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INTERACTION BETWEEN TOPOLOGY AND SEMANTICS IN CONCEPT MAPS: A NEUROLINGUISTIC INTERPRETATION

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Abstract. This article analyses, from a neurolinguistic perspective, results obtained from the application of a taxonomy of concept maps developed at the *Conéctate al Conocimiento* Project in Panama to a sample of over 500 maps. The 2-part taxonomy consists of a topological taxonomy and a semantic scoring rubric. Of particular interest to us is the association found between structural and semantic complexity of completed concept maps. Results of this first application of the complete taxonomy indicate that positive changes in semantic levels tend to be accompanied by positive changes in topological levels; also, negative changes in topological levels tend to result in negative changes in semantic levels. The converse does not appear to be true, that is increasing the complexity of the special configuration of concept maps does not translate into more intricate and sophisticated semantic texts. These results evidence a need to focus on improving semantic quality in order to achieve overall improvement in map quality, including its viso-spacial configuration or topology. Neurolinguistic Theory seems to contribute to understanding the nature of this relationship, and provides theoretical guidance for the design of new didactic strategies to improve significant learning based on concept maps.

1 Introduction

A study carried out by Miller (2008) at the *Conéctate al Conocimiento* Project in Panama (Tarté, 2006) has made evident the degree of association that exists between topological and semantic aspects of concept maps. The results of the cited study indicate that positive changes in semantic levels tend to be accompanied by positive changes in topological levels; also, negative changes in topological levels tend to result in negative changes in semantic levels. The converse does not appear to be true, that is increasing the complexity of the spatial configuration of concept maps does not translate into increased semantic complexity.

The present article attempts to offer elements for analysis from a neurolinguistic perspective that might contribute to explain these results. The paper is organized in the following manner: 1) summary of relevant neurolinguistic theoretical arguments; 2) brief description of the study that gave rise to the results being considered; 3) neurolinguistic analysis of these results; and 4) conclusions and recommendations for classroom applications.

2 Summary of neurolinguistic arguments

"Language is so much a part of our daily lives that we tend to take it for granted and not to stop and think about how useful language is for translating commonly recognized regularities into code words we can use to describe our thoughts, feelings and actions. An awareness of the explicit role language plays in the exchange of information is central to understanding the value and purpose of concept mapping and, indeed, central to educating" (Novak & Gowin, 1984, p. 17).

Language is used to articulate each person's model of the world, but at the same time, neurological processes are organized and sequenced through language; hence, language reflects the way each person perceives the world. Being such a psycho-biological process, one could say that mental maps are a sort of biological path along which words travel. The mental representations of individuals depend on their experiences, culture, and physiology, among other things. Language refers to the way individuals makes use of verbal expression to communicate experience, and this is done with the structure implicit in their own language. At the same time, all human experiences, as well as their expression through language, are subject to processes that may constitute evidence of failures in the representation of the world, failures in the form of omissions, distortions, generalizations.

According to Cobb (1997), every individual has a particular way of relating and ordering perceived sequences of events that is captured through his/her conversations. This is because human beings communicate through a narrative language that has a time, a space, and a logic for building relationships, all of which is reflected as coherence. In conversing, human beings express the manner in which they relate things, but also the manner in which they relate to one another. This is done through words that express meanings.

In every conversation human beings construct a sort of text that can be understood as an analyzable object in which different structures can be identified, ranging from concrete organizations to abstract entities (Serrano, 2001b). Meaning is built up through language; hence, the semantic value of the resulting text.

In an effort to give meaning and significance to the texts, human beings apply a variety of organization strategies, assigning to structures defined as semantic units, a relational order. This order (M.V.G. De Erice, 2002), may be a positional order, where language alignment is mediated by space-time variables (also known as syntagmatic order); a functional order, of codified association, since semantic units can only take on value on related to others that may substitute it and constitute contextual relationships (called paradigmatic order). There exists an ordering of text production and interpretation conditions, communication phenomena that go beyond pragmatic factors to include situations of codified communication inherited from culture and history. There is also included a referential order, that determines the influence of the linguistic over the non-linguistic strata in practice. In this manner, the interpretive path of a text entails a series of operations that allow us to assign one or more meanings or senses to a linguistic series.

The interaction among different semantic units gives cohesion to a linguistic series, which is defined by its internal semantic relationships. However, the dynamic interaction also defines a coherence mediated by the relationships it establishes with its environment. The hermeneutic order is the one guiding the production and interpretation of texts, that is to say, the one generating the content which is what has been defined as the text's plan, made from the set of meanings.

