
...apply the steps	Decision making
...evaluate (self-evaluation)	Return on decisions and actions

Table 1: Description of metacognitive abilities.

Self-evaluation is considered as indicative of the learner's overall degree of metacognition. Mariné and Huet (1998), among others, go further by subdividing self-evaluation into prospective and retrospective. Prospective self-evalaution is the feeling *a priori* regarding one's own future performance in a given task. Retrospective sel-evaluation is the feeling *a posteriori* of one's own performance after the task.

From the information gathered above, we can ask some questions. Can we develop students' metacognition since it renders them more autonomous and improves their academic performance? Do training programs exist which are quick, efficient, adapted to different learning levels, and applicable in classe?

Presently, there exists a certain consensus in education that it would be important to develop an awareness and the regulation of thoses learning strategies which are called metacognition since the research from Flavell. Thus, when metacognitive abilities are developed in a learner, his academic performance improves (Landine & Stewart, 1998). A metacognitive learner is more mature, more autonomous concerning the control of his own learning and behavior during problem solving (Brown, 1987).

Teaching of metacognitive strategies should facilitate attention span, motivation, learning, the memory, and understanding as well as help in solving certain learning problems (Wittrock, 1986). By its heuristic and educational nature, metacognition appears therefore, for many, as an essential component of learning. Some researchers, such as Noël, Romainville, and Wolf (1995) even propose that schools become centers for the development of metacognition where students are trained to become aware of their learning processes and master those acquisitions.

Nevertheless, there exists a controversy regarding the advantages of metacognition. Indeed, according to a meta-analysis by Romainville (2000), it seems that certain training programmes to develop metacognition have not been as efficient as predicted compared with their goals, such as improving metacognition and academic performance.

Earlier in the text we have seen that concept-mapping is a tool to synthesize and organize information. Would a student, trained in concept-mapping through a short program, develop his metacognition? The answer to this question could permit us among other things to ensure that such a technique, concept-mapping, is worthwhile to develop metacognition thus saving time and energies.

4 Methodology

The present study has been done with 10^{th} grade Physical Science students from urban Montréal (Patry, 2003). Two groups from regular physical science classes have been randomly assigned to the teacher. The students had been assigned to each group randomly by the school's computer. Then, again randomly, one group was designated experimental while the other became the control group. However, within each of these groups, we have retained only those students who were up to date in math and French and hadn't done this science course previously. At first, the experimental group had 20 subjects, the control group, 21 subjects. During the process of testing, some subjects were removed from part of the study for different reasons such as absence or not answering some questions. However, for practical reasons, within these two groups we selected a small sample (exp. = 6, ctrl. = 8) for the "thinking aloud" tests on proportion reasonning tasks (Côté & Noelting, 1971).

Concept-mapping training was applied only to the experimental group. Since the content of the Physical Science course is very heavy, we have chosen a short duration training program (Patry, 1998). In this previous study, after such a training, there had been a significant difference between experimental, semi-experimental and control groups in concept-mapping capabilities. Indeed, in a physical science context the experimental and semi-experimental groups were equally better concept-mappers than the control group. However, when all groups had to transfer these competencies to another domain (history), the experimental group was significantly much better than the other two groups.

At first, the subjects went through a class of 75 minutes during which they were explained everything about a concept-map, its design and construction and they did exercices. This introduction was followed by 5 sessions of 45 minutes spread throughout four months of practical classes with the construction of concept-maps and the use of progressive devolution concept-maps at the end of every segments (x4). These maps are concept-maps in which a growing proportion of concept is removed with each passing segment. Two months after the end of the treatment, both groups were administered the post-tests described below.

Apart from the introduction above, the students performed the sessions with the same teacher who had received a similar but more advanced training. The Physical Science course as taught in the province of Québec is a mixture of traditionnal and participative approach. Students are encouraged to develop their critical thinking through the practice of the scientific method and performing lab experiments. Little is done to develop at this point "metacognitive behaviors". During training, students were motivated to complete their maps for it was explained to them that in doing so it would enable them to identify erroneous conceptions and synthesize at the end of a given segment the information they received in the previous classes.

5 Results

The independant variable corresponded to the short term training program in concept-mapping. The dependant variable, metacognition, was subdivided in three sub-variables to which was associated a different measuring tool for each one. Metacognitive knowledge was evaluated with the help of a questionnaire called COMÉGAN on metacognition (Richer, Mongeau, Lafortune, Deaudelin, Doudin & Martin, 2004). In this test, the subjects chose a level on a Likert scale (disagree, agree, etc.) for 18 statements during a problem solving situation such as: "I know the strategies which help me the most to learn", I can name my strong points which help me to learn better", "I know what type of tasks are easy for me." Self-regulation was analysed with "thinking aloud" tests on proportion reasonning task so as to mesure the frequency in the use of metacognitive abilities. And last, self-evaluation (prospective and retrospective) has been evaluated from knowledge exams in mathematics and science. Self-evaluation is often used as a global indicator to determine the degree to which a learner is metacognitive (Huet, Mariné & Escribe, 1994; Osborne, 1998, 1999; Wilson, 1997).