The specificity of a text "results from the intersection of a great number of structures which, when taken separately, are quite general" (Serrano, 2001a). Nevertheless, experience shows that it is the point of view of the text, from a hermeneutic perspective, the one compelling the addition of contextual elements: without this, interpretation is incomplete, and comprehension unsatisfactory. In this manner the semantic process, the discourse, which is the set of codified linguistic uses together with a certain social practice – understood as the sphere of shared mental representations – defines a sort of associative network between units of meaning, which in their interactional dynamics define the context for reinterpreting the text.

The object of concept maps is to represent meaningful relationships between concepts in the form of propositions. A proposition consists of two or more concepts joined by linking words to form a semantic unit, that is, a unit with meaning (Novak & Cañas, 2008). For Novak & Gowin (1984, p. 15), a concept map "can provide a kind of visual road map showing some of the pathways we may take to connect meanings of concepts in propositions." Several authors have stated that concept maps are networks of semantic relationships, where semantic refers to the meaning or interpretation of the meaning which individuals attribute to a given symbol, word, language or other formal representation. According to Novak & Gowin (1984, p. 20), it can be "useful to think about concept maps as tools for negotiating meaning ... Learning the meaning of a piece of knowledge requires dialog, exchange, sharing, and sometimes compromise."

It is during this negotiation (which may take place with others, but also with oneself), if done conscientiously, that individuals may come to recognize the generalizations, omissions, and distortions contained in their texts, and restructure their narratives. This action is what ultimately results in learning, a modification of cognitive structure or, in the terminology of neurolinguistic theory, a new mental model of the world; hence, the importance of concept maps.

These theoretical arguments seem useful for analyzing and understanding results obtained by Miller (2008), which indicate a relationship between the topological and semantic aspects of concept maps. We now give a brief description of the tools used to evaluate the structure and content of the maps, followed by the results obtained, in order to contextualize the subsequent discussion.

3 Evaluation tools and data

Concept maps were analyzed using the taxonomy for concept maps developed at Panama's Conéctate al Conocimiento Project. This taxonomy consists of two complementary parts: a topological component, for classifying concept maps according to the complexity of their structure; and a semantic component, which evaluates the quality of their content. The former is discussed in detail in Cañas et al. (2006); the latter is described in Miller & Cañas(2008). In the next two sections we offer a brief outline of the criteria taken into account in the design of each of these measurement tools.

3.1 Topological taxonomy

The topological taxonomy classifies concept maps according to five criteria: *concept recognition*, *presence of linking phrases*, *degree of ramification*, *depth*, and *presence of cross-links*. These criteria consider progressively more complex topological entities, beginning with concepts, passing through propositions, and ending with the complete concept map.

We note that in order to apply the first criterion, one must consider content. Therefore, this would appear to be a semantic criterion – and it is. However, the ability to recognize individual concepts is so basic to being able to build up rich, interconnected, flexible concept map topologies that this criterion is included among the structural criteria. In other words, the focus is not on what is actually said, but on whether the mapper is able to recognize concepts in their original context and depict the way in which they are related to one another.

Once nodes (concepts) have been placed in a map, they are related to one another to form larger graphic structures, usually triads, by means of any form of symbolic representation – this is the linking phrase. Ramification occurs when several relationships emanate from the same node or make use of the same linking element; this event is usually thought to be related to Ausubel's (1968) notion of "progressive differentiation"; hierarchical depth refers to the number of levels of concepts nested under the root (main) concept of the map. Though this nesting may indeed be evidence of conceptual subsumption, the two are not to be confused; this topological criterion considers only the number of level, not what concepts are placed in each of them.

The last criterion deals with cross-links. From the perspective of spatial organization, cross-links, when accompanied by all the other elements mentioned above, lead to topological entities of greater overall complexity. They are thought to be associated to "integrative reconciliation," another fundamental principal of Ausubelian theory.

3.2 Semantic scoring rubric

The scoring rubric used to evaluate the maps consists of six semantic criteria: *concept relevance and completeness*, *correct propositional structure*, *presence of erroneous propositions*, *presence of dynamic propositions*, *number and quality of cross-links*, and *presence of cycles.*

As before with the topological taxonomy, in this semantic rubric content is considered at different, increasingly complex, levels. The first criterion involves the level of individual concepts, what one might call the "atomic" level of meaning present in a concept map; criterion 2 moves up a notch, to the "molecular" level, which involves being able to construct and express coherent units of meaning in the form of propositions; continuing to higher levels, criterion 4 looks at the sophistication of the relationship established between concepts in a proposition along a static-dynamic scale; further up, criterion 3 ascertains the veracity of those units, relative to external objective standards, that is, in relation to contextual elements; finally, criteria 5 and 6, involve the entire concept map, in our metaphor, this might be the level of "matter," where individual strings of meaning present in a concept map are tied together, as the mapper draws from his or her life's experiences to generated an integrated, coherent whole.

4 Results

The results presented below are based on a total of 258 in-service Panamanian public elementary schoolteachers being trained in concept mapping at Panama's Conéctate Project. Initial and final concept maps created using CmapTools (Cañas et al., 2004) were obtained. Completed Cmaps were analyzed in terms of their structure and content, using our topological taxonomy and scoring rubric, respectively. Our interest in this article, however, is centered on the relationship between content and structure; that is, on the association between structural and semantic complexity of the completed maps.

In this regard, calculations yielded a moderate degree of correlation between semantic and topological level: in the initial map the correlation coefficient was 0.50; in the final map the value decreased slightly to 0.37. However, examining the relationship between change in semantic and change in topological level, we found (see table 1) a significant association. On the one hand, those who had a positive change in semantic level were 3.3 times more likely to have a positive change in topology; while those who had a negative change in topology where about half as likely (0.6) to improve semantics. On the other hand, those who had a positive change in topology had only a slightly greater chance to improve semantic level (1.1). Overall, we see that changes in

content have a greater effect on structure than vice versa. That is, improving content quality tends to improve topology, not the other way around.

		SEMANTIC LEVEL CHANGE		
		Null or negative change	Positive change	Total
TOPOLOGICAL LEVEL CHANGE	Null or negative change	48	29	77
	Positive change	85	96	181
	Total	133	125	258

Table 1. Contingency table showing a significant association ($P = 0.002$) between changes in topological level and changes in semantic level.

5 Neurolinguistic interpretation of results

As pointed out earlier, a concept map is a graphic representation of a network of semantic units whose interactions define a context of meanings. The "graphed text" has a topological structure which represents the way in which the individual organizes semantic content, concepts and propositions, in his/her cognitive structure through subsumption, differentiation and integration. As Novak & Gowin (1984, p. 40) have noted, "Concept mapping has been developed specifically to tap into a learner's cognitive structure and to externalize...what the learner already knows." Although concept maps certainly do not provide a "complete representation of the relevant concepts and propositions a learner knows... [they do constitute] a workable approximation" (ibid.)

This is the forcing argument that evidences the relationship between topology and semantics, between graphical configuration and meaning, made plain by the results reported in the previous section. These results imply a dynamic relationship between the topological and semantic aspects of concept maps, where the former may be conceived as the dependent variable, and the latter as the independent one. Being a dynamic interaction, in giving expression to a text in a concept map the dependent variable helps to reorganize the independent variable (this is Piaget's concept of intelligence, where the interaction established between the environment and the subject helps to modify the environment, and in doing so the subject itself is modified).

This would explain why it is stated that there are no good or bad concept maps; it is the reason why it is said that the concept map represents the state of a subject's knowledge on the topic at a given moment (assuming the subject has sufficient skill in concept mapping to adequately represent his/her knowledge); it also explains why so much importance is given to dialogue and interaction during map construction. Thus, it is acknowledged that concept maps must be understood as cognitive construction processes, rather than as finished products.

The topological-semantic relationship would seem to be led by semantics. In other words, changes on the semantic front give rise to changes on the topological front. Changes in topology however have little influence upon semantics, but do offer important information that can provide feedback to the subject to help produce changes in his/her cognitive structure, that is, to learn in a meaningful way.

The results presented here about the relationship between semantic and topological complexity in a concept map, offer – from the perspective of neurolinguistic theory – interesting opportunities for didactic strategies addressing on the construction of concept maps.

From the view point of the neurolinguistic model, each person said to have a mental representation of the world in which his or her life unfolds. This representation is called the individual's "mental model of the world," which in turn becomes expressed through narrative texts. Thus it can be said that the concept map as a text representing meanings, is a reflection of the person's narrative, of the way the person converses with him/herself and with others. When that conversation is to be represented graphically through a concept map, its physical layout or configuration reflects the way he or she arranges sequences of relationships, makes differentiations and identifies or discovers integrations, all of which serve to construct meanings. But this viso-

spacial aspect of a concept map depends on the content with which the subject interprets the world and its relationships.

This is why, from the didactic point of view, concept maps are powerful tools allowing individuals to reread the text of the relationships they establish, and in doing so to discover omissions, distortions, and generalizations, and through this process, to construct new ways of relating to generate a new narrative, a new text. This contributes to the dynamic exchange between assimilation and accommodation stipulated by Piaget, as strategies for the construction of knowledge easier.