During pre-testing, we have found that the two groups were equivalent for every measuring tool. Afterwards, to compare the two groups, we have mainly used "t" tests for mean comparison. This choice has been motivated by the fact that the number of subjects was small and the selection process was not completely random (see above).

Concerning metacognitive knowledge (table 2), we have found that at the post-test, there were no significant differences between the two groups (t = 1,27, p > 0,10).

		Pre-test			Post-test		
Groupes	N	M	s	t	M	s	t
Experimental	18*	51,81	5,92		52,92	6,27	
Control	14*	55,00	6,21	0,149 (n.s.)	56.11	4,87	0,127(n.s.)

n.s. : non significant (p > 0,05)
* The difference in sample sizefrom its original number is due to the f act that some subjects were absent.

Table 2: Metacognitive knowledge (test « t », independant sample).

So as to analyse the frequency in the use of metacognitive abilities, we have proceeded to a statistical analysis with a Chi square test, X^2 for all of the statements since we had nominal data (table 3). Analysis demonstrated that there were no significant differences between the two groups at the post-test (X^2 = 0,103, df = 1, p > 0,70).

	Pre-test		Post-test	
Statements	Contr. N = 8	Exp. N = 6	Contr. N = 8	Exp. N = 6
Metacognitive	104 (58%)	125 (58%)	56 (48%)	104 (49%)
Non-métacognitve	74 (42%)	92 (42%)	61 (52%)	109 (51%)
Sum Meta. + non- meta.	178 (100%)	217 (100%)	117 (100%)	213 (100%)

Table 3: Frequency in the use of metacognitive statements.

Regarding self-evaluation (prospective and retrospective), we compared the two groups in regards to the precision with which a subject predicted his performance before and after a test. For the prospective self-evaluation, each subject had to give a value which indicated the success level for a given problem (from 0 = failure to 4 = success) **before** solving the problem. For retrospective self-evaluation, the subject had to proceed likewise, this time **after** solving the problem. We have calculated the differences between the value given by the subject (prospective and retrospective self-evaluation) and the actual performance (maximum of 4 points). These differences gave us the degree of disagreement between these values (tables 4 and 5).

	Pre-test				Post-test			
Groups	N	M	S	t	N	M	s	t
Experimental	20	8.85	2.72		19*	7.26	3.33	
Control	21	7.81	2.73	1,22(n.s.)	21	6.80	2.31	0.51(n.s.)

n.s. = non significant (p > 0,05)

Table 4: Prospective self-evaluation. Means of the sum total of the degrees of disagreement.

	Pre-test				Post-test			
Groups	N	M	S	t	N	M	s	t
Experimental	20	6.50	2.31		18*	7.44	3.29	
Control	21	6.57	3.36	0.08(n.s.)	16*	7.06	2.14	0.40(n.s.)

n.s. = non significant (p > 0,05)

* The differences in the number of subjects are due to the fact that some of them have not answered some questions in the self-evaluations.

Table 5: Retrospective self-evaluation. Mean of the sum total of the degrees of disagreement.

For the prospective self-evaluation, we have observed that there were no significant differences between the two groups during the post-test (t = 0,51, p > 0,60). Regarding retrospective self-evaluation, there again, there were no significant differences between the two groups during the post-test (t = 0,40, p > 0,60).

Our analysis has demonstrated that a short term training program in concept-mapping as used in this study has no effect whatsoever on the development of metacognition. Concept-mapping encourages mainly the organization of information and structures this organization without necessarily implying self-questionning typical to the metacognitive process. The learner organizes himself better without necessarily self-regulating.

We may ask ourselves if the training itself, its short duration was appropriate. On the other hand, the heavy content of present curricula doesn't allow us for the moment to give more time. Metacognition remains difficult to measure quantitatively. We used tests that aimed at measuring specific components of metacognition. Maybe, for students having attained the formal stage, the reasoning test has been easier to solve and corresponded more to a situation during which one applied a rule. Consequently, it was not conducive to the expression of a metacognitive reasoning. The test could have been more adapted for students about to attain the formal stage. Nonetheless, even though our sample was small, we perform three different tests and the results of our stastical analysis point out that a short term training in concept-mapping doesn't affect the development of metacognition.

6 Summary

The desire to encourage the learner to become aware and master his own regulation processes during a problem solving situation is essential. In this study, we wanted to know if it was possible to develop such competencies, metacognition, to accelerate its evolution through a rapid training in concept-mapping. During this training, we tried to avoid any references to metacognition so that we could really study a basic program on concept-maps training. However, the results of our research do not demonstrate that a short duration in concept-map training affects the learner in this sens. Metacognition, the awareness and control of our own cognitive processes, is in fact a "work in progress". It develops throughout the years as the learner matures. Concept-mapping helps him to learn how to learn, to organize and synthesize his knowledge. For many decades, a lot of emphasis has been put on content (notions, knowledge) by the teaching community. Less on the "how to learn" approach. The present study shows that there is no "quick fix". The learner, the brain, must take time and practice to develop his competencies. We may ask if a longer training period linked directly to problem solving with an approach explicitely metacognitive could produce better results. It is, according to us, in this direction that research aiming to identify an efficient stratetegy to develop metacognition should go. There remains a lot to learn about metacognition and programs which encourages its development. It is motivating to know that there is still more territory to explore.

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