When meanings are negotiated in the construction of a concept map, as Novak & Gowin (1984) pointed out, the structure of the individual's mental model is modified. If this process is done together with others, collaborative learning takes place.

Neurolinguistics, from its practical approach (the so-called Neurolinguistic Programming) states that by generating changes in an individual's language, changes in his/her mental model can be achieved and this new model will generate new behaviors. In other words, a change in the cognitive structure occurs, which is what is commonly defined as learning.

When the frame of reference for the mental model is located (be it in memory, imagination, or in the point of view of others), with new words (new symbols and new representations), with the intention of obtaining new meanings within that frameset, the consequence will be a shift in individuals' emotional state, responses and behaviors.

Human beings utilize certain cognitive strategies to integrate coherence and cohesion into meanings. These information organization strategies are generalizations, distortion and elimination of data. For this reason, neurolinguistic theory considers it indispensable that individuals acquire the ability to recognize their generalizations, to recover the parts omitted from their model of the world, and to correct its distortions, in order to guide in a precise way the process of shifting their mental models. In that new context, mediated by "new conversations," underlying mental models are modified, and consequently changes are produced in semantic processes. This requires a new organization, which shows up in a concept map as changes in topological structure. Changes in the semantic structure of a concept map generate changes in the topological structure.

6 Conclusions and recommendations

The insertion of concept mapping in the everyday classroom is an issue that seems to require evermore the designing of innovative methodological proposals to ensure the sustainability of the use of concept maps in school life.

Those who have assumed the task of training teachers in the use of this tool, enriched in recent years by technological tools such as CmapTools, are facing a number of situations such as: a) not all teachers trained in concept mapping use the tool in their classrooms; b) those who do use them, do not do so in a regular fashion and/or use them only as an effective summarization tool; c) few teachers use concept maps to facilitate the construction of new knowledge construction; d) even fewer use them to promote collaborative learning.

Informal inquiries carried out with teachers concerning the reasons for this low usage of concept mapping in school life, relative to the number of teachers who should be using them, we find the following explanations:

- They require too much classroom time
- Only some children enjoy using them
- They require changes in class schedule (time) and classroom arrangement (space)
- They are not applicable to all courses of the curriculum

It would seem that the training strategies used so far, have not attained the expected results. Efforts to provide better theoretical arguments are thus sought.

The previous neurolinguistic discussion of the results of the application of the topological and semantic components of the taxonomy of concept maps (Miller, 2008), offers interesting contributions for the design of didactic strategies aimed at integrating concept maps in the school context. It would seem appropriate to develop

a methodological proposal which includes the neurolinguistic approach, that is, an emphasis on semantic elements both in teacher training, as in the strategies those same teachers can apply in their classes.

Some strategies that may contribute to the design of a new methodological proposal include:

1. Teachers, as facilitators of the construction of new knowledge, must consider students' first concept maps as "draft versions" which can be improved through dialogue; likewise, teachers must understand that a concept map is the viso-spacial representation reflecting a person's cognitive structure and state of knowledge at a given moment. This first map constitutes the working material to begin a process of change, an excuse to construct new knowledge.

2. The importance of the use of questions as a way to stimulate the construction of deeper concept maps has been recommended. Such questions are aimed at inducing students into exploring new ways of linking concepts. Hence, it crucial to encourage students to re-read their maps, identifying generalizations, searching for possible omissions or distortions of information, in order to provoke modifications of the previously constructed text. These changes, when mediated by dialogue, conversation and interchange, will generate a new text with a new semantic structure, which will necessarily reflect a change in the topological structure of the map. Examples of such questions are: Is there another way of stating this relationship? Are there related topics that can help to deepening this relationship? How could we complete this idea? Does the map contain information related to or helpful in explaining this relationship? To insist in producing changes in a map's topology in order to improve its conceptual quality, appears to be, in light of present results, a practice that needs to be discarded.

3. Most teachers can not break loose from the practice of using concept maps as a strategy to evaluate academic contents. However, the mere fact of repeating the concepts, the relationships given in textbooks and lectures, does not signify the presence of real assimilation and accommodation processes taking place in the learner's cognitive structure.

Teachers must consider concept maps as a "text under construction," a necessary stage for the creation of new knowledge. Thus arises a new theoretical argument which strengthens the pedagogical proposal, advocated by many in the past, concerning the construction of concept maps: the stimulation of dialogue and exchange mediated by conversation, with the object of impelling changes in cognitive structure.

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